NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS, SOUTHEAST REGION (NIAE-SER)

A DIVISION OF
THE NIGERIAN SOCIETY OF ENGINEERS

PRESENTS

3rd South East Regional Conference Nsukka 2018

DIVERSIFICATION OF NIGERIAN ECONOMY: THE ROLE OF AGRICULTURAL BIORESOURCES ENGINEERS

BOOK OF PROCEEDINGS

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DATE:
27th - 30th August, 2018

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DETERMINATION OF THE ONSET OF FLAMMABLE BIOGAS PRODUCTION AND BIOGAS YIELD FROM DIFFERENT BLENDS OF SWINE MANURE AND CABBAGE LEAF WASTE

Uzodinma, E.O.[2],Ojike, O[1],. and Ofomatah, A.C[3]

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ABSTRACT

Performance of flammable biogas produced from waste blends of swine faeces and cabbage leaf was evaluated. The waste blends were separately charged into prototype metallic fixed dome bio-digesters of 41 litre working volume and anaerobic digestion carried out within average ambient temperature range of 25.5 to 35.0^{0}C under 35 days retention time. The 50:50 waste blends acted as the control. Results of volume of biogas yield obtained indicated that the 60: 40 blended system had highest amount of cumulative volume of biogas yield (160.20 L/kg. TS) while 50:50 and 70:30 systems amounted to 145.20 and 93.70 L/kg TS respectively. The 70:30 bio-digester systems had shortest onset of flammable gas production of 9 days and retention time of 33 days. Flammable gas composition analysis of the blended waste systems carried out showed that 70:30 systems had highest wet methane content of 85%, while CO_2 and O_2 were obtained in variable proportions. Results of evaluation of biogas produced showed that the 70:30 blends had highest fire power of 53.06 KW, percentage heat utilized in heating pot and water (PHU) as 0.53%-lowest and efficiency of 0.5%-lowest. Overall results indicate that renewable energy for cooking could be generated from the waste blends.

Keywords: Biogas, flammable, renewable, water boiling test

1. INTRODUCTION

Energy generation, supply and utilization are major determinants in the evaluation of a country's extent of development and her standard of living. However, in most African countries and indeed other developing countries, fire wood obtained from felling of trees is one of the main fuels for cooking (Wereko-Brobby and Hagen, 1996). Felling of trees is known to cause deforestation, desertification and alterations in carbon sequestration (Wereko-Brobby and Hagen, 1996). Fossil fuels which have been the major source of world's energy supply are under much stress since 1970 and a great decline is envisaged in the world wide production of crude oil in near future (Anonymous, 1989). Besides, fossil fuels such as coal, natural gas, bitumen, tar-sand and others create unfriendly environment through emission of greenhouse gases. Hence, renewable energy as one of the primary energy sources has caught the attention and interest of so many countries but contribution in developing countries is still limited. Energy demand is expected to increase more than 50% by 2025 (Balat and Balat, 2009). Consequently, there is an on-going search to develop sustainable, environmentally sound energy from renewable energy sources particularly biofuels (biodiesel, bio ethanol and biogas). Biogas is produced from readily available biomass wastes from industries, homes, markets, plant litters and others. Hence, a lot of effort is being made through research to ensure production of sufficient biogas for cooking, lighting, transportation, electricity generation etc, in many developing countries. Cabbage leaf waste has been used alone in the production of biogas (Uzodinma *et al*., 2009) although much report was not found in literature. Various plant and animal wastes have been exploited in production of biogas in Nigeria (*Eze et al*., 2003; Garba *et al*., 1996; Machido *et al*., 1996; Ofoefule and Uzodinma, 2005; Uzodinma and Ofoefule, 2008) but evaluation of cooking potential of methane content of each system have not been carried out as much and dissemination is not yet popularized.

Water boiling test is an international standard for testing the efficiency of wood burning stoves (Rani *et al*., 1992; Wereko-Brobby and Hagen, 1996). The test helps to demonstrate fuel efficiencies for boiling and frying as well as for the simmering and slow cooking of foods. The present paper reports on a study undertaken to evaluate efficiency of methane content of biogas produced from blends (50:50-control, 60:40, 70:30) of swine manure and cabbage leaf waste using the laboratory-water boiling test.

2. MATERIALS AND METHODS

The cabbage and swine manure used as the waste materials under this study were procured from Nsukka main market in Enugu State. Chemicals of analytical grade such as anhydrous sodium sulphate, selenium powder, sodium hydroxide, conc.H_2SO_4, etc, used for physico-chemical analyses were of analytical grade provided by Department of Crop Science Laboratory, University of Nigeria, Nsukka. Metallic prototype digesters of 41.0L capacity each utilized were constructed at the National Centre for Energy research and Development in the same University. Other materials used in this study include; top loading balance-50kg model no. Z051099), gas collection accessories (APHA, 1989), pHep-pocket sized pH tester-RI02895 (Hanna Instruments Italy), mercury in glass thermometer (-0 to 110^0C), a small Tower- brand pot with cover and a locally fabricated burner for checking gas flammability/water boiling test.

2.1 Experimental studies:

The cabbage leaf waste collected in fresh form was allowed to partially degrade for four days to reduce toxicity of the waste (Fulford, 1988). Wastes were weighed out according to different blends of 50:50, 60:40 and 70:30 of swine manure: cabbage waste. They were all fed into three different digesters of 41.0L capacity (Fig. 1). The mixed swine manure-cabbage waste and water (1:2.5-waste to water) were charged and operated for 35 days under ambient temperature range of $25.5\text{-}31^{oC}$. The digester contents were stirred adequately on daily basis initially as the experiment progressed to ensure uniform dispersion and to prevent formation of hard scum on the surface that would lessen release of biogas (Richie, 1983). Daily gas production was measured (liter/total mass of slurry-L/kg.TS) through water displacement set-up (APHA, 1989). The pH changes for each system were also measured at two days intervals throughout the experimental period.

Fig. 1: Prototype bio-digester

2.2 Physico-chemical analyses of undigested wastes

Moisture, ash, crude fiber, fat, nitrogen and protein contents of all undigested waste blends were determined using AOAC (2010) methods. Carbon content was carried out using Walkey and Black (1934) method. Total carbohydrate was by difference (AOAC, 2010), total and volatile solids were also determined using the methods described in AOAC (2010).

2.3 Microbial analysis

Total viable counts (TVC) for the slurries of all blends were carried out using the method of Frazier and Westoff (1986). This was determined at three different periods during digestion: at the point of charging the waste blends; at the point of flammability and end of study, to monitor microbial population during experimental period.

2.4 Determination of the composition of flammable gas

The flammable gas produced was analyzed using the Sperian gas analyzer; model number SN 66429, USA. This analyzer captured CH_4, CO, H_2S and O_2 concentrations in the flammable gas.

2.5 Determination of water boiling test

The biogas generated from the three blended systems (50:50, 60:40, 70:30) was used for water boiling test as outlined in Rani *et al., (1992*) to determine the combustion efficiency, PHU and fire power of the biogas. This was carried out at the peak of flammable gas production of each system. Water boiling test is a short and simplified imitation of standard cooking procedure established by Volunteers in Technical Assistance-VITA. The test allows for the measurement of fuel consumed by boiling specific amount of water and time required for simulated cooking task. A high-power phase of the test was applied in this study.

2.6 Statistical Analysis

Statistical analysis of data obtained from the physiochemical composition of the undigested waste blends and mean volume of biogas yield from the different digester systems was carried out using One-way Analysis of Variance (ANOVA) and Duncan's Multiple Range Test for mean separation. Significance level was accepted at probability level of 5% (P = 0.05%).

3. RESULTS AND DISCUSSION

Daily biogas production from the different waste blend systems (50:50-control, 60:40 and 70:30) is displayed in Fig. 2 while the general performance of each digester is found in Table 1.

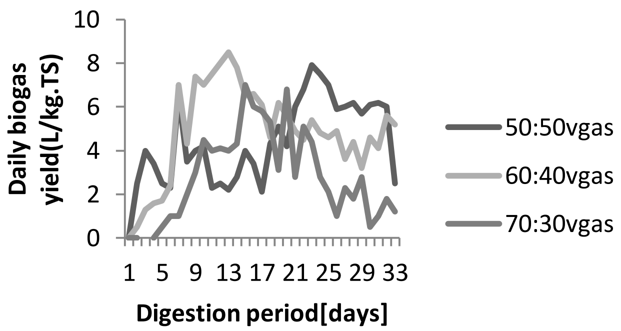

Fig. 2: Daily biogas yield for all the blends during digestion period.

Table **1:** Lag period, cumulative yield and mean volume of gas produced from the waste blends

Parameters	50:50	60:40	70:30
Lag period (Days)	20	12	9
Cumulative gas yield (L/kg.TS)	145.2	160.2	93.7
Mean gas yield (L/kg.TS/day)	4.40 ± 0.57^{b}	4.86 ± 0.28^{a}	2.84 ± 0.14^{c}
Retention time (Days)	35	35	35

Results for mean volume of gas yield are means ± standard deviation of duplicate determinations. Values with different superscript on the row are significantly different (P = 0.05).

The gas production from 50:50 system commenced on the 2nd day, 60:40 on 3rd day and 70:30 on the 5th day of digestion period. The 70:30 bio-digester systems had shortest onset of flammable gas production of 9 days (Table 1). Flammability of biogas empowers it to be useful and effective in cooking, lighting and transportation. However, where flammability does not occur in a biogas system, it indicates that it contained more of incombustible gases such as CO_2, NH_3, H_2S, etc, instead of mainly methane. Hence, it becomes useless in terms of energy utilization (Anonymous, 2003). The results of physico-chemical properties of undigested waste blends are shown in Table 2. The properties are part of major factors considered for efficient biogas production (Kanu, 1988). This is because lack of balanced diet for the biogas microbes could lead to poor biogas yield at the end of process. It could be observed from Table 2 that each of the undigested waste blends has appreciable quantities of the nutrients.

Table 2**:** The physico-chemical properties of undigested swine manure-cabbage waste blends

Parameters	50:50(control)	60:40	70:30
Moisture (%)	$30.09^{a} \pm 0.01$	$28.55^{b} \pm 0.01$	$26.99^{c} \pm 0.01$
Ash (%)	$20.82^{c} \pm 0.02$	$22.72^{b} \pm 0.03$	$24.66^{a} \pm 0.01$
Crude protein (%)	$7.60^{a} \pm 0.01$	$7.26^{b} \pm 0.00$	$6.92^{c} \pm 0.01$
Fat (%)	$7.36^{c} \pm 0.01$	$8.02^{b} \pm 0.00$	$8.70^{a} \pm 0.01$

Crude fiber (%)	14.78[a]±0.01	14.02[b]±0.01	13.24[c]±0.02
T. Carbohydrate (%)	19.36[b]±0.01	19.42[b]±0.01	19.45[b]±0.02
Total carbon (%)	20.63[a]±0.01	20.47[a]±0.02	20.35[a]±0.00
Total solid (%)	65.22[c]±0.01	67.06[b]±0.01	68.91[a]±0.01
Volatile solid (%)	37.35[a]±0.01	36.91[b]±0.01	36.47[c]±0.02
C/N ratio	17.80[c]±0.14	18.35[b]±0.01	19.02[a]±0.01

Results are means ± standard deviation of duplicate determinations. Values with the same superscript on the row are not significantly different (P = 0.05).

However, the carbon to nitrogen ratio (C/N ratio) for each of the blends was a little below the expected range (25-30:1) required for optimum gas production from a biogas system (Dennis and Burke, 2001; FAO/CMS, 1996; Kanu, 1988). This may have contributed generally to the cumulative volume of gas obtained at the end of the study (Table 1, Figure 2). Again, all the systems had the problem of pH stabilizing initially at the required range (6.5-8.0—slightly acidic to slightly alkaline range) during digestion period (Figures 3, 4 and 5) for the maximum performance of methanogens (Anonymous, 1989; FAO/CMS, 1996). The 50:50 digester systems could not reach the required range until the 21stth day while 60:40 digester systems entered the range by the 12th day. This may be due to better synergy that existed between the two wastes during the period of digestion. Swine as a mono-gastric animal has some native microbial flora in its digestive system and this would be transferred to its manure. The presence of the microbes in the manure would help to initiate pH stabilization that may result in the system producing flammable gas on time. However, this may depend on the nature of feed and daily ration for the animals before release of feaces. In 70:30 blend that had 70% of feaces, the waiting period for the digester system was shorter (9 days-Table 1). This trend observed in 70:30 blends may indicate that when more feaces was added, less good synergy between the two wastes (swine feaces-cabbage waste) resulted and led to shorter retention time than found with the other systems.

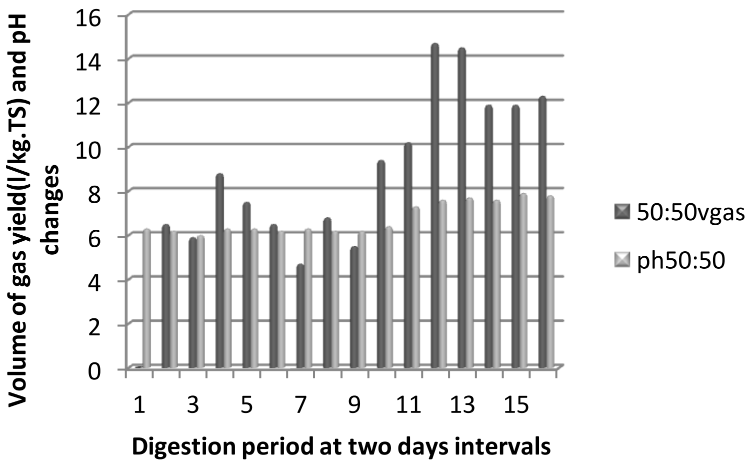

Figure 3: The pH changes at two days intervals with equivalent volume of biogas yield during digestion period (50:50 blends).

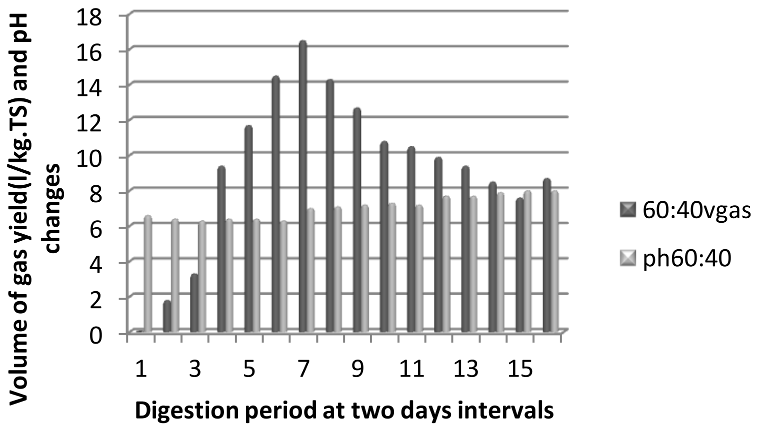

Figure 4: The pH changes at two days intervals with equivalent volume of biogas yield during digestion period (60:40 blends).

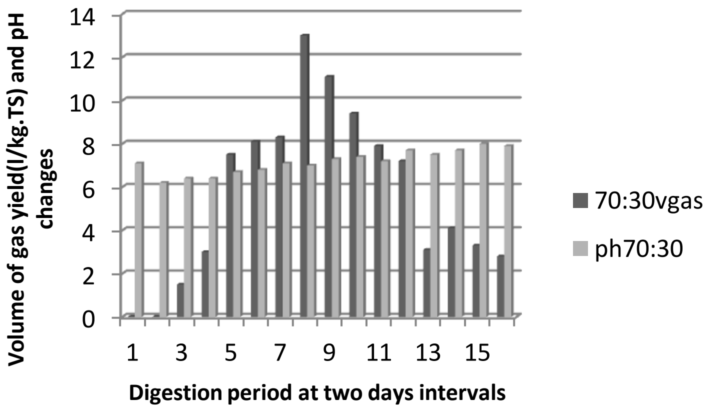

Figure 5: The pH changes at two days intervals with equivalent volume of biogas yield during digestion period (70:30 blends).

The changes in pH and volume of biogas yield as graphically represented (Figures 3, 4 and 5) for each of the system highlights that peak of production for each system can be identified. Hence, to maximize gas production in subsequent times, each system could be buffered using pH range that gave higher volume of biogas yield during the experimental period. Table 3 shows the methane content of each system. The 70:30 was recorded with highest amount of wet methane-85%. There was no H_2S in all the systems indicating that the flammable biogas produced if scrubbed a little further could be used for transportation and welding purposes.

Table 3**:** Components of flammable biogas from the waste systems

Wastes	**CH_4 (%)**	**O_2 (%)**	**CO_2 (%)**	**H_2S (%)**
50:50	75	6.6	18.4	Nil
60:40	70	7.6	22.4	Nil
70:30	85	8.9	6.1	Nil

Tables 4 shows the results of water boiling test with 70:30, 60:40 and 50:50 blend having efficiency of 0.5%, 0.7% and 0.9% respectively. This result depended on the volume of gas yield (at full capacity) and gas pressure. The 70:30 system also had rate of energy release (fire power) by burning its methane as 53.06 kW while 60:40 and 50:50 amounted to 49.22, 45.90 kW, respectively. Percentage heat utilized (thermal efficiency of pot and water combination), an index of percentage heat released from the flame that is absorbed by pot and water, was obtained as 0.53% for 70:30 blend, 0.7%-60:40 and 0.9% for 50:50 blend (Table 4).

Table **4:** Computed results

Parameters	**50:50**	**60:40**	**70:30**
Fire power (P) (kW)	45.90	48.82	53.06
Percentage heat utilized (PHU) (%)	0.90	0.70	0.53
Efficiency (%)	0.9	0.7	0.5

Consequently, the pattern of these results obtained from the simulative cooking indicate that flammable biogas from all the systems have high rate of energy release greater than equivalent fuels such as wood (1 kg fuel wood with calorific value of about 19,000kJ had fire power of 5.4kW) (Rani, et al., 1992). Although the 50:50 systems did not produce flame on time, it had highest efficiency in the cooking test while 70:30 blends has highest rate of energy release, an indication of higher quality methane.

4. CONCLUSION

The present investigation has shown that under the prevailing weather conditions, 60:40 blended system gave highest cumulative volume of biogas yield while 70:30 blend had shortest onset of flammable gas production and retention time. However, 50:50 systems had highest combustion efficiency (0.9%) and highest amount of heat absorbed by its pot and water in the imitative cooking test whereas the 70:30 blends had largest amount of fire power. Results of the percentage heat utilized indicate that biogas stove utilized in the study should be modified to improve on its efficiency. Consequently, biogas production from these waste combinations could be good source of alternative energy for both urban and rural dwellers since the wastes are readily available. However, initial treatment of waste blends to encourage pH stabilization early enough during digestion is recommended.

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ANALYSIS OF SOLID WASTE COMPOSITION AND ITS TREATMENT POTENTIALS AT UNIVERSITY OF NIGERIA NSUKKA CAMPUS

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Abstract

This work reports on a waste characterization study that was conducted at University of Nigeria Nsukka Campus. Solid waste samples were collected from four different points of generation: (1) academic buildings, (2) administrative offices, (2) corridors, and (4) cafeteria use sampling bags. The wastes were separated into different fractions namely paper, plastic, Metal , Organic, Glass

Others. In total, 4821.1kg of waste were segregated, of which, 1034.9 kg originated from samples taken from academic buildings, 910.7 kg from corridor, 502.5kg from the cafeteria, and 2373 kg from departmental offices. The mean quantities of waste generated are 114.99kg, 113.83kg, 167.57kg and 38.27kg for building, corridors, cafeteria and departmental offices respectively. This indicates that on the average that the highest quantity of waste is generated from cafeteria but there is a lot of variation in the amount generated (±63.17). The waste fractions generated are in a decreasing order as follows: paper (33.18%), organic (28.35), plastic (20.43%).metal (7.20%), others (7.16%) and glass (3.69%). The waste with the highest mean bulk density for all the four activity areas namely (1) academic buildings, (2) administrative offices, (2) corridors, and (4) cafeteria is the one from the cafeterias (241.2kg/m^3) with standard error (SE) of 49.9kg/m^3. Based on the current student population of 36,000 and a total solid waste of 4821.1kg/week. Therefore the daily per capita waste generation of the university is calculated as 0.019kg/capita/day from the four sources analyzed. It was also observed that 28.35% of the waste generated is compostable while 64.49 % is recyclable. Moreover, only a small proportion of 7.16% can be diverted to landfill. However, recovery of resources and recycling at UNN, call for segregation of waste at the source, through providing separate waste containers for different waste types.

Keywords: Solid Waste; Composition; Quantity; Recycling Potentials; University Nigeria Nsukka

Introduction

Evaluation on waste generation for disposal habit, changes and trends is indispensable in waste management (Beigl et al., 2008). The amount and composition of waste generated comprise the basic information needed for the planning, operation and optimization of waste management systems. The demand for reliable data concerning waste generation) implicitly included in the majority of national waste management laws. The landmark Federal legislation on environmental protection in Nigeria was the decree Number 58 of 1988, which established the Federal Environmental Protection Agency (FEPA).

The specific role of FEPA with respect to solid waste management was highlighted by Imam et al (2007). For effective implementation of these guidelines, reliable data are needed but unfortunate these data are not available especially in the area of waste generation from University Campuses in Nigeria. The type of decision making that leads to adequate solid waste management (SWM) requires a sound understanding of the composition and the processes that determine the generation of waste (Acurio et al., 1997).

Special attention should be paid to the waste generation sources since the characteristics and composition of the waste differ according to their source (Tchobanoglous et al., 1996).Considering this, Armijo de Vega et al (2008) suggested that waste management programs based on the knowledge of the waste composition and on the condition of the market for recyclables would be more successful than the ambitious programs copied from somewhere else.

According to Armijo de Vega et al (2008), more attention must be paid to solid waste characterization studies and solid waste management (SWM) on campuses since higher education institutions are a special case of study based on the following reasons:(I) not much has been reported on this issue, (ii) being autonomous to a great extent, campuses can accommodate innovative SWM approaches that can trickle down to other communities later, (iii) since SWM on campuses involve students at various levels it can serve to sensitize as well as informally train them in good SWM practices, and (iv) SWM practices adopted by higher education institutions have a great potential of being adopted by surrounding communities because these institutions generally are held in high esteem. The utility of waste characterization studies is justified for the obvious benefit for the planning and implementation of waste management strategies.

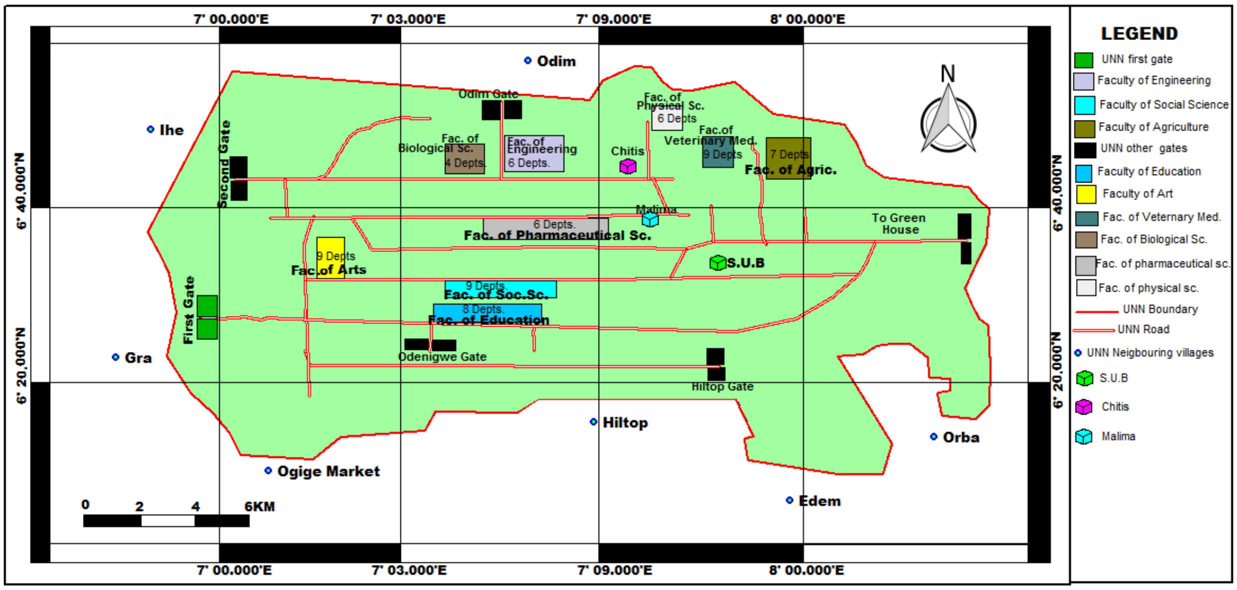
Nigeria is blessed with more than sixty (60) universities and many other institutions of higher learning but no research publication is available on the quantity of waste generated and their recycling potential by any of these institutions.

Moreover, the administration of these institutions cannot engage in recycling program due to lack of baseline studies on the solid waste composition, quantities and recycling potentials. While waste characterization from households, markets and cities in some parts of Nigeria has been considered in recent studies on waste management in Nigeria(Adedibu,1985;Agunwamba et al., 2003, Ogwueleka, 2003; Ogwueleka,2004; Sha'Ato et al., 2007; Imam et al., 2007; Igoni et al., 2007; Kofoworola,2007; Afon, 2007; Ayininuola and Muibi, 2008; A Glance at the World,2009; Adewole ,2009; Nzeadibe,2009; Nnoroma et al.,2009; Ogwueleka, 2009a; Ogwueleka,2009b;Nzeadibe and Ajaero, 2011; Oguntoyinbo,2012 ; Ezeah and Roberts 2012; Ogwueleka, 2013; Abila,2014; Ezeah and Roberts, 2014), the characterization of wastes from higher education institutions such as University of Nigeria Nsukka(UNN) has not been done. The objectives of this study are: To determine the quantity and composition of solid waste generated in one of the three campuses of the first Nigerian indigenous degree awarding institution, University of Nigeria, Nsukka (UNN); To determine the effect of source of generation on the solid waste quantities, quality and compositions and; To determine the recycling potentials of the solid waste and recommend the best management strategies based on the findings.

Materials and Methods

Description of study area

The University of Nigeria was found in 1955 and formally opened on 7 October 1960. The university has three campuses namely University of Nigeria Nsukka(UNN) Campus, University of Nigeria, Enugu Campus(UNEC), University of Nigeria, Teaching Hospital (UNTH) Ituku Ozala (www.unn.edu.ng). The seat of the university administration is located at Nsukka campus usually referred to as the main campus on 871 hectares of hilly savannah in the town of Nsukka, about eighty kilometers north of Enugu (latitude: 6^{o}51’33.41” and longitude: 7^{o}23’52.51”) South East Nigeria(www.unn.edu.ng). The University of Nigeria Nsukka Campus is made up of Nine (9) academic faculties with a total of sixty-two (62) departments (University of Nigeria Calendar Editorial Board, 2008; www.unn.edu.ng).The Faculties and Departments are as shown in fig.1. The university has three major cafeteria namely Chitis, SUG Building, and Malima cafeteria.



Map of UNN Showing Nine Faculties Sixty Two Departments Malima S.U.B and Chitis

Fig.1. Map of University of Nigeria Nsukka showing Faculties and Cafeterias

Solid waste sampling and characterization of the sample

The samples were taken from four different points of generation: (1) academic buildings, (2) administrative offices, (2) corridors, and (4) cafeteria. One academic building and one corridor was selected respectively in each faculty (see table2.1) making a total of Nine (9) academic buildings and Nine (9) corridors. A total of sixty-two offices representing the departmental administrative offices were sampled (Table 2.1).Three (3) major cafeteria namely Chitis, Malima and SUB were selected. The samples of solid wastes were collected from four different sources with varying sampling points as follows: Building (9), Corridor (8), Cafeteria (3) and Departmental offices (62) which gave a total of 82 sampling points. This fits the classical one-factor (source of waste) experimental design for the solid waste samples with responses being rate of solid waste generation, rate of waste fraction generation and bulk density of solid waste after 1week of sampling.The characterization of the solid waste was carried out using the modified methodology for the characterization of household waste according to Armijo de Vega et al (2008). Samples were taken during 9 consecutive days (excluding Saturdays and Sundays); the samples on the first 2 days were trial samplings. This trial sampling helped to unify criteria for data collection and for the identification of the solid waste. The results from the solid waste analyzed during the following 7 days are the ones reported in this article.

The characterization of data was done using the format of data collection by sub-products according to Armijo de Vega et al (2008). A research team of 32 persons performed the samplings of the wastes. Firstly, the waste from each point sampled was weighed in pre-weighted basis using a weighing scale with a sensitivity of 0.01 kg and registered on a sampling sheet. Secondly, the samples were then spread flat on a high density polyethylene sheet on the ground and manually sorted into six different components: paper, plastics, glass, organic, metals, and others. Each component was weighed and recorded and the total weight of all the components checked against the original weight of the samples. At the end of the sorting process, the fractions were weighed separately on a calibrated digital scale and compared with the total. Thirdly, the bulk density (BD) was determined using a calibrated bin with a volume of 50 liters. The empty calibrated bin and the bin full for each waste were then weighed accordingly.

$$BD = \frac{weight\ of\ waste\ collected(kg)}{Volume\ of\ collecting\ container\ (m^3)} \quad 2.1$$

Data analysis

One-way ANOVA (no blocking) was performed on the responses namely rate of solid waste generation, rate of waste fraction generation and bulk density of solid waste after 1week of sampling to determine their respective variations with the source of waste. Significant differences among the means were separated by Games-Howell and Tukey HSD at a 5% probability level. The weight percentage for each subcategory was calculated using the mathematical expression (Armijo de Vega et al, 2008):

$$PS = \frac{PL}{PT} \times 100 \qquad (2.2)$$

Where PS is the sub-category percentage, PL is the amount of sub-category in kg, and PT is the total weight of sample in kg. The recycling potential was determined based on the local recyclables market in the city of Nsukka.

Results and Discussions

Waste characterization and descriptive statistics

In total, 4821.1kg of waste were segregated, of which, 1034.9 kg were from buildings, 910.7 kg from corridor, 502.5kg from the cafeteria, and 2373 kg from departmental offices. The waste analyzed from the four sources provided the waste composition results shown in Table 1 while the descriptive statistics for the solid waste quantity and bulk density are presented in tables 3.2 and 3.3 respectively.

Table 1 shows that the waste fractions are generated in a decreasing order as follows: paper (33.18%), organic (28.35%), plastic (20.43%).metal (7.20%), others (7.16%) and glass (3.69%). Table 3.1 also shows that the highest percentage of paper comes from departmental offices(41.02%) while the highest percentages of plastic(26.78%), metal(23.78%), organic(55.49%), glass (13.59%) and others(10.50%) comes from building, cafeteria, cafeteria, cafeteria and building respectively. The later, shows that building, produce the highest quantities of plastics and other unclassified waste fractions while cafeteria produce the highest quantities of metal, organic and glass in UNN. The results of table 1 entails different waste management approach for the waste sources (Jibril et-al, 2012). A focus on sources of waste in respect of management is justified by the fact that waste characteristics and composition differ according to source (Tchobanoglous et al., 1993). From table1, reusing and recycling of wastes from buildings is a veritable option, while composting is most suitable option for diversion of wastes from UNN cafeteria There is a great potential of recovery of organic waste from UNN cafeteria if the waste is sorted at the source.

It is worthy of note that some of the plastics and metal fractions identified in the wastes stream are parts of spoilt desktop and laptop computers, printers and photocopy machines. The presence of these e-wastes according to Ogbomo et al. (2012) is due to lack of efficiency in managing ICT e-waste in higher education institutions. Agamuthu et al (2015) recommended that Institutional policy on e-waste management should be in all universities. The institutional e-waste management policy would aim to raise awareness on environmental and human health hazards posed by e-waste as well as raise awareness on recycling at universities targeting faculty, college, university staff, and students. Furthermore, the policy would endeavor to implement strategies to enhance campus-recycling systems if any, or introduce such systems if non-existent at the institution. They further opined that proper and responsible disposal implemented in campus-recycling systems would ensure environmental safety, worker's safety, data security, and consumer responsibility.

Table 1.Composition (% by wt.) Solid Waste of Generated in UNN

Waste Fraction	Building	Corridor	Cafeteria	Departmental Offices	Total in UNN
paper	31.67	31.86	1.67	41.02	33.18
plastic	26.78	24.12	4.96	19.51	20.43
Metal	3.45	3.70	23.78	6.66	7.20
Organic	25.53	32.26	55.49	22.32	28.36
Glass	2.07	1.02	13.59	3.32	3.69
Others	10.49	7.04	0.51	7.16	7.16
Total	100	100	100	100	100

The descriptive statistics in Table 2 shows that the mean quantities of waste generated are 114.99kg, 113.83kg, 167.57kg and 38.27kg for building, corridors, cafeteria and departmental offices respectively. On the average, the highest quantity of waste is generated from cafeteria but there is a lot of variation in the amount generated (±63.17).Waste generated from building is slightly less on average than cafeteria,. Also, the most extreme values for the entire waste stream are 2.78kg and 303.34kg, the minimum and maximum. Table 2 also indicates that the more the sample size the smaller the standard error. The SE of 2.69 for departmental offices being relatively small (Table 2), gives us an indication that the mean is relatively close to the true mean of the overall population. The margin of error (at 95% confidence) for the mean is (roughly) twice that value (+/- 5.38), telling us that the true mean is most likely between 32.90 and 43.65

Table 2 .Descriptive Statistics of the solid waste quantity in UNN

Solid waste (kg/week)									
					95% Confidence Interval for Mean				
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum	Between- Component Variance
Buildings	9	1.15E2	60.65	2.02E1	68.37	161.61	39.74	233.46	
Corridors	8	1.14E2	83.72	2.96E1	43.84	183.83	44.14	303.34	
Cafeteria	3	1.68E2	63.17	3.65E1	10.66	324.49	98.74	222.88	
Departmental Offices	62	3.83E1	21.16	2.69E0	32.90	43.65	2.78	94.12	
Total	82	5.88E1	53.06	5.86E0	47.14	70.45	2.78	303.34	

Table 3 lists bulk density determination results. It can be noted that the waste with the highest mean bulk density for all the four activity areas is the one from the cafeterias(241.2kg/m^3) with SE of 49.9kg/m^3 . The margin of error (at 95% confidence) tells us that the true mean is most likely between 26.46 and 456.0.The high bulk density of the waste is attributable to high moisture containing waste like food leftovers and fruit peelings found in such wastes . For a similar argument Mbuligwe (2002) found out that canteens and residential areas have comparably high bulk density waste. Because of containing mainly paper which is light, waste from offices had the lowest mean bulk density (76.5kgm^{-3}). The figure also compares well with bulk density data given in literature, for example 300–500 kg m^{-3} for developing countries (Diaz et al., 1996), 295 kgm^{-3} for three institutions in Tanzania (Mbuligwe, 2002). The determined bulk density values also compare well with an average value of 240 kg m^{-3} for household waste generated in Abuja, Nigeria (Ogwueleka, 2013). The waste from the four areas studied is not fit for collection and transportation in a compactor truck because of its high density. High density reduces the effectiveness of compaction vehicles for waste transfer (Mbuligwe, 2002).

Table 3. Descriptive Statistics of the bulk densities of the waste stream

Bulk Density(kg/m^3)								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Buildings	9	1.50E2	10.19	3.40E0	141.87	157.53	130.20	160.30
Corridor	8	1.62E2	12.02	4.25E0	151.63	171.73	141.80	178.00
cafeteria	3	2.41E2	86.46	4.99E1	26.46	456.01	146.80	316.50
Departmental offices	62	7.65E1	42.32	5.37E0	65.80	87.29	5.56	188.24
Total	82	9.89E1	58.01	6.41E0	86.16	111.65	5.56	316.50

Waste generation rate

Based on the current student population of 36,000 and a total solid waste of 4821.1kg/week. Therefore the daily per capita waste generation of the university is calculated as 0.019kg/capita/day from the four sources analyzed.

Waste from buildings

The percentage composition of waste fractions from each faculty building is presented in Fig.2.From Fig.2; it is evident that paper, plastic and organic are generated more than the other fractions analyzed. Paper fraction is more in faculties of Agriculture, Pharmacy and Engineering. While plastics are more in School of general studies, Arts, veterinary medicine and Social sciences. Moreover, organics are more in Engineering and biological sciences. Percentage composition of paper is more in those buildings because of proximity to photocopying centers.

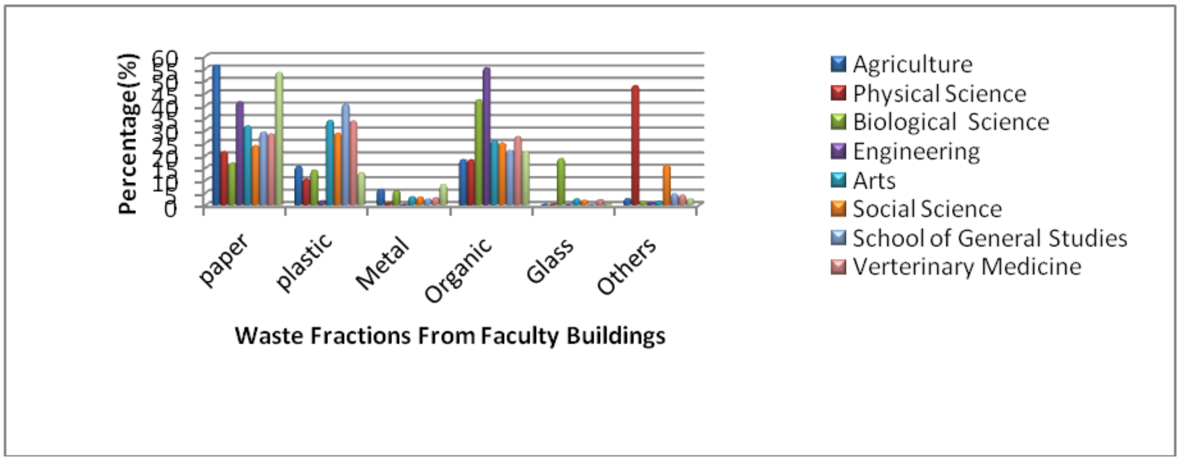


Fig.2.Percentage Waste Fractions from Faculty Buildings in UNN

Wastes from Corridors.

Results of waste composition analyses for waste from corridors are presented in fig. 3. The highest quantities of paper, plastic, metal, organic, glass and other unclassified wastes from corridors are generated from faculties of physical science, Arts, Engineering, Education, Social Sciences, and Education respectively.

Littering on the corridors of the campus of the institution may be attributed to : (1) absence of waste bins ;(2) insufficient environmental education and ethics; (3)Lack of codes of good waste handling practice ;(4) increased population, and the various complex activities and;(5) presence of unorganized retail outlets. In order to solve the envisaged problem of solid waste management, Mbuligwe (2002) recommended that good waste handling practice must be put in place. Additionally, funding, expertise, equipment and facilities as well as other provisions that are currently lacking or inappropriate must be provided. Furthermore, since the envisaged solid waste management practices call for some behavioral changes, there is a need for community sensitization on pertinent issues.

In a similar study, Zhang et al (2011) attributed a parallel impact on the natural environment **as** one of the consequences of expansion on physical infrastructure and services on campuses and at student halls of residence (HoR).

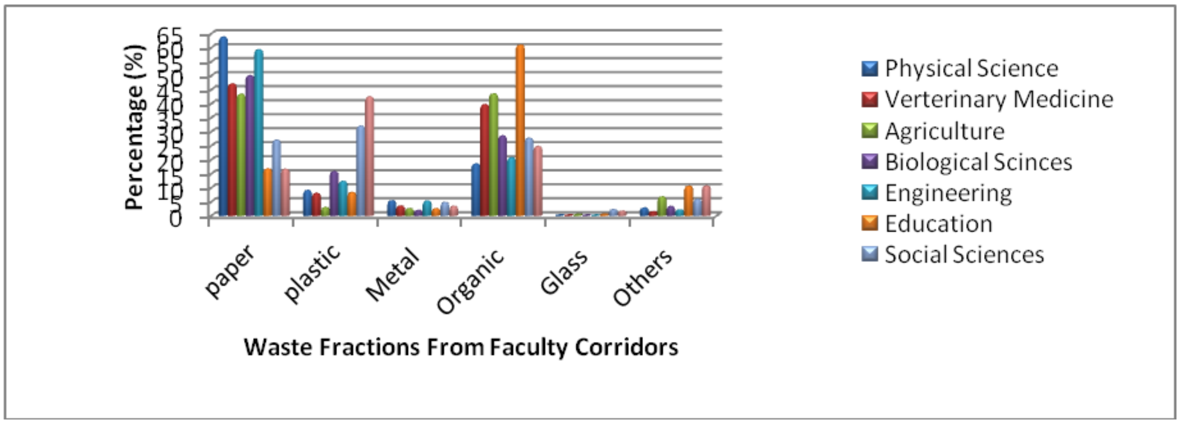


Fig.3.Percentage Waste Fraction from Faculty Corridor in UNN

Waste from cafeteria

The percentage distribution of waste fractions from cafeteria is as shown in Fig. 4.Organic represents the highest proportion of the waste stream from cafeteria followed by metal. It is also very clear that the highest proportion of organic comes from Chitis while the highest proportion of metal comes from Malima.

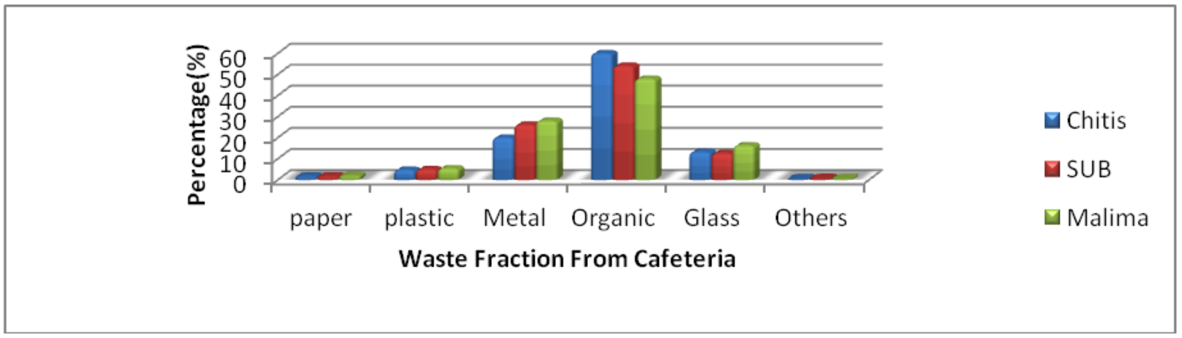


Fig.4.Percentage Waste Fractions from Cafeteria in UNN

Waste from departmental offices

The distribution of waste fractions from the 62 departmental offices analyzed is as shown in Fig.5. The dominance of paper, plastic and organic in the waste stream from departmental offices indicates a huge potential for reuse, recycling and diversion of waste for composting. The overall sample composition indicates that capturing the recyclable material, in particular paper and paper products, would result in the greatest waste diversion in UNN.

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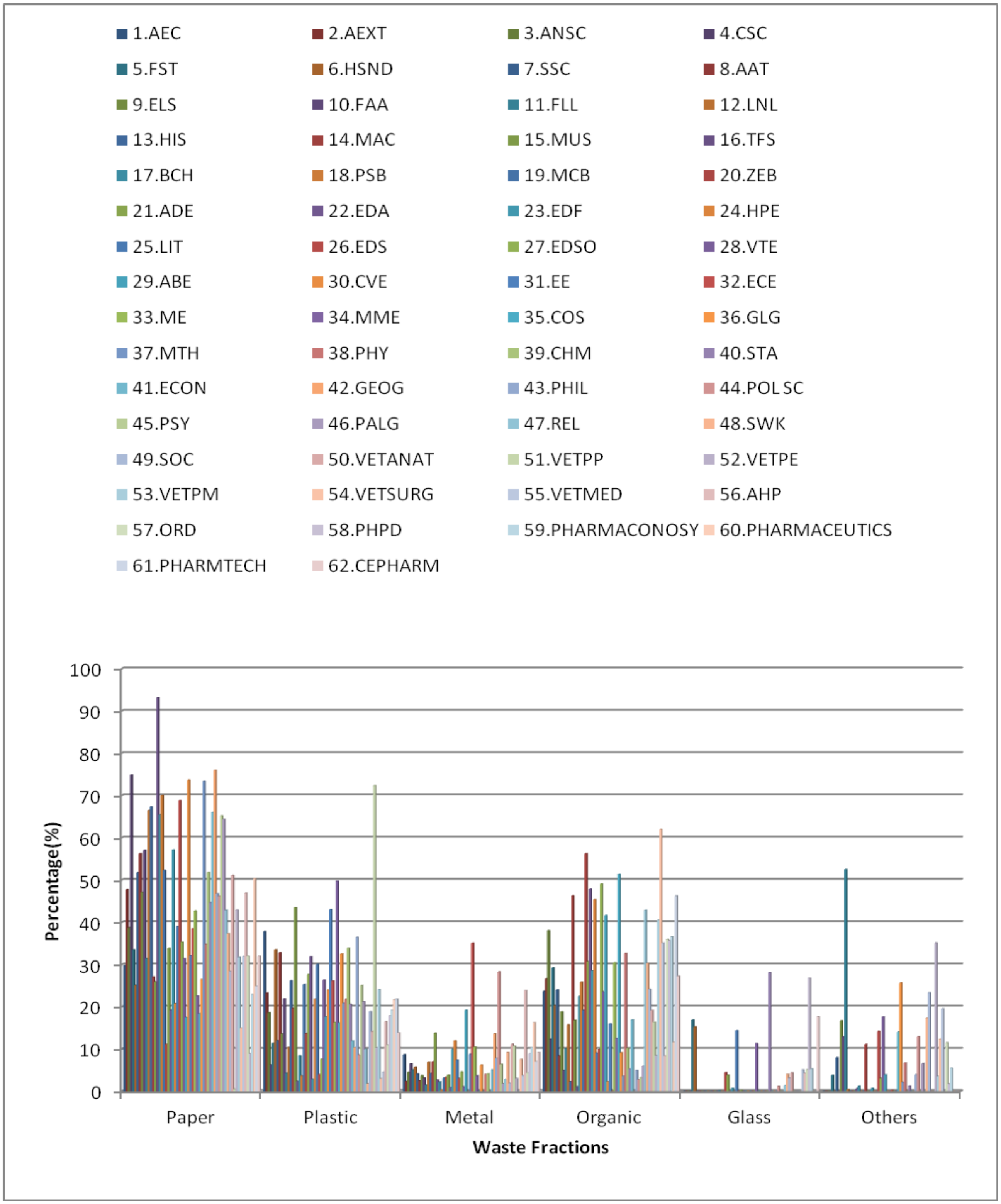

Fig.5. Percentage Waste Fractions from Departmental Offices in UNN

Comparison of solid waste quantity from the activity areas in UNN

The waste stream from the activity areas studied is compared using Fig.6. The highest proportion of waste comes from departmental offices (49.22%).The second largest proportion comes from building (21.47%)

while the third largest proportion comes from corridors (18.89%) which are a little less than that generated from buildings.

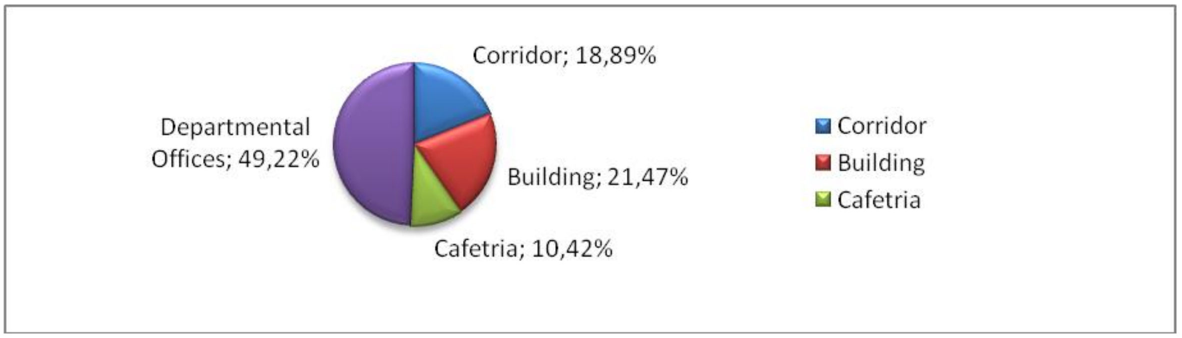

Fig.6.Percentage Quantities of Solid Waste from Activity Areas in UNN

The comparison of waste fractions from the activity areas is also presented in Fig.6. From Fig.6, the highest proportion of paper comes from the departmental offices. It was observed that most white papers found in the UNN campus had been used in most cases only on one side of the sheet, which shows that the reuse of paper in the UNN is practically non-existent. It is important to point out that, besides its recycling potential, waste such as paper has a high reduction potential. Reuse is one of the strategies to reduce waste and, in the case of the UNN, if white paper were to be reused, in the best of cases; the generation of paper waste could be reduced in half.

Moreover, the largest proportion of plastic and other unclassified wastes are found in buildings while the largest proportions of metal, organic and glass are found in cafeteria (Fig.7).Most of the plastic, metal and glass found in the waste stream were as a result of packaging and containerization of food, beverages and water. Appropriate management of these wastes therefore call for implementation of the 3Rs (Reduction, Reuse and Recycling) on UNN campus and this will improve the efficiency and cost savings in the institution's waste management system (Jibril et al, 2012).

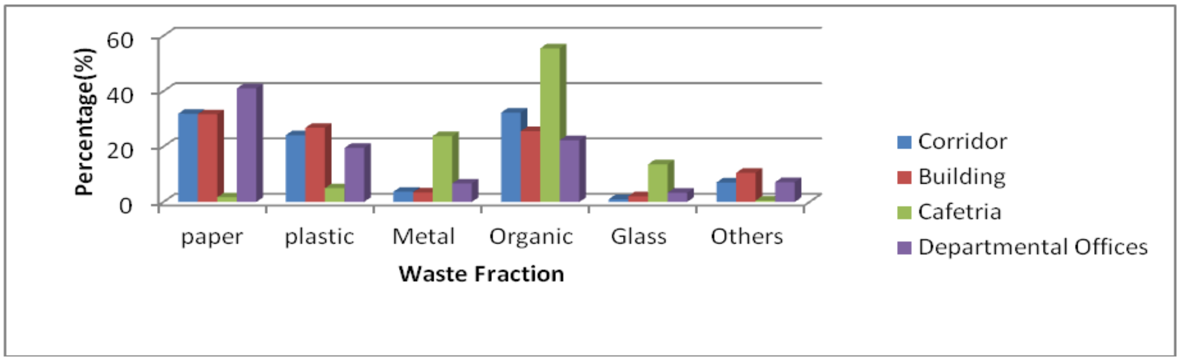

Fig.7.Comparison of Waste Fractions From Activity Areas in UNN

The money saved can be reinvested in improving the schools or supporting other actions of social interest (Maldonado, 2006).

Composition (% by wt.) of Solid Waste Generated in UNN

The composition (% by wt.) of solid waste generated in UNN campus is presented in Fig.8. The waste stream comprises paper (33.18%), plastic (20.43%), metal (7.20%).organic (28.35%), glass (3.69%) and others (7.16%). The waste composition (Fig.8) suggests a huge potential for minimization of waste that is sent to landfill from UNN campus.

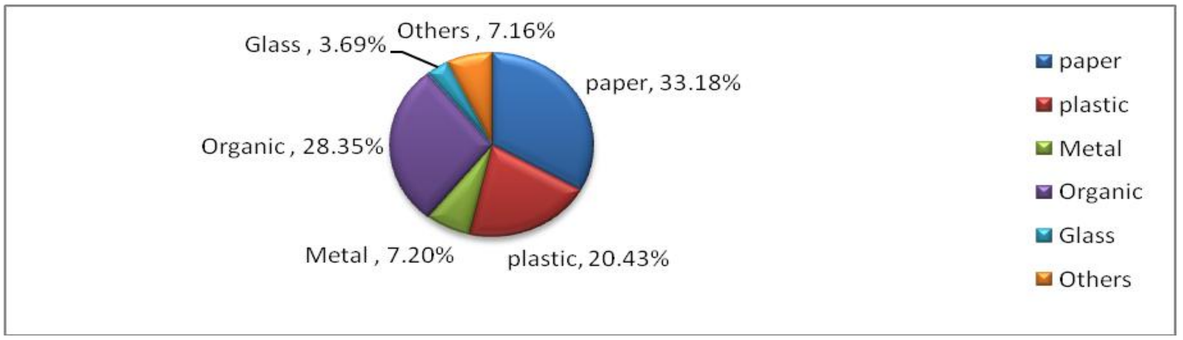

Fig.8 .Composition (% by wt.) Of Solid Waste Generated in UNN

Recycling potentials of the waste

The recycling categories of waste generated in UNN is presented in Fig.9.From Fig. 9, it can be gathered that 28.35% of the waste generated is compostable while 64.49 % is recyclable. Fig.9 also indicates that only a small proportion of 7.16% can be diverted to landfill. However, recovery of resources and recycling call for segregation of these wastes at the source, through providing separate waste containers for different waste types (Mbuligwe, 2002). In a pilot study by Chaggu et al. (1998) in Sinza, Dar es Salaam, segregation of waste at the source through use of different waste containers was found to be practicable at community level. Mbuligwe (2002).reported a similar waste recovery potential of 71% in three institutions of higher education in Tanzania. He mentioned that, in an unofficial manner, the institutions studied practice reutilization of food waste by delivering it to cattle growers who use the waste as animal feed. He further explained that this practice reduces the expenses for the institution's waste management significantly. With reduced amount of waste to be disposed of as 7.16% (Fig.9), one will agree with Mbuligwe (2002) that it is easier and cheaper to establish and operate own sanitary landfills for an institution such as UNN.

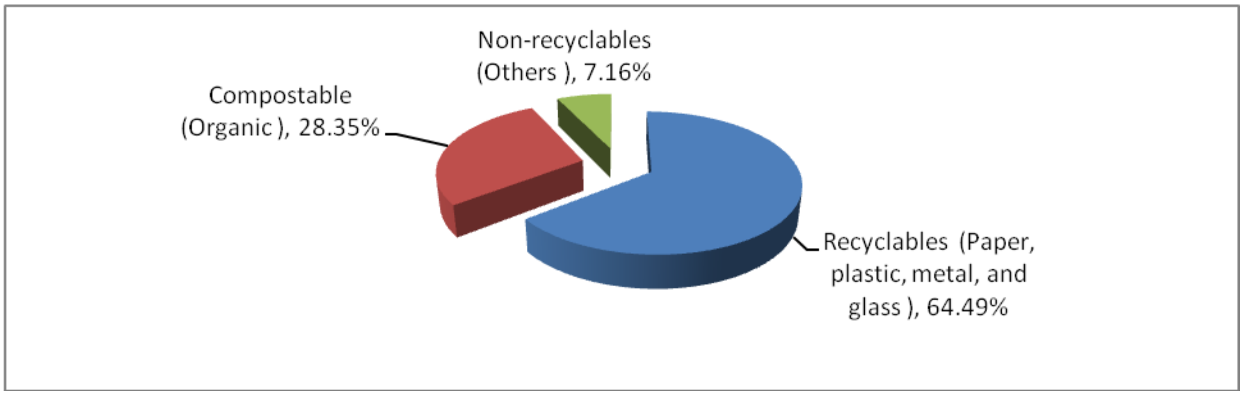

Fig.9. Recycling categories of Waste Generated in UNN

Statistical analysis results for the waste Stream

Test of homogeneity of variance

The test of homogeneity of variance for the solid waste quantity and bulk density is presented in Tables 4 and 5 respectively. The Levene statistics, .000 <.05 both in Table 4 and 5 rejects the null hypothesis that the group variances are equal.

Table 4.Test of Homogeneity of Variances for Solid Waste Quantity

Solid_waste_Quantity (kg)			
Levene Statistic	df1	df2	Sig.
11.323	3	78	.000

Table 5.Test of Homogeneity of Variances for Solid Waste bulk density

Bulk Density(kg/m^3)			
Levene Statistic	df1	df2	Sig.
8.177	3	78	.000

Analysis of variance (ANOVA)

The ANOVA for solid waste quantity and bulk density is presented in tables 6 and 7 respectively. Statistically significant difference existed between the quantities and bulk densities of solid waste generations in different activity areas during this survey {$F(3, 78) = 26.110$, $p < 0.000$ and $F(3, 78) = 30.227$, $p < 0.000$}.

Table 6. ANOVA of Solid Waste Quantity.

Solid waste					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	114261.631	3	38087.210	26.110	.000
Within Groups	113778.491	78	1458.699		
Total	228040.122	81			

Table 7. ANOVA of Solid Waste Bulk Density

Bulk Density					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	146508.836	3	48836.279	30.227	.000
Within Groups	126022.217	78	1615.669		
Total	272531.053	81			

Robust test of equality of means.

The robust test of equality of means for solid waste quantity and bulk density are presented in Tables 8 and 9 respectively. The Brown-Forsythe test statistic for quantity and bulk density are significant {0.002< .05 and 0.035 <0.05}. The Welch statistic for both quantity and bulk density are also significant {0.01<.05 and 0.000<0.05).The Welch statistic is more powerful than the standard F or Brown-Forsythe statistics when sample sizes and variances are unequal, we therefore strongly reject the null hypothesis that the quantities and bulk density of the waste from the four activity areas are the same.

Table 8. Robust Tests of Equality of Means for Solid Waste Quantity

Solid waste(kg)				
	Statistic[a]	df1	df2	Sig.
Welch	9.022	3	6.613	.010
Brown-Forsythe	8.431	3	12.717	.002
a. Asymptotically F distributed.				

Table 9.Robust Tests of Equality of Means for Solid Waste Bulk Density.

Bulk Density				
	Statistic[a]	df1	df2	Sig.
Welch	50.947	3	8.218	.000
Brown-Forsythe	18.637	3	2.382	.035
a. Asymptotically F distributed.				

Multiple comparisons of means

One way ANOVA was used to test the Null hypothesis Ho: That the mean value of solid waste quantity and bulk density are the same in all activity areas. From Table 6 and 7, the ANOVA results, the significance values comparing the activity areas were <.05, showing that the mean value of quantity and bulk density of waste in the four activity areas differed. The significance results for homogeneity of variance, Table 4 and 5 were both .000 < .05 which showed that the error variance of the dependent variables was not equal across the groups. The assumption of homogeneity of variance was okay. Therefore, we reject the null hypothesis.

There was a significant effect of activity area on quantity and bulk density of generated waste (Table 6 and 7) {$F(3, 78) = 26.110$, $p < 0.000$ and $F(3, 78) = 30.227$, $p < 0.000$}.The significance values of these were both <.05. Post hoc tests were carried to know the extent of each activity area on quantity and bulk density of generated waste. Both Turkey and Games-Howell tests were used as popular tests to separate the means of the response variables. The Tukey test relies on homogeneity of variance but Games-Howell test is commonly used when the assumption of homogeneity of variance has been violated. Tukey test indicated that the quantity of solid waste generated from departmental offices differed significantly from quantity of solid waste generation in buildings, corridor and cafeteria, ($p = .000 < .05$) and there was no statistically significant differences between quantity of solid waste generation in building, corridor and cafeteria, {buildings and corridors ($p = 1.000$); building and cafeteria ($p = .174$); corridors and cafeteria ($p = .169$)}. Games-Howell test indicated that quantity of solid waste from departmental offices differed significantly from solid waste generated in buildings only ($p = .022 < .05$). and there was no statistically significant differences in quantity of solid waste generation between: building and corridor($p = 1.000$); building and cafeteria($p = .634$) ; corridors and cafeteria($p = .682$) ;corridors and departmental offices($p = .135$); cafeteria and departmental offices ($p = .169 > .05$).Since the Levene test (.000 <.05 from table 3.5 above) confirmed the suspicion that the variances of the groups are different ,we therefore accept the result of the Games-Howell test that only the solid waste quantities between buildings and departmental offices are statistically significantly different($P = 0.022 < .05$)

Tukey test also indicated that the bulk density of solid waste generated from departmental offices differed significantly from that of buildings, corridor and cafeteria($p = .000 < .05$).Also based on the Tukey test, the bulk densities of waste from cafeteria showed significant differences from the bulk densities of wastes from buildings and corridors(($p = .05$ and $p = .023 < .05$) and there was no statistically significant difference between quantity of solid waste generation in building and corridor(($p = .928 > .05$). The Games-Howell test showed that the bulk density of waste from departmental offices is statistically different from the bulk densities of waste from buildings and corridor but no statistically significant difference exist between bulk density of waste from departmental offices and cafeteria ($P = .190 > .05$).The Games-Howell test result may be as a result of the suspicion that the variances of the groups differs which was confirmed by the Levene test (.000 <.05 from table 3.5 above). However, the mean plot fig.10 suggests that the means of quantity and bulk density of waste from cafeteria is higher than that of other activity areas while the means of these responses are lowest in departmental offices.

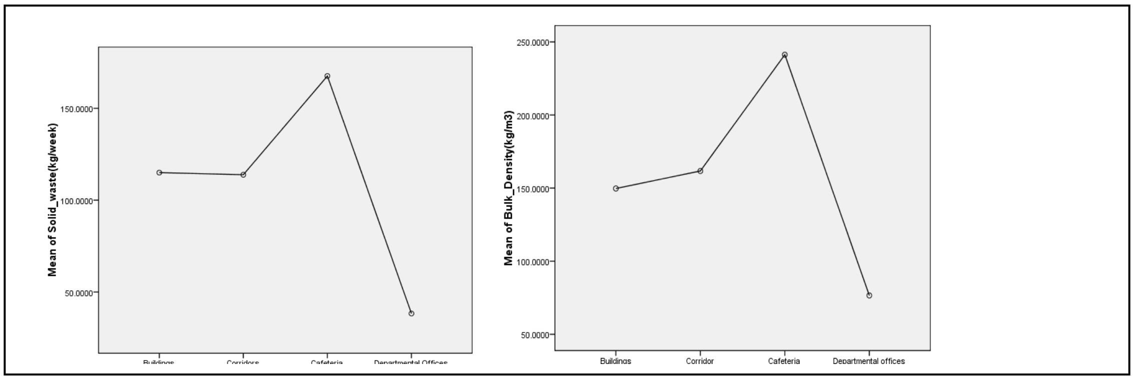

Fig. 10 Comparison of Mean Solid Waste Quantity and Bulk Density from Activity Areas in UNN

Analysis of variance (ANOVA) result for the waste fractions

The **anova** result showed that there was statistically significance between the activity areas for paper {$F(3, 78) = 16.737$, $p = 0.000 < .05$},Plastic {$F(3, 78) = 7.021$, $p = 0.000 < .05$},Metal {$F(3, 78) =$

125.170, $p = 0.000 < .05\}$,Organic $\{F(3, 78) = 56.793$, $p = 0.000 < .05\}$,Glass $\{F(3, 78) = 45.332$, $p = 0.000 < .05\}$ and other unclassified wastes $\{F(3, 78) = 3.043$, $p = 0.034 < .05\}$. Post hoc tests were not used.

Conclusions

In total, 4821.1kg of waste were segregated, of which, 1034.9 kg originated from samples taken from buildings, 910.7 kg from corridor, 502.5kg from the cafeteria, and 2373 kg from departmental offices. The mean quantities of waste generated are 114.99kg, 113.83kg, 167.57kg and 38.27kg for building, corridors, cafeteria and departmental offices respectively. This indicates that on the average that the highest quantity of waste is generated from cafeteria but there is a lot of variation in the amount generated (±63.17). The ANOVA results showed that source of waste generation on the campus has significant effect on the solid waste quantities, quality and compositions ($\alpha = 0.05$). It was determined that the waste fractions are generated in a decreasing order as follows: paper (33.18%), organic (28.35), plastic (20.43%).metal (7.20%), others (7.16%) and glass (3.69%). It was noted that the waste with the highest mean bulk density for all the four activity areas is the one from the cafeterias(241.2kgm^{-3}) with SE of 49.9kg/m^3. Based on the current student population of 36,000 and a total solid waste of 4821.1kg/week. Therefore the daily per capita waste generation of the university is calculated as 0.019kg/capita/day from the four sources analyzed. It was also observed that 28.35% of the waste generated is compostable while 64.49 % is recyclable. Moreover, only a small proportion of 7.16% can be diverted to landfill. However, recovery of resources and recycling call for segregation of waste at the source, through providing separate waste containers for different waste types. Paper and paper products, disposable drink containers and compostable organic material represented three of the most significant material types for targeted waste reduction and recycling efforts.

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EXPERIMENTAL PRODUCTION AND EVALUATION OF CEMENT-BONDED COMPOSITE CUBES FOR CONSTRUCTION MATERIAL

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Abstract
Cement-bonded particle cubes were investigated for its potentials as a construction material. As a cost reduction strategy, the effects of partial replacement of Portland cement with calcium carbide waste, rice husk ash and bone meal ash on the properties of the composite cubes were also investigated. 100 mm × 100 mm × 100 mm cube specimens were manufactured. Cement and Sawdust were mixed at a ratio of 3:1 as a control experiment. Partial replacement of cement with calcium carbide waste, rice husk ash and bone meal ash were by weight of cement (5%, 10% 15%). The use of calcium carbide waste, rice husk ash and bone meal ash has advantages like: reduction in material cost, solving environmental pollution problems as well as reduced the number of landfill areas required for disposing the calcium carbide waste, rice husk and bone meal. Also, sawdust has been used in combination with inorganic binders to produce wood-cement composites replacing sand and aggregate in concrete mix. Moisture content, density, water absorption and compressive strength were assessed using standard methods. Results obtained showed that the density (< 2 Kg/cm^3), water absorption (< 15 %) and moisture content (< 4 %) of the cubes were generally within acceptable limits. The compressive strength of composite cubes decreased with percentage increase in proportions of calcium carbide waste, rice husk ash and bone meal ash. The bone meal ash appeared to have more negative effect on the cube properties than calcium carbide waste and rice hush ash when considering its strength properties.
Keywords: Composite Cubes, Sorption Properties, Compressive strength, Carbide Waste, Rice Husk Ash and Bone Ash.

1.0 INTRODUCTION

Rapid growth in construction activities, housing and other building raises the cost of production. Also, the introduction of new materials in today's construction market is as a result of resource constraints, advances in engineering techniques and cost-serving measures. Attempts have equally been made by various researchers to reduce the cost of concrete and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial raw material.

Cement-bonded particleboards are low-cost composite materials produced from a mixture of cement, water, and particles obtained from wood and other lingo-cellulosic materials to provide a wide range of products for structural and nonstructural applications. In addition to their fire resistance, these materials have a special attraction for use in warm, humid climate where termites and decay are a major concern.

Further benefits include easy machining with conventional wood-working tools and simple fabrication. The cement binder provides a durable surface as well as one that can be easily embossed and colored for an attractive, low-maintenance finished product (Wolfe and Gjinolli, 1999)

However, cement production is known to contribute to the greenhouse effect due to the emission of CO_2 gas during the clinker manufacturing process (Price *et al*. 1999). Mehta (2009) proposed ways for reducing the CO_2 emissions of the cement industry as targets for the next 20 years which include consuming less concrete, consuming less cement in concrete mixtures, and consuming less clinker in cement. Gartner (2004) and Damtoft *et al*. (2008) suggested that the use of pozzolanic materials such as fly ash, blast-furnace slag, silica fume, metakaolin, and natural pozzolans, to replace Portland cement clinker could help to reduce CO_2 emissions associated with cement production. Several pozzolans such as fly ash, rice husk-bark ash, and palm oil fuel ash, which are agricultural or industrial by-products, are found in Nigeria. Many studies have reported that these pozzolans can be used to replace some portion of cement to achieve high compressive strength of concrete (Kiattikomol *et al*. 2001; Sata *et al*. 2004). However, their utilizations are limited because of insufficient data and lack of confidence; thus, most of these materials are disposed of in landfills.

Calcium carbide waste, a by-product from an acetylene gas welding process is largely made up of calcium hydroxide $Ca(CO)_2$ in slurry form. Most of the residue is sent to landfills as waste causing environment problems, including groundwater pollution due to alkaline contamination. The problem of carbide disposal has a long history. Semikolennykh *et al.* (2012) reported that spent carbide is toxic for biota, with calcium hydroxide being one of the toxic components. They also recommended that spent carbide de-activation could be provided within isolated bowls filled with water (micro sediment bowls) or within water-proof storage containers, while complete recycling could be achieved through the addition of the deactivated waste to solid building materials such as cement that are meant to solidify and thus bound toxic compounds and exclude their dissolution.

Rice husk ash produced after burning of Rice husks has high reactivity and pozzolanic property. Indian Standard code of practice for plain and reinforced concrete, IS 456-2000, recommends use of rice husk ash in concrete but does not specify quantities; Chemical compositions of rice husk ash are affected due to burning process and temperature. Silica content in the ash increases with increasing temperature. Mehta (1992), reported that rice husk ash contains silica in amorphous and highly cellular with cement 50 -1000 m^2/g surface area under controlled burning condition in industrial furnace. So use of rice husk ash with cement improves workability and stability by strengthening transition zone, modifying the pore-structure, blocking the large voids in the hydrated cement paste through pozzolanic reaction.

(Varma*et al*. 2016) reported that partial replacement of cement by bone powder ash provides environmental and technical benefits. Chemical components of bone powder ash and cement are almost the same therefore, bone powder ash can be used as normal pozzolanic material to replace cement. Cost of concrete reduces and high strength and workability are assured due to partial substitution of cement with bone powder ash. In addition, compressive strength of cement-bone powder ash composite cubes increases to ten percent in seven days compared to fifteen percent increase in the strength of cement cubes devoid of bone powder ash component during the same period. Bone mineral comprises of calcium, phosphate and magnesium, strontium and bicarbonate. The strontium and bicarbonate in the bone mineral can replace calcium and hydroxyl ions respectively in cement.

The specific objectives of this study were to (i) produce cement-bonded composite cubes using carbide wastes, rice husk ash and bone powder as partial replacements of ordinary Portland cement, and (ii) determine selected engineering properties of the cubes.

2.0 METHODOLOGY

2.1 MATERIAL USED

The materials used for this experimental work are Cement, Calcium carbide waste, Bone meal ash, Rice husk ash, Sawdust, Sand and Water

2.1.1 Cement

Ordinary Portland cement was procured from local market in Ikot Akpaden. It was stored in air tight nylon bag and was used up soon after delivery to prevent strength deterioration.

2.1.2 Sawdust

The sawdust generated from Iroko wood (*Milica excela*) was collected from sawmill at Ekim, Ikot Akpaden. The species was selected due to it availability and relatively high strength. The sawdust was sieved and the percentage pass sieve number 900 µm and retained on 600 µm sieve was used. It was soaked in ordinary water for 24 hours to reduce the amount of water-soluble sugars and tannins that could inhibit the setting of cement and air-dried. The oven dry moisture content was determined as 8.52%.

2.1.3 Carbide Waste

Calcium carbide waste in slurry form was collected from a mechanical workshop at Ikot Akpaden. Because the calcium carbide residue had high moisture content, it was sun-dried for approximately 3-4 days to reduce the moisture content. After that, it was ground in a grinding machine until the particle pass through a 212µm sieve and retained on a pan.

2.1.4 Rice Husk

Rice husk was collected from FADAMA III ground at Ikot Ekpene Udo in Nsit Ubium Local Government Area. Rice husk ash is the agro waste product obtained from burning rice husk at temperature of 300-800℃ at Mechanical Engineering workshop, Akwa Ibom State University. After that, it was ground in a grinding machine until the particles passed through a 212µm sieve and were retained on a pan.

2.1.5 Cow Bones

Cow bones were collected from abattoir at marina junction in Eket. The bones were sun dried for number of days. The bones were burnt in a furnace at a temperature of 300 to 800 ^oC. After that, it was ground in a grinding machine until the particles passed through a 212µm sieve and were retained on a pan.

2.1.6 Fine Aggregates

Medium size sand particles of about 2mm were collected from the University construction site. The sand was washed and air-dried. After drying, it was sieved to remove dirt and big stones using sieve number 600 µm and retained on a pan.

2.1.7 Water

Water is an important ingredient of composites as it actively participates in the chemical reaction with cement. The water used for the study was collected from a borehole at Agricultural Engineering Laboratory, Akwa Ibom State University. The water was clean and free from any visible impurities.

2.2 EXPERIMENTAL DESIGN

2.2.1 Batching

The experimental procedures were made at the following production levels:

(i) Control experiment:

a. Sand + Cement Ratio 3:1 by volume.

b. Cement: Sawdust Ratio 3:1 by weight.

(ii) Experimental specimens: Partial replacement of cement with calcium carbide waste, Rice husk ash and bone meal ash by it weight (5 %, 10 %, 15 %).

2.2.2 Mixing of the Ingredients

The aggregate were weighed accordingly and mixed manually. The Portland cement, rice husk ash, bone meal ash, calcium carbide waste and sawdust were mixed in a dried state until high level of uniformity and even distribution was obtained. The water was slowly added while mixing until uniform consistency and colour were achieved.

2.2.3 Forming

Moulds of 10 cm × 10 cm × 10cm were coated with engine oil for the easy removal of the set/hardened composite cubes; the blended finish was uniformly distributed into the moulds placed on a level surface free from vibration using hand trowel. The moulds were removed after 24 hours and the resulting samples were left in the open air under room temperature to dry. This same procedure was carried out for all the samples produced.

Figure 1. Moulds Specially Fabricated for Cube Production

2.2.4 Curing of Cubes

After production, the composite cubes were kept at a room temperature for 28 days in order to complete setting of the cement before testing. Curing preserves water for hydration, maximizing cube strength and durability. It also helps to prevent the surface from drying out more quicker than rest of the material, reducing the possibility of surface damage due to differential shrinkage (Grove, 2006).

2.3 Experiments

The experiments and tests carried out on the samples were as follows:

a. Moisture Content
b. Density
c. Water Absorption
d. Compressive Strength

2.3.1 Moisture Content

The moisture content test was carried out on the cubes of length 10 cm × 10 cm × 10 cm. The moisture content was ascertained at a temperature of $148 \pm 2\ ^{0}C$ for 2 hours at constant weight. It is expressed as percentage of oven dry weight and calculated as:

$$M.C\,(\%) = [(M_w - M_d)/(M_d)] \times 100\%$$

Where, M_w is initial weight (g) at room temperature at 28 days, and M_d is the oven-dried weight (g) at $148 \pm 2^{0}C$ after 2 hours.

2.3.2 Density

The samples were weighted using electronic weighing balance and the volumes of the samples were calculated. Density is calculated by dividing the weight by the volume of the samples. The relationship is expressed as:

$$\text{Density } (\rho) = [\{\text{Weight of the test sample (g)}\}/\{\text{Volume of the test sample (cm}^3\}]$$

Volume of the cubes is given as $V = \text{length} \times \text{width} \times \text{height}$ Cube's volume = S^3

2.2.3 Water Absorption

The water absorption (A) is expressed as the weight percentage for the specimen after 24 hours submersion in water to the dry samples. The samples were submerged in water at normal room temperature for 24 hours after which, each sample was withdrawn from water and allowed to drain for 5 minutes before the final weight was taken. The amount of water absorption is calculated from the increase in weight and expressed as the percentage by dry weight.

$$A\ (\%) = [(m_2 - m_1)/(m_1)] \times 100\ \%$$

Where m_2 is the weight (g) of the specimen after soaking and m1 is the weight (g) of the specimen before soaking.

2.3.4 Compressive Strength

Fifteen cubic specimens of 10 cm ×10 cm × 10 cm were tested to determine the compressive strength at 28 days of curing. After curing the specimens for 28 days at a room temperature, they were taken to the concrete crushing machine [LM-02 Type Digital Dynamometry Appea – (MC) Zhe (Made in) 06820009-1] where load was applied and increased until failure. The machine automatically stops when failure occurs, and then displays the load and the compressive strength was evaluated. The compressive strength of each sample was determined as follows;

$$\text{Compressive strength} = \frac{\text{Crushing load (N)}}{\text{Effective Area (mm}^2\text{)}}$$

Figure 2. Crushing of Cubes

3.0 RESULTS AND DISCUSSION

3.1 Moisture Content of Composite Cubes

Figure 3.1 shows the mean moisture content of composite cubes. Composite cubes made with cement: sawdust ratio had the highest moisture content, while cement: sand ratio recorded the lowest moisture content. The moisture content of composite cubes decreased with increase of partial replacement of cement with calcium carbide, bone meal ash and rice husk ash.

There was significant difference ($p = 0.05$) between the cube made with rice husk ash, bone meal ash and calcium carbide but there were significant differences between the control and experimental samples. This may be due to the hydrophilic nature of the rice husk ash, bone meal ash and calcium carbide that absorb and lose moisture to the surroundings.

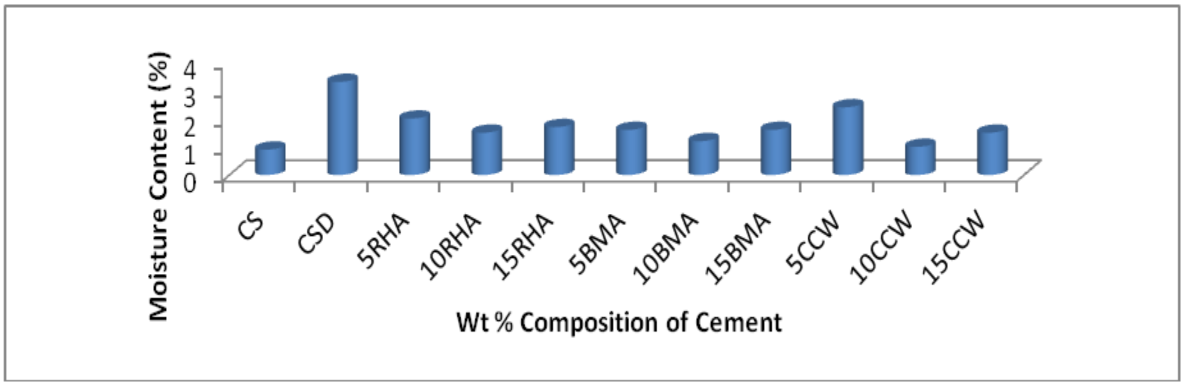

Figure 3.1 Mean Moisture Content of the Composite Cubes

Legend:

CS - Cement + Sand (Control)

CSD - Cement + Sawdust (Control)

5RHA - 5 % Rice husk ash

10RHA - 10 % Rice husk ash

15RHA - 15 % Rice husk ash

5CCW - 5 % Carbide carbide waste

10CCW - 10 % Carbide carbide waste

15CCW - 15 % Carbide carbide waste

5BMA - 5 % Bone meal ash

10BMA - 10 % Bone meal ash

15BMA – 15 % Bone meal ash

3.2 Densities of Composite Cubes

The most important indicator of composite's performance is density, which basically affects all the properties of composites. Density depends on cement: sand ratio and cement: sawdust ratio which explains the trend of increasing density. Figure 3.2 show the mean densities of composite cubes. Density of the composite cubes decreased with increase of partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste. Cube made with rice husk ash recorded the lowest density and control cement: sand ratio recorded the highest densities. The highest densities were found with controls cement: sand ratio followed by cement: sawdust ratio. At high-density indices, a material is more compact in lattice structure (Wolfe and Gjinolli, 1999). There was no significant difference ($p = 0.05$) between the cube made with rice husk ash, bone meal ash and calcium carbide waste; also there were significant differences between the control and experimental samples.

Generally the higher the percentages of partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste, the lower the matrix density. This is common observation in wood fibre matrix since wood particles generally tend to have lower bulk densities than cement. This implies that the greater the proportion of cement in composite cubes the greater the weight, and the greater the proportion of partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste, the lower the density.

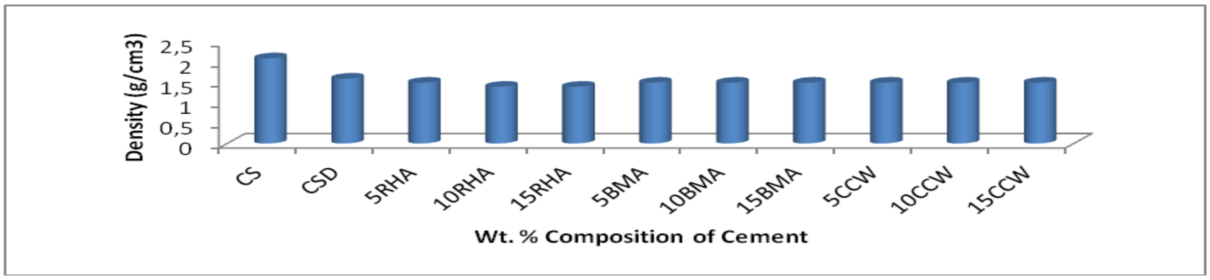

Figure 3.2 Mean Moisture Content of the Composite Cubes

3.3 Water Absorption (WA) of Composite Cubes

Figure 3.3 shows the mean water absorption of composite cubes. Composite cubes made with partial replacement of cement with rice husk ash had the highest water absorption, while the controls cement: sawdust ratio had the lowest. This suggests that rice husk ash has more affinity for water and also is a hygroscopic material. There was significant difference ($p = 0.05$) between the cube made with rice husk ash, bone meal ash and calcium carbide waste; there were significant differences between the control and experimental samples.

Water absorption rate is a primary indicator of the durability of cement composites. Water absorption increased with increase of partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste. Therefore, replacing cement with rice husk ash, bone meal ash and calcium carbide waste had notable effect on water absorption. This may be due to unevenly distribution of rice husk ash, bone meal ash and calcium carbide waste in the mixture which resulted in the formation of voids and the presence of extractive compounds in the composite cubes which have strong affinity for moisture.

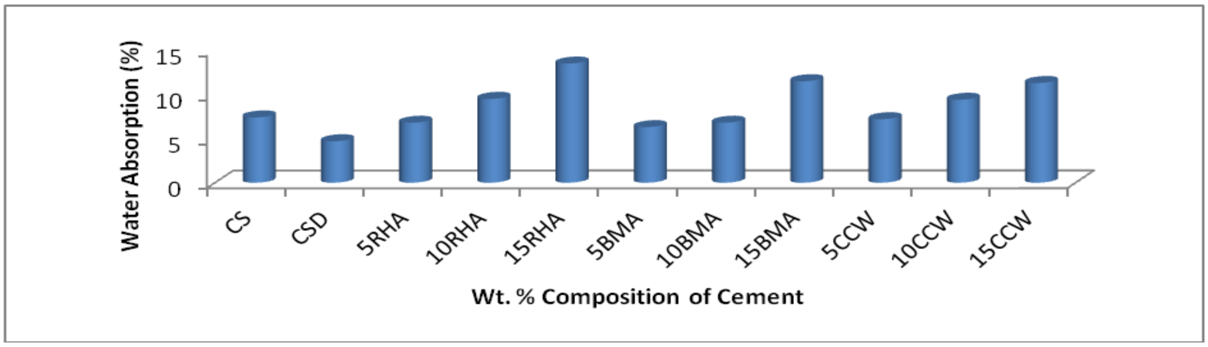

Figure 3.3 Mean Water Absorption of the Composite Cubes

3.4 Compressive Strength

Figure 3.4 shows the mean compressive strength of composite cubes. Composite cubes made with cement: sawdust ratio had the highest compressive strength. There was significant difference ($p = 0.05$) between the cube made with rice husk ash, bone meal ash and calcium carbide waste; also there was a significant difference between the control and experimental samples.

Compressive strength of the composite cubes decreased with increase of partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste. This may be mainly attributed to the poor adhesion between the hydrophilic lignocellulosic materials, which did not allow efficient stress transfer between the phases of the material and the agglomeration of rice husk ash, bone meal ash and calcium carbide waste. The compressive strength of composite cubes also appeared to depend on the density of the cube and sawdust: cement ratio. Generally, the compressive strength in controls cement: sawdust ratio was higher than cement: sand ratio and decreases with those of 5%, 10% and 15% partial replacement of cement with rice husk ash, bone meal ash and calcium carbide waste. This implies that the greater the proportion of cement in the composite, the higher the strength would be. The bone meal ash apparently had more negative effect on the cube properties.

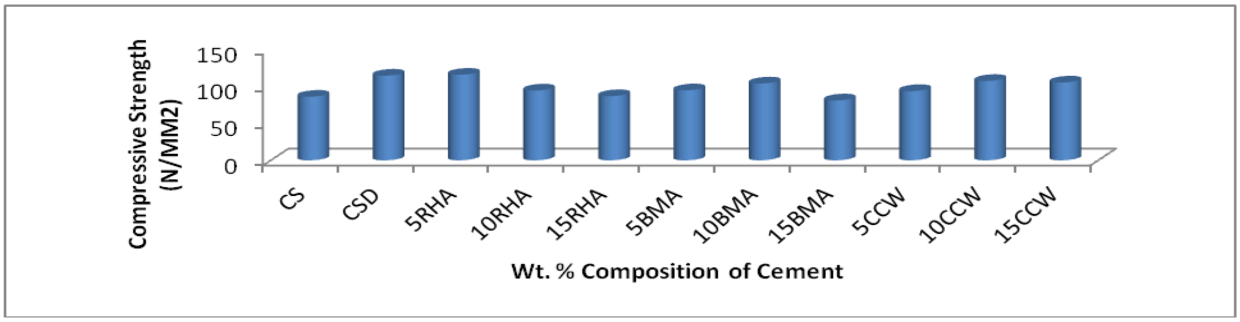

Figure 3.4. Mean Compressive Strength of the Composite Cubes

5.0 Conclusions

Composite cubes were successfully produced using cement-bonded particleboard and partially replacing cement with calcium carbide waste, rice husk ash and bone meal ash respectively. Results obtained showed that the moisture content, density and water absorption of the cubes were generally within acceptable limits. Compressive strength reduces when cement is replaced with calcium carbide waste, rice husk ash and bone powder ash. As percentage partial replacement increases compressive strength decreases. It concluded that calcium carbide waste, bone meal ash and rice husk ash can be innovative supplementary cementitious construction material.

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INVESTIGATION OF BIOGAS PRODUCTION FROM ANAEROBIC CO-DIGESTION OF CASSAVA WASTEWATER AND COW MANURE

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ABSTRACT

Biogas production from cassava waste water (CWW) blended with abdominal cow dung (ACD) in different proportions was studied in five treatments. The five treatment cases A: 100% CWW; B: 100% ACD; C: 90%CWW +10%ACD; D:70%CWW+30%ACD; E: 50%CWW+50%ACD were digested under anaerobic conditions in model batch, metallic biodigesters of same working volume (32.0 litres) for 30 days within ambient conditions. Results indicated that 100% ACD system flamed on the 20th day, 50%CWW+50%ACD on the 20th day while 100% CWW, 70%CWW+30%ACD and 90%CWW +10%ACD systems didn't flame. 100% CWW had cumulative gas yield of 12.7 liters; 100% ACD had 28.85 liters; 90%CWW +10%ACD had 12.5 liters,70%CWW+30%ACD had 11.1 liters while 50%CWW+50%ACD had cumulative gas yield of 15.8 liters per 24kg mass of slurry. 100% ACD had 91.20% methane; while 50%CWW+50%ACD produced 92.999% methane. Weekly biogas yield was also modelled as functions of some physicochemical parameters and results recorded.

Key words: Cassava Wastewater, Abdominal Cow Dung, Weekly Biogas Production, Cumulative Biogas Production, Anaerobic, Co-digestion.

INTRODUCTION

Anaerobic digestion is a process by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce fuels. Cassava wastewater (CWW) and cow dung (CD) may constitute environmental nuisance, if not handled properly. These wastes can be fed into an anaerobic digester to produce biogas. Co-digestion refers to the anaerobic digestion of multiple biodegradable substrates in a digester. The idea is to maximize the production of biogas in the digester by adding substrates that produce much more biogas per unit mass than a base substrate. Biogas is a mixture of gases produced by the breakdown of organic matter in the absence of oxygen. During the process, biomass wastes are transformed in an air-tight tank into primarily methane (CH_4), carbon IV oxide (CO_2) and small amounts of hydrogen sulphide (H_2S), moisture and siloxanes (Richards et al, 1994). Biogas technology produces renewable energy that can be used for heating, electricity and in many gas engine operations. Principally, it reduces global warming which is a crucial issue.

Literature contains substantial biogas production from different wastes in the locality. Ukpai and Nnabuchi (2012) carried out a study on the “Comparative Study of Biogas Production from Cow Dung, Cow Pea and Cassava Peeling using 45 Litres Biogas Digester”. They found out that cow pea has the highest methane content followed by cow dung and cassava peeling. Cow dung had the highest cumulative biogas yield followed by cow pea and cassava peeling, respectively. Diaho et al. (2005) carried out a research on “The Production of Biogas from the Mixture of Cow Abdominal Waste and Its Dung”. They found out the mixture of cow abdominal waste and its dung yielded biogas within 24 hours. The pure dung yielded appreciable biogas after 7 days. Ezekoye and Ezekoye (2009) researched on “Characterization and Storage of Biogas produced from the anaerobic digestion of cow dung, spent grains/cow dung and cassava peels/rice husk”. They discovered that cow dung yields biogas faster than spent grains/cow dung and cassava peels/rice husk. Spent grains/cow dung were found to produce larger amount of biogas on complete digestion of the three wastes. These studies focused on the rate of biogas production and ultimately the cumulative biogas yield. Model predictions that could lead to higher biogas production were not investigated. Hence, the aim of this study is to obtain model for higher gas yield.

MATERIALS AND METHODS

The study adopted custom response design. Cassava waste water was collected from local processors of the product. The abdominal cow dung waste was collected from the abattoir in (Ikpa) market, Nsukka in Nsukka Local Government Area of Enugu State, Nigeria. Metallic model biodigesters, figure 1, utilized for the study were each of 32.0L working volume (fabricated locally at the National Centre for Energy Research and development, University of Nigeria, Nsukka). Materials such as top loading balance (Camry Emperors Capacity 50kg/110 Ibs), plastic water troughs, graduated transparent plastic buckets for measuring daily gas production, The pHep pocket-sized pH meter (Hanna Instruments), thermometers, pressure gauge, thermoplastic hose pipes, metallic beehive stand, biogas burner fabricated locally for checking gas flammability, were used.

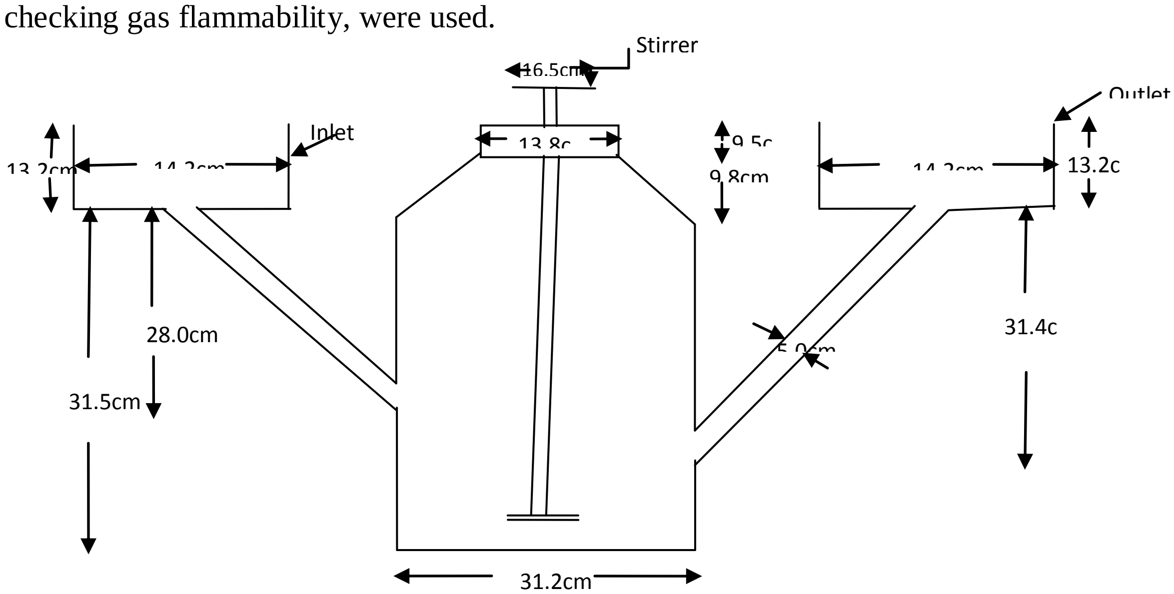

Figure 1: Schematic Diagram of the Biodigester

Figure 2: The experimental set-up

EXPERIMENTAL STUDY

The fermentation of the blends took place for 30 days at the prevailing ambient mesophillic temperature range of 23.5 to 36.5^{o}C. The ratio of the water to waste in each charging was 2:1. This was based on the moisture content of the organic wastes at the point of charging the biodigesters. Cassava waste water (CWW) was co- digested with abdominal cow dung (ACD) in the ratio of 9:1, 7:3, 5:5 while the CWW alone and ACD alone served as control resulting to the five treatment blends A(100% CWW); B(100% ACD); C(90%CWW +10%ACD); D(70%CWW+30%ACD) and E(50%CWW+50%ACD). Co-digestion is used to increase methane production from low-yielding or difficult to digest materials. The moisture content of the respective wastes determined the waste to water ratios used. Volume of gas produced, slurry pressure, pH, ambient and slurry temperatures were monitored on daily basis throughout the period of digestion. Flammability check was also carried out on daily basis until the system produced flammable biogas and occasionally till the end of digestion period. The study was carried out at the exhibition ground of National Centre for Energy Research and Development, University of Nigeria, Nsukka.

Physicochemical and Microbial Analyses

The physical and chemical compositions of the undigested wastes were determined before the digestion. Ash, moisture, crude fibre, crude nitrogen, crude fat, crude protein, BOD, COD, total solid and suspended solid contents were carried out using AOAC method of 2005. Phosphorus, potassium, energy and SO_2 contents were determined using methods described in Pearson (1976). HCN was determined using method described by Onwuka G.I. (2005). TVC was determined using methods described by Ochei and Kolhatkar (2000). Carbon content was determined using methods described by Schumacher (2002). Proximate analysis was done using AOAC method (2005).The population of the microbes in each of the treatment cases was determined at different times (at charging, flammable, peak of production and end of digestion), during the period of study to monitor the growth of the microbes at the various stages.

Gas Analysis

The flammable gas compositions from the 100%ACD and 50%CWW+50%ACD were analyzed using BACHARACH (PCA2) Gas Analyzer, made in United States.

Data Analysis

The data obtained for the volume of gas production from each of the systems were subjected to statistical analysis using SPSS ver.20, Microsoft Excel XP 2007 and Minitab 17 software.

RESULTS AND DISCUSSION

Table 1 shows the physicochemical properties of undigested Cassava waste water and Abdominal Cow Dung blends.

Table 1: Results of Physicochemical Analysis of Undigested Cassava Wastewater and Abdominal Cow Dung Blends

Parameter	Treatment Cases				
	100%CWW	100%ACD	90%CWW+10%ACD	70%CWW+30%ACD	50%CWW+50%ACD
BOD (mg/l)	460	720	580	650	715
COD (mg/l)	36866.67	86833.33	24379.33	34000	40000
HCN (mg/l)	21.03	1.3	20.38	16.6	11.47
SO_2 (ppm)	0	0	0	0	0
TVC (cfu/ml)	1800000	29000000	6700000	13000000	27500000
ASH (%)	0.83	0.47	0.45	0.67	0.65
MOISTURE (%)	98.23	98.42	99.73	99.15	98.47
CRUDE FIBER CONTENT (%)	0.1	0.37	0.3	0.47	0.63
CRUDE FAT (%)	0.36	0.49	0.25	0.49	0.61
CRUDE NITROGEN (%)	0.513	0.0552	0.289	0.12	0.181
PHOSPHOROUS (Ug/g)	16.5	4.86	0.85	3.05	4.3
POTASSIUM (ppm)	1.89	1.73	1.15	1.37	1.22
CRUDE PROTEIN (%)	0.21	0.03	0.04	0.05	0.05
OXIDIZABLE ORGANIC CARBON (%)	4.36	1.65	4.19	2.1	4.57
ENERGY (KCal/g)	5.37	5.46	5.01	1.31	4.05
TOTAL SOLID (%)	1.75	1.58	0.27	0.85	1.53
DISSOLVED SOLID (%)	0.67	0.14	0.06	0.03	0.04
SUSPENDED SOLID (%)	1.68	1.44	0.21	0.82	1.49
CARBOHYDRATE (%)	0.55	0.22	0.2	0.18	0.14
TOTAL ORGANIC CARBON (%)	5.81	0.27	1.45	0.85	1.55
ORGANIC MATTER (%)	10.01	0.46	2.5	1.47	2.67
CARBON-NITROGEN RATIO	8.5	29.9	14.5	17.5	25.2

The cumulative volume of biogas (vog) and methane contents for the various waste combinations are presented in table 2

Table 2: Field Analysis of the Treatment Cases

Digester/Waste	Flammable Time/Lag Time (Days)	Retention Time (Days)	Cumulative Volume of biogas (L)	Component of Biogas (%)			
				CO_2	CO	CH_4	Other components
T1 (100%CWW)	-	30	12.7	-	-	-	-
T2 (100%ACD)	20	30	28.85	5.8	0.0001	91.20	3
T3 (90%CWW+10%ACD)	-	30	12.5	-	-	-	-
T4(70%CWW+30%ACD)	-	30	11.1	-	-	-	-
T5 (50%CWW+50%ACD)	20	30	15.8	18.3	0.0001	92.999	3

DIGESTERS' PERFORMANCE

The results of digester performances (from table 2) indicated that both 100% ACD and 50% CWW+50% ACD systems flamed on the 20th day while 100% CWW, 70% CWW+30% ACD and 90% CWW+10% ACD systems didn‘t flame at all. The cumulative gas yield from the five treatments were different: the 100% CWW had cumulative gas yield of 12.7 liters/24kg mass of slurry and a mean vog of 0.423 L; 100% ACD had cumulative gas yield of 28.85liters/24kg mass of slurry and a mean vog of 0.962 L; 90% CWW +10% ACD had cumulative gas yield of 12.5 liters/24kg mass of slurry and a mean vog of 0.417 L; 70% CWW+30% ACD had cumulative gas yield of 11.1 liters/24kg mass of slurry and a mean vog of 0.37 L while 50% CWW+50% ACD had cumulative gas yield of 15.8 liters/24kg mass of slurry and a mean vog of 0.54 L during the 30 days retention period. 100% ACD had 91.20% methane; while 50% CWW+50% ACD produced 92.99% methane.

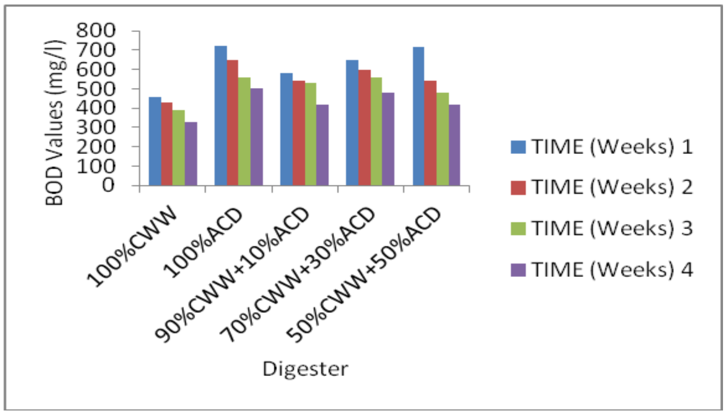

Figure 3: Weekly BOD Values

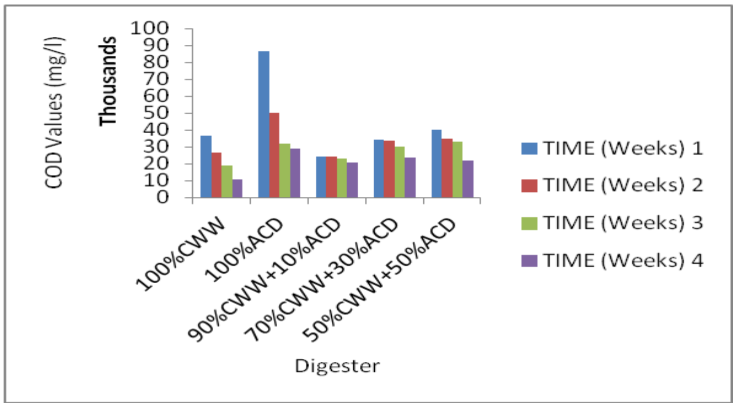

Figure 4: Weekly COD Values

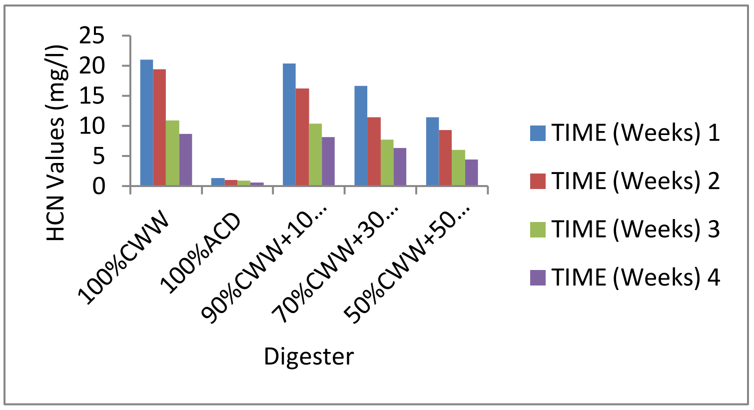

Figure 5: Weekly HCN Values

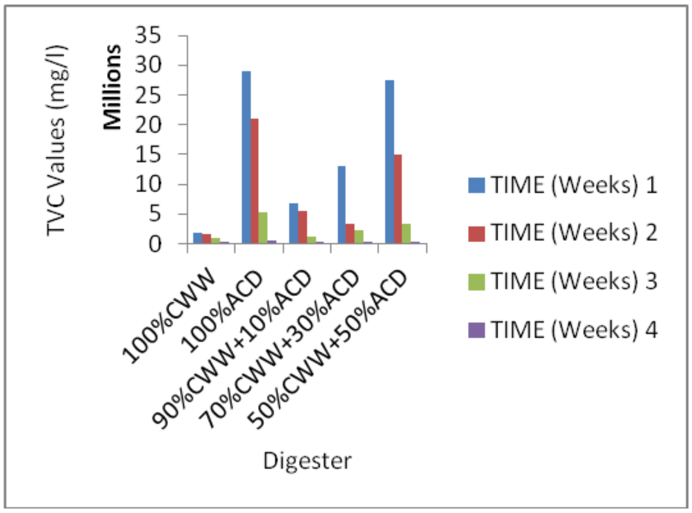

Figure 6: Weekly TVC Values

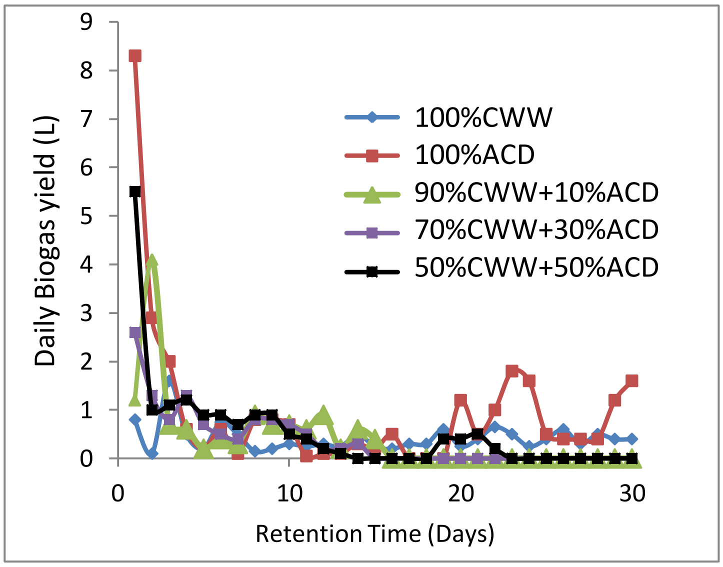

Figure 7: Daily biogas yield versus Retention time for the wastes

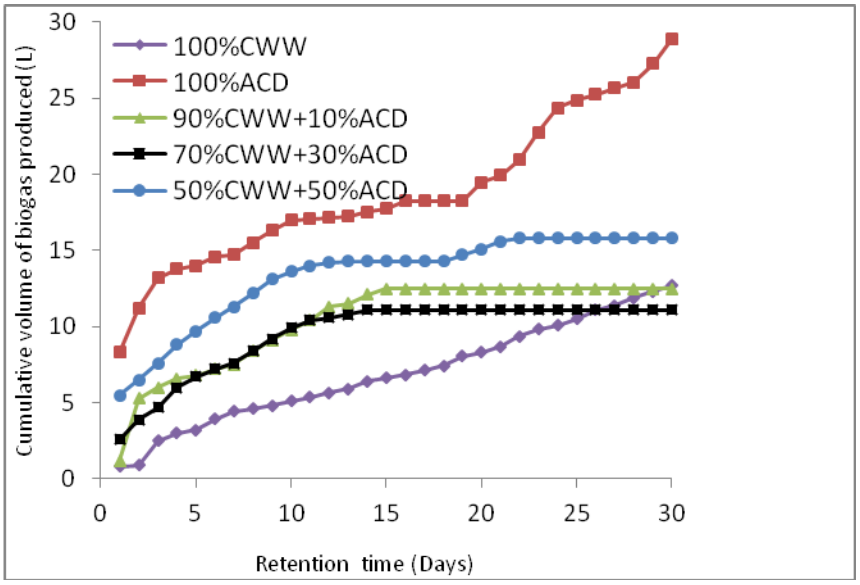

Figure 8: Cumulative volume of biogas produced versus Retention time

EFFECT OF C/N RATIO ON THE SYSTEMS

From the results of table 1, the C/N ratio of 100% ACD and 50% CWW+ 50% ACD, were seen to be within the range of the optimum C/N ratio. Consequently, each of these digesters flamed. Digesters 100% CWW, 90% CWW+10% ACD and 70% CWW+30% ACD each had low C/N ratio that possibly led to ammonia accumulation and consequently could not flame. C/N ratio is an important indicator for controlling biological systems. High C/N indicates rapid nitrogen consumption by methanogens and leads to lower gas production while low C/N ratio results in ammonia accumulation and an increase in pH values, which is toxic to methanogenic bacteria (Moller et al., 2004). During anaerobic digestion, microorganisms utilize carbon 25 to 30 times faster than nitrogen (Yadvika et al., 2004). To meet these requirements, microbes need 20 to 30:1 ratio of C to N.

PROXIMATE ANALYSIS OF THE SYSTEMS

The proximate composition includes the ash, moisture, crude fibre and crude fat contents of the wastes. The ash and crude fibre contents of the wastes for each of the systems were minimal. Each of the wastes for the systems had optimum moisture content because of the mix (which was 2 portion of water to 1 portion of waste). Biological activities are increased when digester fluid are mixed to provide homogenous temperature and nutrient condition throughout the digester (Lay et al, 1997). The crude fat for each of the wastes was also minimal.

PHOSPHORUS AND POTASSIUM CONTENTS OF THE TREATMENT SYSTEMS

Cationic elements such as phosphorus and potassium are required for microbial growth in anaerobic digestion of waste, but can be inhibitory to microbial activity if present in high concentrations (Appels et al., 2008). The metal contents are however low in this case therefore, their presence effects the microbial growth positively. From table 1, there is the presence of phosphorus and potassium which are the nutrients contained in the digestate. Digestate is an excellent biofertilizer (Werner et al, 1989). 100%CWW, 100%ACD, 90%CWW+10%ACD, 70%CWW+30%ACD and 50%CWW+50%ACD each had a phosphorus content of 16.5µg/g, 4.86µg/g, 0.85µg/g, 3.05µg/g and 4.3µg/g respectively. The potassium content of 100%CWW, 100%ACD, 90%CWW+10%ACD, 70%CWW+30%ACD and 50%CWW+50%ACD are 1.89ppm, 1.73ppm, 1.15ppm, 1.37ppm and 1.22ppm respectively.

THE SOLID CONTENT OF THE WASTES

Total solid shows the total solid matter constituent of the entire organic waste both degradable and non-degradable. The total solid content of 100%CWW, 100%ACD, 90%CWW+10%ACD, 70%CWW+30%ACD and 50%CWW+50%ACD are 1.75%, 1.58%, 0.27%, 0.85% and 1.53% respectively.

ENERGY, OXIDIZABLE ORGANIC CARBON, TOTAL ORGANIC CARBON AND ORGANIC MATTER CONTENT OF THE WASTES

From table 1, it can be seen that 50%CWW+50%ACD waste had 4.57% oxidizable organic carbon content, 1.55% total organic carbon content and 2.67% organic matter content. 100%CWW had 4.36% oxidizable organic carbon content, 5.81% total organic carbon content and 10.01% organic matter content. It can be concluded that the higher the oxidizable organic carbon content, the higher the total organic carbon content and then the higher the organic matter content (Navarro et al, 1993).

THE EFFECT OF HYDROGEN CYANIDE ON THE SUBSTRATES

Figure 5 showed concentration of HCN for each of the digesters. Each figure showed reduction trend in weekly HCN with digester 100% CWW having the highest initial HCN, followed by each of 9:1, 7:3 and 5:5 combinations of the wastes over the 30 days retention time. Digester 100% ACD had little or no appreciable HCN. It could not be said that its biogas production and flammability was as a result of the effect of HCN. However, HCN had positive effect on biogas production and flammability of digester 50% CWW+50% ACD. This is confirmed by the fact that even though 100% CWW and 90%CWW+10%ACD and 70%CWW+30%ACD had higher initial values of HCN (21.03mg/l, 20.38mg/l and 16.6mg/l respectively), they could not produce flammable gas. Total cyanide includes both bound and free cyanide but the free cyanide is labile (volatile) in the form of hydrogen cyanide. The cyanide determined is majorly the bound cyanide since the hydrogen cyanide which is free cyanide is labile such that on collection of sample and exposure, the free cyanide is lost (Jones, 1993). The cassava wastewater is known to have high level of cyanide and also known to have the capacity to produce linamarase which is an enzyme that metabolizes cyanide to hydrogen cyanide that becomes volatile.

WEEKLY BOD, COD, SO_2, TVC AND ANAEROBIC DIGESTION AS A WASTE MANAGEMENT TECHNOLOGY

Figures 3, 4 and 6 showed reductions in weekly BOD, COD and TVC, respectively. This is expected as the wastes stabilized. However, it was observed that there were no traces of SO_2 in all the wastes and their combinations. Anaerobic digestion is the most important method for the treatment of food waste because of its techno-economic viability and environmental sustainability. The use of anaerobic digestion technology generates biogas and preserves the nutrients which are recycled back to the agricultural land in the form of slurry or solid fertilizer. The relevance of biogas technology lies in the fact that it makes the best possible utilization of food wastes as a renewable source of clean energy since there is always reduction in BOD, COD and TVC. Total Viable Count (TVC) a quantitative idea about the presence of microorganisms such as bacteria, yeast and mold in a sample. To be specific, the count actually represents the number of colony forming units (cfu) per g (or per ml) of the sample. A TVC is achieved by plating dilutions of the culture until 30-300 colonies exist on a single plate. Microorganisms (mainly bacteria and fungi) are involved in decomposition, the chemical and physical processes during which organic matter is broken down (in the absence of oxygen) and reduced to its original elements.

The relationship between volume of gas and cassava waste water using linear regression was obtained as

$$\text{WEEKLYVog (L)} = 8.948\text{E-}005\text{COD} + 6.116\text{E-}008\text{TVC} \qquad [1]$$

$$R^2 = 81.7\% \qquad [2]$$

CONCLUSION

This study has shown that wastes such as cassava wastewater and abdominal cow dung which have been termed nuisance to the environment can be utilized to produce biogas which can be used as an alternative to the widely known and used fossil fuel. The digestate after biogas has been produced can also be used as fertilizer to enrich the soil and improve plant growth. From the research even though cassava wastewater is poor in methane production, it can be co-digested with abdominal cow dung which is rich in methane production. Therefore, it can be concluded that co-digestion of the wastes resulted in improved biogas production.

This study has shown a new source of wealth creation and at the same time a means of decontaminating the environment by waste recycling and transformation. These wastes that are consumed in large quantities in homes can be used to produce biogas, thus helping them lose the name attached to them as being nuisance to the environment.

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POTENTIALS OF BAMBOO LEAF ASH AS SUPPLEMENTARY CEMENTICIOUS MATERIAL FOR CONCRETE IN SOUTHERN NIGERIA

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ABSTRACT

Nigeria's industrial development policy is hinged on sustainable utilization of its locally available raw materials. This has necessitated the most promising alternatives as bamboo which has become a substitute to solid wood in most applications. Little wonder therefore, that the construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in Nigeria and other developing countries. This study investigates the potentials of bamboo leaf ash as a partial replacement of cement in concrete. The study involved three experimental processes which include: aggregate, fresh, and harden concrete testing processes. The results obtained from the aggregate testing were used for mix design of 25N/mm^2 targeted Strength giving mix ratio of 1:1.9:3 with 0.5 W/C ratio. The mix was calculated for 0%, 5%, 10%, 15%, 20% and 25% replacement of cement with BLA. Concrete cubes were cast representing curing days of 3,7,14, and 28 days. The experimental results were classified in three phases as aggregate, fresh and harden concrete test results. From the results, the parameters for the engineering properties were computed. The Slump was within 10-30mm design Slump. Water Absorption falls below the range of (1-4) for 25N/mm^2 ASTM C330/C330M concrete and the Compressive Strength met the design Compressive Strength of 25N/mm^2 and as well as the minimum of 17N/mm^2 stipulated by EN 1881 and ASTMC 330-8. Hence 15% BLA concrete met the various criteria and had the best workability for light weight concrete. Therefore, 15% replacement of cement with BLA is recommended for use in structures, especially structures with mild condition of exposure.

Keywords: Bamboo Leaf Ash, Pozzolan, Slump, Water Absorption, Setting Time, Compressive Strength.

1. INTRODUCTION

Truly, conventional materials such as cement, granite and sand are integral part of concrete—the indispensable components of a structure, offering protection against excessive cold, heat, rain, high winds and any other form of inclement weather as well as protection against unwanted aggression on human existence. As observed by Mustapha. Z. (2004), homelessness and the incidence of people living in poor housing and unhealthy neighbourhoods are rapidly growing. The housing problem is acute especially in the urban areas due to shortage of affordable housing for low-income earners and the poor who constitute over 70% of the urban population. Anthonio, J.B. (2002) asserts that the high cost of building materials has been observed to be the major factor besetting housing delivery in Nigeria. This has been partly traced to the rising cost of cement; which is commonly used in the production of sandcrete blocks, concrete and as stabilizing admixture in soil blocks. In addition, there are also issues arising from the production processes of cement which range from huge energy consumption to large emissions of CO_2 and $CH_{4,}$ the, major greenhouse gases. Hence, for a nation faced with what can be described as an unprecedented energy crisis and with the global campaign against the emission of greenhouse gasses to curb warming of the environment, it is only appropriate to seek alternative means to the use of cement in the effort to achieving the goal of housing delivery. Little wonder therefore that the construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. Since the high and increasing cost of these civil engineering materials has greatly hindered the development of shelter and other infrastructural facilities in Nigeria and other developing countries, there arises the need for engineering consideration of the use of cheaper and locally available materials to meet desired need of enhance self-efficiency, and lead to an overall reduction in construction cost for sustainable development.

Tenacious efforts have ultimately been made by various researchers to reduce the cost of concrete constituents and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include bamboo leaves ash, pulverized fuel, ash palm kernel shells, slag, fly ash etc. which are produced from waste disposal units, milling stations, thermal power station, waste treatment plants etc.

Frankly, our society is hinged on a quagmire to protect its environment using any available procedure by eliminating waste and paying meticulous attention to safeguarding it. The use of these waste materials that constitute environmental nuisance becomes an advantage when they are directed and used to supplement cement in concrete production—"Turning Waste to Wealth."

In this effort, the effects of bamboo leaf ash blended with cement on the engineering properties of concrete have been investigated so as to establish the optimum bamboo leaf ash content suitable for stabilizing concrete for building construction. Since these materials are readily in abundance, they are expected to impact positively on the building industry in Nigeria; particularly in the area of cost of housing delivery and environmental protection from harmful gases.

The increasing demand for cement is expected to be met by partial cement replacement (Coutinho, 2003). Studies by Arikan, (2004) and Turanli *et al*. (2004) indicated that substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intensive Portland cement. RMRDC (2004) reported that bamboo is widely distributed in the South and Middle belt regions of Nigeria. According to the report, distribution of bamboo is related to ecological conditions with the rainforest areas having the most abundant. Bamboo is found in abundance in all the States of Southern Nigeria except Lagos and Bayelsa where the distribution is considered relatively less.

The most endowed states in terms of bamboo occurrence are observed to be Ogun, Oyo, Osun, Ondo, Edo, Delta, Rivers, Akwa Ibom, Cross River, Abia, Ebonyi, Enugu, Anambra and Imo States.

In general, the purpose of this research is to study the use of Bamboo Leaf Ash (BLA) to obtain lightweight, cheaper and environment-friendly concrete. The objectives of this research are to look at the performance of Bamboo Leave Ash (BLA) blended with cement in concrete with the general objectives:

- To study the feasibility/possibility of Bamboo Leave Ash (BLA) as supplementary cementitous material in the production of concrete.
- To study the physical and mechanical properties of this concrete.
- To experimentally determine the maximum and optimum limits of both these materials in combination.
- To determine the maximum replacement limits of cement by Bamboo Leave Ash (BLA).
- To recommend and identify specific uses and applications of this concrete material.
- To introduce this concrete as a cheaper alternative to existing products.
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2. MATERIALS AND METHODS

2.1. Materials

Bambusa Vulgaris Leaf Ash: Bamboo Leaf Ash (BLA) used for this study was generated from the open air burning of bamboo leaf, which have been properly sun dried prior to the combustion. The Bamboo leaf samples were obtained from Umuimo Community in Abia State. The community is located about 434Km South of Abuja, the country's capital; with latitude and longitude of 5^{o}11'9.61" and 7^{o}2017'.23" respectively. After the open air combustion, it was allowed to cool before sieving with sieve aperture 150µm; and was kept in waterproof bags. The pozzolanic property of the BLA was ascertained and it conformed to the requirements of ASTM 618-15 (1991).

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Fig.1 (a) BLA after incineration and sieving. (b) BLA in wet purchased condition .

Ordinary Portland Cement (OPC): The Ordinary Portland cement was purchased from Dangote cement factory in Gboko, Benue State of Nigeria. This cement conformed to the requirement of (BS 12, 1996).

Coarse Aggregate: The granite (coarse aggregate) used for the study was 20mm maximum size. It was sourced from a quarry site at Umunneochi LGA Abia State Nigeria; and conformed to the requirements of (BS 882, 1982).

Fine Aggregate: The sand (fine aggregate) was sourced from Ovim River in Isukwuato LGA Abia. It was thoroughly flushed with water to reduce the level of impurities and organic matter –deleterious materials and later sun dried to conform to the requirements of (BS 882, 1982).

Water: The water used for the study was obtained from the tap inside the concrete laboratory of the institution. The water was clean and free from any visible impurities. It conformed to (BS 3148, 1980) requirements.

2.2. Methods

The study methodology involved three experimental phases which included: aggregate, fresh, and hardened concrete testing. The aggregate test included the Particle Size Distribution, which was carried out for the fine and coarse aggregates; using sieve sizes arranged from 80mm - 4.75mm for coarse aggregate and 4.75mm –0.075mm for fine aggregate in accordance to (BS 1377:part2: 1990); and the result showed that the aggregates were well graded. The specific gravity for the aggregates and the cement and bamboo leaf ash, as well as the water absorption tests for aggregates were performed in accordance according to BS 1377:part2:1990 as well as ASTM C 127 (2011). The results obtained from the aggregate testing were used for mix design of $25N/mm^2$ targeted Strength in accordance to BS 5328-13 and BS 8110-14 (1985), giving mix ratio of 1:1.9:3 with 0.5 W/C ratio. The mix was calculated for 0%, 5%, 10%, 15%, 20% and 25% replacement of cement with BLA. Concrete cubes were tested for curing days of 3,7,14, and 28 days; using three samples as test specimens for each of the required curing days. The experimental results were classified in three phases as aggregate, fresh and hardened concrete test results. From the results, the parameters of the engineering properties were computed.

3. RESULTS AND DISCUSSIONS

3.1. Aggregate test Results

3.1.1. Chemical Composition of Bambusa Vulgaris Leaf Ash.

Table 1: Chemical Composition of Bambusa Vulgaris Leaf Ash.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3	IR	LOI
BLA	**75.90**	**4.13**	**1.22**	**7.47**	**1.85**	**5.62**	**0.21**	**0.20**	**1.06**	**------**	**-----**

From table 1, the average percentage composition of SiO_2 + Al_2O_3 + Fe_2O_3 is 81.25%. This satisfies the minimum percentage requirement for pozzolana which is 70% according to ASTM C 618 (1991) which is also in line with the report by Olutoge F. A, Oladunmoye O.M. (2017), that BLA contains all the main chemical constituents of cement since the sum of (SiO_2 + Al_2O_3 + Fe_2O_3) is greater than 70%.; confirming that it is a good pozzolan .ASTM 618 (1991).

3.1.2. Specific gravity of Bambusa Leaf Ash (BLA):

The specific gravity was determined on relative paraffin (kerosene) value for the bamboo leaf ash at room temperature and standard atmospheres to obtain the results below as appropriately recorded:

Table2: Specific Gravity of Bamboo Leaf Ash (BLA).

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of empty 50ml specific gravity bottle(W_1) (g)	27.9	27.7
Mass of bottle +Sample (W_2) (g)	36.5	37
Mass of bottle +*Sample* +kero (W_3)	92.2	93.37
Mass of bottle +kerosene (W_4) (g)	68.2	36.2
Mass of bottle + water (W_5) (g)	77.9	77.9
SPof kerosene = (W_4-W_1)/(W_5-W_1)	0.81	0.80
SP of BLA =(W_2-W_1)/[(W_3-W_1)-(W_5-W_1)]	0.60	0.60
Average specific gravity	**0.6**	

3.2. Fresh Concrete Test Results

3.2.1. Slump Test of Fresh Concrete Mix:

From the slump test having height 300mm performed within 120 seconds of batching and mixing, the following results were ultimately obtained:

Table 3: Slump Test Results as percentage replacement of BLA increases

% cement replaced	**Height of concrete(mm)**	**Slump of concrete(mm)**
0% BLA	276	24
5% BLA	277	23
10% BLA	279	21
15% BLA	282	18
20% BLA	286	14
25% BLA	293	7

From table 3, the values obtained from the slump test carried out in accordance to BS EN 12350-2 (2009), correspond to the designed slump range of 10mm-30mm. The slump which decreases from the control sample of percentage BLA with value of 24mm to 25% BLA replacement with a value of 7mm. This is as a result of more fibre bond between the cement material and BLA which was still workable, but has high plasticity than that of the control. This shows that it serves as plasticizer and makes concrete for substructure work and rebar possible.

3.2.2 Setting Time of Cement and Cement Partially Replaced with BLA

The results of the setting time experiment as obtained are displayed thus:

Table 4: Setting Time of Cement at various replacement levels of BLA

% cement replaced	Initial Setting (mins)	Final Setting (mins)
0% BLA	150	260
5% BLA	163	272
10% BLA	172	283
15% BLA	188	290
20% BLA	193	293
25% BLA	196	298

From table 4, it can be deduced that the presence of BLA in cement increased the initial and

%BLA	**3days**	**7days**	**14days**	**28days.**

final setting time performed in accordance to BS EN 196-3 (2005). This is evidently observed in the progressive upward adjustment of the setting times (initial and final) for 0% replacement from 150mins and 260mins initial and final respective setting times to 196mins and 296mins of initial and final respective setting times.

3.3. Test on Hardened Concrete

3.3.1 Water Absorption of Concrete after the Curing Period

From table, the control samples at 3 days curing period have quite lower water absorption followed progressively by the 5% BLA, 10%BLA, 15%BLA, 20%BLA and 25%BLA; having respective average values of 0.013,0.020, 0.023, 0.027, 0.08, and 0.12. This trend showed a constant approximated increase from 0%BLA- 25%BLA. Thus, there is indicated gradual increase in the rate of BLA after absorption. This is negligible as it falls below 1-4% for a 25N/mm^2 characteristic strength, as specified in BS 1881-122 (2011).

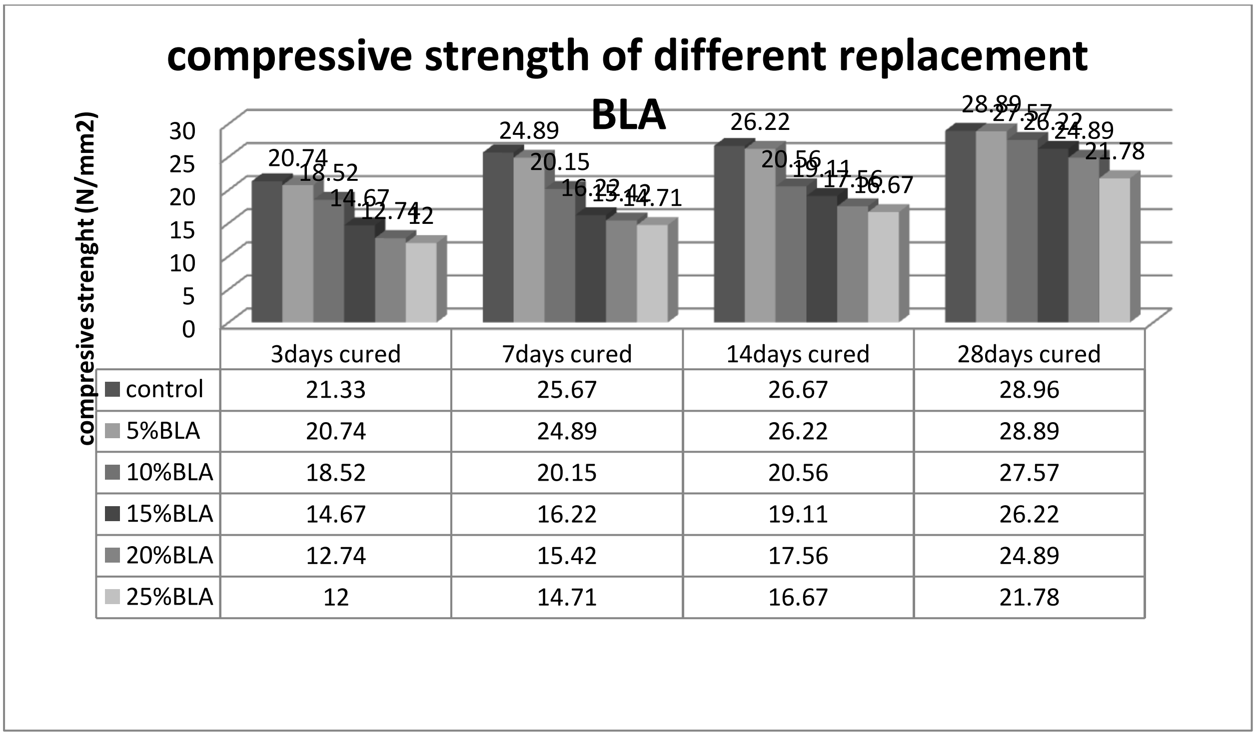
Table 5: Water Absorption of concrete after Curing.

0%	0.01	0.01	0.02	0.03	0.03	0.02	0.07	0.03	0.05	0.07	0.08	0.09
Avg.		**0.013**			**0.03**			**0.05**			**0.08**	
5%	0.02	0.02	0.02	0.03	0.05	0.05	0.07	0.05	0.06	0.10	0.11	0.90
Avg.		**0.02**			**0.04**			**0.06**			**0.10**	
10%	0.02	0.02	0.03	0.04	0.06	0.07	0.08	0.07	0.07	0.12	0.11	0.10
Avg.		**0.02**			**0.06**			**0.07**			**0.11**	
15%	0.03	0.03	0.02	0.06	0.07	0.08	0.08	0.08	0.09	0.13	0.12	0.12
Avg.		**0.03**			**0.07**			**0.08**			**0.12**	
20%	0.07	0.08	0.09	0.07	0.08	0.12	0.08	0.09	0.10	0.15	0.14	0.13
Avg.		**0.08**			**0.09**			**0.09**			**0.14**	
25%	0.11	0.11	0.13	0.15	0.13	0.14	0.13	0.15	0.16	0.16	0.17	0.15
Avg.		**0.12**			**0.14**			**0.15**			**0.16**	

Table 5 shows max of 0.16 which is less than the permissible range of 1-4 for Fcu 25N/mm^2 concrete according to BS 1881-122 (2011),Showing that BLA has negligible water absorption capacity.

3.3.2 Compressive Strength of Concrete after 3, 7, 14, and 28 days curing

From figure 2 below, the various Compressive Strengths have constant and progressive strength growth from 3days to 28days. At 3days the control had the highest value followed by the 5% concrete and down from 10% strength to 25% but at 7 days the strength of control was higher than that at 3 days and as well decreased uniformly as the % replacement increases from 5% to 25%BLA. At 28 days curing the control exceeded the target mix design Strength of 25N/mm^2 thus notifying that the mix at 0.5% water cement ration was adequate. Also at this 28days control, 5%, 10% and 15% met the stipulated design Strength but the remaining concrete of 20% and 25% replacements of cement with BLA were below the design compressive strength. Hence, replacements above 15% are not permitted, in accordance with BS EN 12390-3 (2009).



	3days cured	7days cured	14days cured	28days cured
control	21.33	25.67	26.67	28.96
5%BLA	20.74	24.89	26.22	28.89
10%BLA	18.52	20.15	20.56	27.57
15%BLA	14.67	16.22	19.11	26.22
20%BLA	12.74	15.42	17.56	24.89
25%BLA	12	14.71	16.67	21.78

Fig. 2 Compressive Strength of Concrete at 3, 7, 14,28 Days Curing ages(N/mm^2)

4. CONCLUSION

Conclusively, the importance of bamboo as an industrial raw material and a precursor of new products can no longer be contested. In view of the multiplicity of its application, bamboo is a virile substitute to most of the tropical wood species currently being used in the wood and wood products sector of the economy. The objectives of this research were met by means of the methods outlined in section 2.2. The results were recorded, analysis and discussions outlined in section 3. Concrete with 15% BLA replacement of cement yielded the optimal result from the research results and BLA material up to a cement replacement of 15-20% by weight could be used for applications requiring moderate strength concrete as it exhibited adequate compressive strength. The compressive strength and density of the samples also decreased with more replacement of the cement with BLA while the slump decreased uniformly up 20% but the concrete still retained the expected workability due to its plastic nature, until when the replacement gradually became competitive with the cement that it lost the targeted workability as observed in the 25% replacement. Therefore there is the need to increase the workability by adequate use of admixture such as supper plasticizer so as to improve workability and in turn maintain its high strength.

The BLA exhibited binding and cementing properties as shown by its ability to blend well with the cement and aggregates. It also has a lower specific gravity value than normal cement implying that it would make the resultant concrete lighter with more proportions of cement replaced.

The cost of the BLA was found to be very low as in the BLA processing, they are seen as waste and the only cost to encounter is in the transportation and the increase cost of labour require for its incineration process to make it ready before use. Therefore, the replacement of cement with BLA would be beneficial to low income areas which may not afford to keep up with the rising costs of and difficulty in getting cement with total reduction on the average load on structures making other parameters like foundation work to reduce.

The utilization of this ash material will in turn reduce its effect as environmental pollutant and emission of gases which causes global warming when they are being burnt or disposed.

5. RECOMMENDATIONS

Relative to the results, discussions and conclusions, it becomes sacrosanct to draw the following recommendations:

i. Inasmuch as partial cement replacement with BLA leads to cost savings and reduction of pollution to the environment up to 15% replacement for normal strength concrete, and the normal strength concrete may be put to uses such as the construction of structural members in buildings, it becomes necessary that replacement of up to such extent should be encouraged particularly in Southern part of Nigeria. Any cement replacement above 15% though would be cheaper and friendlier to the environment and workable due its light weight, but is not advisable for use as it will produce low strength concrete.
ii. Owing to the negligible rate of water absorption of the concrete made with BLA I recommend that at least for the tested percentage replacements, it can be used for foundation or any water retaining structure and as well for structure and super structure with mild conditions of exposure.
iii. I recommend for incorporating of the mix with a good add mixture for good workability and high rate of strength gain; replacements can be up to 20% replacement.
iv. Due to the increased initial and final setting times on cement, I recommend its use at areas prone to concrete shrinkage resulting from excess heat like the Northern part of Nigeria.
v. I recommend that government should encourage and motivate the private sector to embark on industrial processing of bamboo to ultimately produce BLA.
vi. The development and utilization of bamboo in Nigeria should adopt a holistic approach. While using the plant to mitigate the effect of deforestation and climate change and to promote industrial development, it is imperative for Nigeria as a nation to also employ the uses of the plant leaf ash for partial cement replacement, especially in the Southern part of the country. Consequently, bamboo development concerns should be addressed at the national planning level.

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KINETIC STUDIES ON METHANE PRODUCTION FROM OKRA WASTES USING GROWTH FUNCTIONS

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Abstract
Degradation kinetics of organics is essential for assessing the performance of anaerobic digestion process. This study investigates the biomethane potentials (BMP) and kinetics of okra waste using AMPTS II BMP assay. Measured data of methane yield were used to fit five models (Modified Gompertz, Stannard, Transference function, Logistic and First-Order models), predict and determine organic degradation parameters of the substrate. Low lag phase (0.143d), positive kinetic constant (0.2994/d) and model fitness indicator (<10) showed that Transference and First-Order kinetic models predicted the methane yield better than other growth functions. The experimental methane yield was 270.98mL/gVS and model simulation (267.5- 270.89 mL/gVS). With %prediction difference (0.03-1.28%), all the growth functions acceptably predicted the kinetics of okra waste.

Key words: Kinetics, Methane Production, Okra, Anaerobic Digestion

1.0 Introduction

Expected global rise of energy demand by 43.64% in year 2030 is attributable to the growing industrialization and population (Deepanraj et al, 2015). The conventional energy sources are fossil based, non-renewable, responsible for huge CO_2 emission and climate change (Shafiee and Topal, 2009). This identified gaps, necessitated the quest for the development of alternative and renewable energy technologies. Biogas technology is a renewable energy type, which combines sustainable waste management and efficient biofuel production (Ding et al., 2017).

This waste-to-energy (biogas) process is an established technology, but it has been under-exploited in most developing climes like South Africa. According to SABIA (2015); Triebel and Damm (2008), households numbering above 2.328 million, representing about 25% families in South Africa, use local fossil fuel sources (charcoal and firewood) for meeting their energy demands. The high cost and unavailability of electricity in most informal and rural settlements has increased both the demand and development of biogas technologies (Muvhiiwa et al, 2017).

Biogas is a product of anaerobic digestion; it is an energy recovery process through the biological degradation of organic wastes in the absence of oxygen for the generation of methane (Lim et al, 2012). This biomass degradation by microbes involves four phases; hydrolysis, acidogenesis, acetogenesis and methanogenesis ((Bharathiraja et al, 2018; Deepanraj et al, 2015; Lim et al, 2012).

According to Bharathiraja et al, (2018), low cost, availability and novelty of feedstocks are the encouragement needed for more investments in biogas production. This has necessitated the aggressive search for future energy crops with potential for ensuring feedstock security, optimization of existing biomass feedstock as well as the technological enhancement of feedstock digestion processes (Bharathiraja et al, 2018). Various efforts towards discovering novel biomass-for-biogas have been studied. Adiga et al. (2012), Patil et al. (2012), Bai-Hang et al. (2017) and Visva Bharati (2018) studied the enhancement of water hyacinth for biogas production. Anongnart et al. (2018), Rodriguez et al. (2018) and Kroger and Muller-Langer (2012) noted that both micro and macro-algae is a viable substrate for biogas production. Saowaluck Housagul et al. (2014) and Aguilar-Aguilar et al. (2017) investigated the use of glycerol from biodiesel industries, singularly or in-combination for biogas production, while Li et al. (2018) tested the potentials of using spent cooking from bakeries in biogas production. Others novel substrates include meadow grasses (Tsapekos et al., 2017), vegetables (Gaibor-Chávez, 2018) etc.

Okra waste is one of such novel waste that is largely unused for biogas production. Okra *(Abelmoschus esculentus)* is a vegetable crop, 96% is mainly grown in Africa and India. Okra waste just like other vegetables and fruits, accounts for 40-50% of the 48.4% total food waste globally (FAOSTAT, 2016). Duman *et al* (2017) stated that Turkey produces above 36,000 tons/year of okra and that the utilization of the okra wastes has been studied as part of the State's developments plan and visions. Okra and its stems have high crude fibers, proteins and fat, on dry bases, okra has about 25% crude fiber, 18% protein (Olaniyan and Omoleyomi, 2013). The entire crop waste according to Alam and Khan (2007) contain 67.5% a-cellulose, 15.4% hemicellulose, 7.1% lignin, 3.4% pectin, 3.9% fat and waxes. From the composition, okra has high biomethane potential.

Kinetic modeling according to Kafle and Kim, (2012) is an accepted method to show the specific parameters of the system performance. Experimental data are used in kinetic studies and results from these studies are often applied under the same conditions in estimating operational efficiencies of scaled-up reactors. Various kinetic model types, mostly First-Order kinetic model have been successfully used to simulate anaerobic digestion processes.

Akin to the phase of bacterial growth, rate of biomethane production showed a rising limb and a decreasing limb which was indicated by exponential and linear equation (Li et al, 2018; Ware and Power 2017).

The variation on the characteristics of Okra waste from place to place, based on agronomical differences and storage conditions before digestion, necessitates the evaluation of its kinetic properties. Fitting kinetic functions to the cumulative methane production curves obtained from Biomethane Potential (BMP) enable information on anaerobic process performance to be gathered, such as maximum methane yield (Bo) attained, maximum rate of methane production (R_{max}), degradation rate constant (K) and the lag phase (λ) duration (Ware and Power, 2017). The accuracy of biogas yield prediction in model is depended on substrates that are used as feedstock.

In the past, numerous researchers have predicted biomethane production potential using modified Gompertz, Logistic and First-Order kinetic model (Adiga et al., 2012; Kafle et al., 2012; Patil et al., 2012; Budiyono and Sumardiono, 2014; Deepanraj et al, 2015), sigmoidal models and other statistical models (Kafle and Chen, 2016; Ware and Power, 2017; Li et al, 2018).

This research leverages on the huge amount of okra waste and its perceived high biomethane potentials in assessing the degradation kinetics of okra waste using a BMP assay and in evaluating the five (5) identified growth functions (Modified Gompertz, Stannard, Transference, Logistic and first order models) with measured BMP data. This study also determined the suitability of these models for anaerobic digestion of Okra waste.

2.0 Materials and Method

Okra waste was collected from Organic Farm, Centurion in Gauteng Province and mechanically pretreated. The total solids, volatile solids, ash content and moisture content were measured using the standard gravimetric method (Method 1684 of the U.S. EPA for Total, Fixed and Volatile Solids in Water, Solids and Biosolids) and shown in Table 1. The nitrogen (N) and carbon (C) content was determined with C-N elemental analyzer (TruMac CN, Argon, LECO Corporation). pH was measured using pH meter (HI 9828 Multi-parameter, Hanna Instruments). The results are as shown in Table 1 below.

Table 1: Proximate and Ultimate Analyses of Samples

Properties	Inoculum	Okra
Initial pH	8.08	8.13
Final pH	7.68	8.15
Moisture content %	98.50±0.01	84.85±0.24
Ash contents %	0.03	0.31
Total Solids %	1.50±0.01	15.15±0.24
Volatile Solids % (wet basis)	1.02±0.04	13.34±0.02
Carbon %	NT	6.69±0.12
Nitrogen %	NT	0.42±0.02
C/N ratio	NT	15.90±0.35

NT= Not tested

The biomethane potential of okra waste was performed using BMP assay (AMPTS II, Bioprocess Control, Sweden) for 25days and the result from the data logging platform of the reactors were retrieved. The reactors were operated at mesophilic temperature (37±1^{o}C), the entire tests were performed as stipulated by AMPTS II standard operation manual. The result of the daily biogas production and the cumulative methane production is shown in Table 2 and Figure 1.

2.1 Kinetic models for biogas production

Non-linear regression analysis was performed using the Curve-Fitting tool in Matlab R2015b to evaluate the growth functions (Modified Gompertz, Stannard, Transference, Logistic and First-Order kinetic models) shown in Equation 1 to 5. The average measured cumulative methane production data was used to evaluate the models; the model parameters and the goodness of fit are shown in Table 2 and Fig. 1.

Modified Gompertz: $$B = B_o Exp\left\{-Exp\left[\frac{R_{max}.e}{B_o}(\lambda - t)\right] + 1\right\} \quad (1)$$

Stannard $$B = B_o\left\{1 + Exp\left[-\frac{(1+kt)}{p}\right]\right\}^{-p} \quad (2)$$

Transference $$B = B_o\left\{1 - Exp\left[\frac{R_{max}}{B_o}(t - \lambda)\right]\right\} \quad (3)$$

Logistic $$B = \frac{B_o}{\left\{1+Exp\left[\frac{4R_{max}}{B_o}(\lambda - t)+2\right]\right\}} \qquad (4)$$

First Order $$B = B_o(1 - Exp(-kt)) \qquad (5)$$

- Where: B: cumulative specific methane production (mL/gVS), B_o: maximum specific methane production potential (mL/gVS), R_{max}: maximum specific methane production rate (mL/gVS- d), e: Exp (1) = 2.718282. λ: lag-phase (days), k: methane production rate constant (day^{-1}), t: digestion time (days), p: slope of growth.

The kinetics of biogas production was evaluated with five (5) growth functions and the parameters (B_o, B_p, k, λ p, R^2, Adj. R^2, R_{max} and RMSE) were determined. Entire experiments in this study were performed in triplicate and the average values were used. Minitab 15 was used for all the statistical analysis carried out and all inference at 95% confidence interval.

3.0 Results and discussion

Graph of measured and predicted methane production results as well as the determined parameters are shown in Fig. 1. and table 2. The cumulative measured biogas was 270.8 mL/gVS, the models predicted cumulative biogas to be 267.38, 267.99, 270.89, 267.50 and 270.15 mL/gVS respectively for Modified Gompertz, Stannard, Transference, Logistic and First-Order models.

Table 2: Kinetic parameters of average cumulative methane production curves.

Parameter	M.Gompertz	Stannard	Transference	Logistic	First-Order
Measured Biogas Yield- $B_{(t)}$ (mL/gVS)	270.98	270.98	270.98	270.98	270.98
Predicted Biogas Yield -$B_{(P)}$ (mL/gVS)	268.38	267.99	270.89	267.50	270.15
Difference between $B_{(t)}$ and $B_{(p)}$ (%)	0.95	1.1	0.03	1.28	0.31
B_o (mL/gVS)	268.4	268.0	271.1	267.5	270.3
R_{max} (mL/gVS)	39.93	-	77.2	34.38	-
λ *(d)*	0.872	-	0.143	1.24	-
$K(d^{-1})$	-	1.449	-	-	0.2994

P	-	3.269	-	-	-
R^2	0.963	0.957	0.983	0.946	0.982
Adjusted R^2	0.96	0.953	0.982	0.941	0.981
RMSE	13.67	14.7	9.209	16.54	9.378

The lag phase λ of the growth functions, which is the time required for bacteria to adapt and start biogas production, was computed as seen in Table 2 and Fig. 1. The values are 0.872, 0.143 and 1.24 respectively for Modified Gompertz, Transference and Logistic models. The Low λ values as noticed in this study was in line with the report of Talha et al. (2018), which stated that lower lag phase is dependent on the activeness of the adapted inoculum and biodegradability of organic part of the okra waste. The term *k* is a measure of the biomethane production rate per time, in this study both *k* computed from Stannard and First-Order models are 1.449 and 0.2994 respectively. The positive *k* values as seen in this study shows faster rate of biogas production and agrees with the reports of Budiyono and Sumardiono (2014) and Kafle et al. (2012).

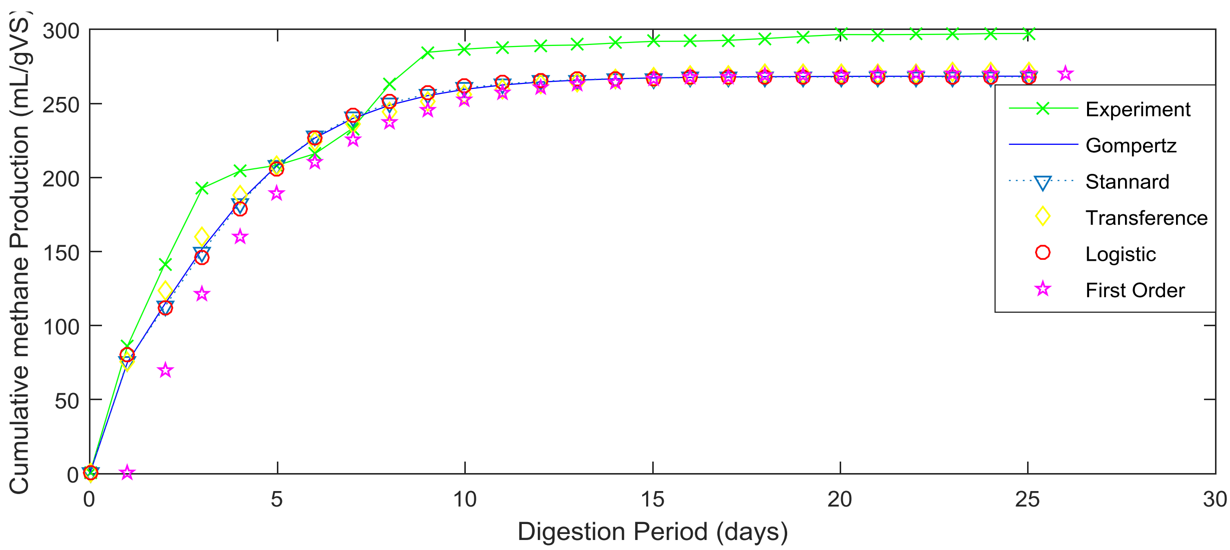

Figure 1: Cumulative biogas production – experimental and kinetic models.

Transference model and First-Order, most predicted okra waste digestion with prediction difference of 0.03% and 0.31% respectively, this is consistent with the report of Kafle and Chen (2016), which showed that the First-Order kinetic model was found to be the best model for predicting BMP for livestock manures. In Li et al (2018), it was reported that Transference performed better than the modified Gompertz model. The statistical indicators of model fitness as shown in Table 2, ranged from 0.946-0.983, 0.941-0.982 and 9.209 -16.54 for R^2, Adj. R^2 and RMSE respectively. In line with the report of Budiyono and Sumardiono

(2014), RMSE value of < 10, shows good model prediction and then based on this criterion, only Transference and First-Order Kinetic models were within the accepted limit.

5. Conclusions

Five growth functions were successfully evaluated with measured BMP results and the kinetic parameters were determined for Okra waste. The good model fitness, good predicted methane yield and lowest percent prediction difference as observed showed that both Transference and First-Order models performed better than other models evaluated. The positive kinetic constant and lower lag phase confirmed high rate of degradation. The Logistic model based on model goodness of fit performed worse when compared to other models.

Acknowledgements

This study was supported by NRF-TWAS- SFH160606168084. The authors appreciate Organic Farmers, Centurion, South Africa for providing the substrates.

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USING BIODEGRADABILITY OF SEWAGE IN COMPOSTED PIT LATRINES TO ASSESS THEIR AGRICULTURAL POTENTIALS

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ABSTRACT.
This research focused on using biodegradability of sewage in ordinary composted pit latrines to assess their agricultural potentials. Samples of fresh faecal sludges collected from already filled pit latrines in selected from 100 households in Aku community were analyzed for their physico-chemical and biological characteristics from which their biodegradability were computed. In this study, ecosan compost toilets in the form of Sanplat latrine i.e. sanitation platform latrine were tested as ecological option for use in growing fruit trees in rural communities of Enugu State. The capacities of selected pit latrines were tested for their levels of biodegradability as an insight into their nutrient and agricultural values. The result showed that in terms of biochemical oxygen demand (BOD), sludges from 12 pit latrines had biodegradability of at least 80% whereas in the case of chemical oxygen demand (COD) and suspended solids (SS), sludges from 9 pit latrines had biodegradability of at least 80%. For the volatile solids (VS), sludge samples from 11 pits had biodegradability of at least 80%. Ten (10) pits sludges had volatile solids to total solids (VS: TS) ratio ranging from 0.90 – 2.93, which means that such pits had high organic content and were readily degradable. Using COD: BOD ratio, eleven (11) pits had values ranging from 0.90 – 1.34, indicating that the pits sludges were readily biodegradable. Lower organic contents resulted in lower faecal biodegradability. From this study, COD, BOD, SS and VS which are classic parameters, can be used to assess the performance of pit latrine sludges and their agricultural potentials provided there is good user-behaviour, favourable conditions of temperature, moisture content, tolerable acidity level (pH), nutrient availability, microbial density and soil conditions. Excreta collected from such pits can be used under controlled situation to enhance the fertility of soil for increased agricultural production. It was found out that faeces can be handled and re-used for agricultural purposes if treated with a combination of ash and sand after use and stored for at least 6 months. However, for safety purposes in the use of the faeces, parasitological assessment was conducted.

Keywords*:* Aerobic and anaerobic biodegradability; faecal sludges; composted pit latrine; parasitological assessment; good user-behaviour; sludge stabilization; favourable conditions; physico-chemical and biological characteristics; nutrient and agricultural values.

1.0 INTRODUCTION

The biodegradability of faecal sludge in pit latrines relates to the conversion of over 90% material into carbon dioxide and water by the action of micro-organisms. In his work, Sims et al., (1999) found out that during biodegradation process, there is the disintegration of materials by bacteria, fungi, or other biological means. Faecal matter deposited into the pit latrine undergoes some level of biodegradation. The extent to which this occurs depends on several factors such as type of food nutrient, population of users, type of anal cleansing materials, soil characteristics and ground conditions, age of depositor, total solids and suspended solids contents, amount of moisture in the substrate, pH of the sludge, microbial density, inflow and infiltration capacity of the soil, characteristics of the surrounding soil, etc. Degradation of organic material causes the rate of pit filling to be lower than the rate at which material is added. The aim of this paper was to study the biodegradability of faeces in selected pit latrines with a view to finding out their agricultural potentials.

Ecological sanitation recognizes that faeces and urine are not mere waste products of human digestion process but are resources that can be recycled and used for the improvement of soil fertility and crop production. In many rural communities of Nigeria, low soil fertility and the increasing cost of inorganic fertilizers hardly allow resource-poor farmers to produce enough food to feed the teeming population. With the present increase in human population competing for the available limited land, survival may become difficult in the near future. Against this background, human excreta and urine from ecological latrines can be sanitized on site and used as organic fertilizers for increased crop productivity per unit area of land. The use of human excreta for crop production has been widely practiced in many parts of the world. The Chinese have been composting human and animal excreta for few thousand years ago (King, 1973; Winblad and Kilama, 1985) and Japan introduced the practice of recycling human faeces and urine for agriculture in the twelfth century (Matsui, 1997). Faeces is rich in organic matter, available phosphorus, total nitrogen and magnesium. The high organic matter helps in the improvement of soil structure, contributes to the cation exchange capacity, adsorbs heavy metal through its chelating agent (organic carbon), retains soil moisture and enhances microbial activities through the supply of organic carbon to soil microbes. Although, excreta is not as rich as urine with regard to nutrient elements, it is a valuable soil conditioner which when applied to the soil, increases the organic matter content, improves the water holding capacity and also increases the activities of beneficial soil microbes. A study in Sweden revealed that annual human urine production contains 15 – 20% NPK equivalent to the amount used as mineral fertilizers in 1993 (Jonnson *et al*, 1996). Also, according to Jonnson (1997), an adult may produce up to 400 litres of urine in a year which contains 4.0kg of Nitrogen, 0.4kg of Phosphorus and 0.90kg of Potassium. Similarly, human faeces consists of undigested organic matter such as fibres made up of Carbon. The total amount produced per person per year is conservatively estimated at 50kg containing 0.55kg of N, 0.18kg of P and 0.30kg of K (Jonnson, 1997). Although, excreta is not as rich as urine with regard to nutrient elements, it is a valuable soil conditioner which when applied to the soil increases the organic matter content, improves the water holding capacity and also increases the activities of beneficial soil microbes. The establishment of ECOSAN toilets in reverine communities of Odukpani Local Government Area of Cross River State with the major aim of improving the health standard of the rural populace is a welcome initiative. The intention of using the end products (faeces and urine) for crop production calls for elemental analysis of these organic wastes, determination of appropriate rate and method of application. Thus, the present research is aimed at evaluating the possibility of using decomposed faeces as organic fertilizer in the production of fluted pumpkin, pawpaw, banana, maize but not vegetables.

The objectives of the research were to:

- Analyse for the physical and chemical properties of the soils obtained from the focal community, Aku and highlight their fertility status;
- Analyse faeces samples collected from the three communities for their chemical composition;
- Evaluate the response of fluted pumpkin to different rates of decomposed faeces relative to an inorganic fertilizer (NPK 20:10:10);
- Ascertain the economic benefits of using faeces in the production of fluted pumpkin, pawpaw, maize and banana.

2.0 LITERATURE REVIEW

Excreta deposited into a pit latrine is subject to some level of biodegradation which substantially reduces the volume of the sludge. There have been a limited number of studies reported on decomposition within pit latrines, and only anecdotal evidence into factors that can slow down or speed up decomposition (Couderc et al., 2008; Nwaneri et al., 2008; Ugwu, 2015). Regardless, microbial communities will play an important role in organic matter degradation within pit latrines, though little is known about the microbial communities present in pit latrines and their association with faecal decomposition within the pit environment. The physico-chemical and biological characteristics of faecal sludge are critical in assessing the effect of sewage co-treatment with domestic sewage in a municipal wastewater plant or its co-digestion with sludge. Work on the degradation of faeces in VIP latrine was carried out by Nwaneri et al (2008). Another work on the degradation of faeces in ordinary pit latrine was carried out by Ugwu (2015). In their work, they carried out the physico-chemical and biological characteristics of fresh faeces from a household and established four stages of sludge decomposition. Biodegradation of pit sludge is mainly anaerobic with aerobic decomposition occurring at the surface. Anaerobic digestion involves the degradation and stabilization of organic materials under anaerobic conditions by microorganisms leading to the formation of biogas (a mixture of CO_2 and CH_4) a renewable energy source and microbial and biomass (Kelleher et al., 2002). Anaerobic decomposition provides relatively little energy to the microorganisms, resulting in a slow growth rate and a small portion of the waste being converted to new biomass. Moreover, anaerobic digestion generally produces gaseous methane as an energy resource (Lettinga, 1995; Sekiguchi et al., 2001).

2.1 Characteristics of pit sludge

Earlier studies have been done by Foxon et al (2008) to characterize pit contents but will be repeated here due to variations in dietary intake. Studies done by (Lopez et al., 2002) and (Lopez et al, 2004) to characterize faeces and to describe the biodegradability of organic matter present in faeces showed that 75-80% of human faeces comprised of slowly biodegradable organic matter while 15-20% is inert material. Readily biodegradable organic matter was not regarded as a component of faeces (i.e. = 0%). The study went further to show that only 15% of the slowly biodegradable material was easily hydrolysable whereas 65% was slowly hydrolysable (Lopez et al., 2014). Human faeces is high in organic matter, contributing about 44% of COD load in domestic wastewater (Almeida et al., 1999). The slowly biodegradable portion cannot be utilized directly by microorganisms and so has to be made accessible through cell external hydrolyte (enzymatic) reaction (Lopez et al., 2004).

2.2 Biodegradability of faeces in Pit Latrine.

Biodegradability is the level of disintegration of materials by bacteria, fungi, or other biological means. Organic material can be degraded aerobically with oxygen, or anaerobically, without oxygen. Biosurfactant, an extracellular surfactant secreted by microorganisms, enhances the biodegradation process. Biodegradable matter is generally organic material that serves as a nutrient for microorganisms. Microorganisms are so numerous and diverse that, a huge range of compounds are biodegraded, including hydrocarbons (e.g. oil), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), pharmaceutical substances. Decomposition of biodegradable substances may include both biological and abiotic steps. The value of the ratio of volatile solids to total solids helps to reveal the extent to which faecal sludge has been biodegraded. If the concentration of volatile solids is higher than that of the total solids, there is more likely that the biodegradability will be higher considering other favourable conditions such as temperature, moisture content, pH, microbial density, soil conditions and of course good user-behaviour. This will also result in lower filling rate and longer life span of the pits. The higher the value, the more the organic content and subsequently greater biodegradability.

The biodegradability for the faecal sludge in each pit latrine can be computed using the following expression:

$$\% \, Biodegradability = \frac{surface\ value - bottom\ value}{surface\ value} x\ 100 \quad (1)$$

2.3 Factors affecting the efficiency of faecal decomposition process in pit latrine.

A number of factors determine the degradation rate of organic compounds (Sims et al., 1999). If the population of viable micro-organisms present in the waste heap is high and environmental conditions are suitable, a high rate of stabilization of feed material will be achieved. Thermophilic anaerobic digestion at between temperatures of 55^0C – 65^0C has additional benefits including a high degree of waste stabilization and destruction of viral and bacterial pathogens (Lo, K. et al., 1985). Rates of biological degradation are also temperature dependent, and rates increase with warmer temperatures.

Total solids concentration of faecal sludge comes from a variety of organic (volatile) and inorganic (fixed) matter, and is comprised of floating material, settleable matter, colloidal material, and matter in solution. The ratio of VS to TS is used as an indicator of the relative amount of organic matter and the biochemical stability of faecal sludge. Dumping of different kinds of household waste into the pit has also been observed and is consistent with literature (Buckley et al., 2008). This affects biodegradability to a reasonable extent. Climate has a direct influence on faecal sludge characteristics, mainly due to temperature and moisture. The moisture content of faecal sludge in the pit latrine affects the rate of degradation. Geological characteristics of the surrounding soil where the pit latrines are placed can have an important influence in the processes happening inside the pit (Bhagwan et al., 2008). A latrine system should be located in areas where the slope is not excessive (Bouma, 1974; Coutera et al., 1979). In terms of soil porosity, microflora and microfauna (higher organisms such as protozoa, metazoan and worms) may move into the pit from the surrounding soil and contribute to decomposition of organic material. Oxygen is extremely toxic to the obligate anaerobic methanogens and these bacteria are inhibited by even small concentrations (Bitton, 1994; Muyima et al., 1997). Household habits associated with toilet usage influence the variability of faecal sludge in the pit latrine. The length of time that faecal sludge is stored in the pit latrine system before the samples are collected and analyzed will greatly affect the characteristics due to the digestion of organic matter that occurs during storage. The concentration and volume of faecal sludge is also greatly influenced by inflow and infiltration of leachate into the environment from the system and or ground water into the system.

2.4 Trials with faeces

Ecological sanitation recognizes that faeces and urine are not mere waste products of human digestion process but are resources that can be recycled and used for the improvement of soil fertility and crop production. In many rural communities of Nigeria, low soil fertility and the increasing cost of inorganic fertilizers hardly allow poor farmers to produce enough food to feed the teeming population. With the present increase in human population competing for the available limited land, survival may become difficult in the near future. Consequently, human excreta from ecological (compost pit) latrines can be sanitized on site and used as organic fertilizers for increased crop productivity. The use of human excreta for crop production has been widely practiced in many parts of the world. The Chinese have been composting human and animal excreta for thousands of years ago (King, 1973; Winblad and Kilama, 1985) and Japan introduced the practice of recycling human faeces for agriculture in the twelfth century (Matsui, 1997).

3.0 MATERIALS AND METHODS

The first phase involved collection of latrine faecal samples from the community and analyzing them for their biodegradability values. Secondly, the chemical composition of measured quantity of faeces only, measured quantity of faeces + measured quantity of sand, measured quantity of faeces + measured quantity of ash, measured quantity of faeces + measured quantity of ash + measured quantity of sand were analysed. The third stage involved agricultural trials involved use of treated latrine sewage with high biodegradability level for planting of selected fruit trees with controlled conditions. The response of fluted pumpkin to different levels of composted solid (faeces) fertilizer (humanure) was evaluated through field experiments in the study community.

Faecal samples collected from 100 filled households pit latrines in the study community, Aku at the surface and at pits vertical intervals of 0.2m, 0.4m, 0.6m, 0.8m and 1.0m using a well designed sampler with minimum alteration of faecal bioactivity were subjected to laboratory analyses to find out their physico-chemical and biological characteristics. Standard methods of measurement in the laboratory (APHA 1998) were employed in the analyses.

These parameters were then used to determine the biodegradability of the various sludges sampled from pit latrines surveyed.

These samples were analyzed for their physico-chemical biological characteristics namely moisture contents, temperature, volatile solids, BOD, COD, total solids, plate count, pH, suspended solids and phosphorous content using standard methods of measurement of faecal parameters (ALPHA, 1998). Moreover, bacteriological analysis was conducted on each sample to ensure safety during use. For the purpose of this analysis, the surface and bottom values of each parameter obtained from laboratory analysis were tabulated and the difference calculated to compute the biodegradability of the faeces in selected pits.

For sociological assessment, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were conducted in the community before the use of the ecosan compost option. It was found that majority (92%) of the community members accepted the introduction of Ecosan compost toilets into the communities as means of enriching the soil. Prior to this, a large

number used pit toilets with either lined or unlined walls. Some structural problems identified in the construction of the toilets were addressed during the study. However some of the community members expressed concern about difficulty in keeping the toilets clean, and felt that the toilets were too communal and may be a potential source of conflict among families.
For microbiological assessment, the compost toilets were regularly examined physically and samples of faeces collected for bacteriological analysis. It was found that if the Sanplat latrines were filled up and left for 8 - 10 months, all the parasites would be killed off and the faeces can be handled and re-used for agricultural purposes if treated with a combination of ash, sawdust and some sand.

4.0 RESULTS AND DISCUSSIONS

Results and discussions in this study were based on biodegradability in terms of measured faecal parameters namely BOD, COD, TS, VS, SS, pH, moisture content, plate count, phosphorus content and temperature as well as parasitological/bacteriological analysis that were conducted. Biodegradability of faecal sludge in the 15 selected pit latrines were determined using the result of parameters obtained in the laboratory analyses. Biodegradability of the various pit sludges analyzed was calculated using Equation 1.

4.1 Variation of pH in the pit sludge with depth

Figure 1 showed the variation of pH of the pit sludge. Pit 6 had pH value of 7.98 at the surface and 6.42 at the bottom with pH range of 1.56 while Pit 11 had pH of 7.93 at the surface and 6.85 at the bottom with a range of 1.08. Next was pit 4 with pH of 7.77 and 8.77 at the surface and bottom respectively with a range of 1.0 value. pH ideally falls within the range 7.5-8.5 (Jenkins, 1994). It was reported that for appropriate microbiologic activity, pH should be within a range of 6.5 – 8 (Bhagwan et al., 2008). Frickle et al (2007) in their study recommended an optimal pH of between 6.4 and 7.2 for an anaerobic digestion process as against 6.42 - 8.95 in this study with reference to ordinary pit latrines. The highest pH measured in this study was 8.96, which was not too high to inhibit the anaerobic process.

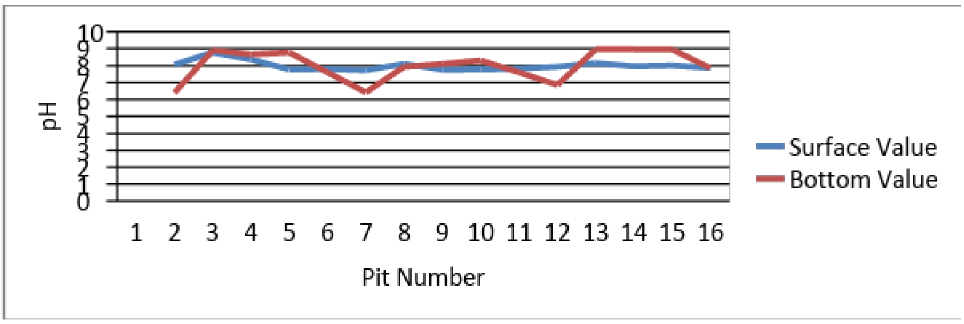

Figure 1: Variation of pH in Pit Sludge

4.2 Variation of VS/TS ratio in sampled pit latrines

Figure 2 showed the variation of the ratio of volatile solids to total solids (VS:TS) in the various pit latrines. In most of the pits, the value was high which was an indication of high organic content. In pit latrines where the volatile solids concentration was higher than the total solids, there was the likelihood of high biodegradability, taking other factors such as favourable temperature, moisture content, microbial density and pH level into consideration. This could be observed in Pits 2, 3, 4, 7, 9, 10, 12 and 15. Looking at the ratio of volatile solids to total solids as contained in Figure 2, the amount of organic solids in the faecal sludge samples varied. The ratio was high in most pits indicating high organic content as against low ratios in Pits 1 and 6 indicating low organic content resulting to low biodegradability. Pits with moderate values of the ratio between 0.67 and 0.91 had relatively high organic contents and relatively high biodegradability under favourable condition. Only Pit 12 exhibited very high volatile to total solids ratio which was an indication that the content of faecal sludge in that pit was mostly organic.

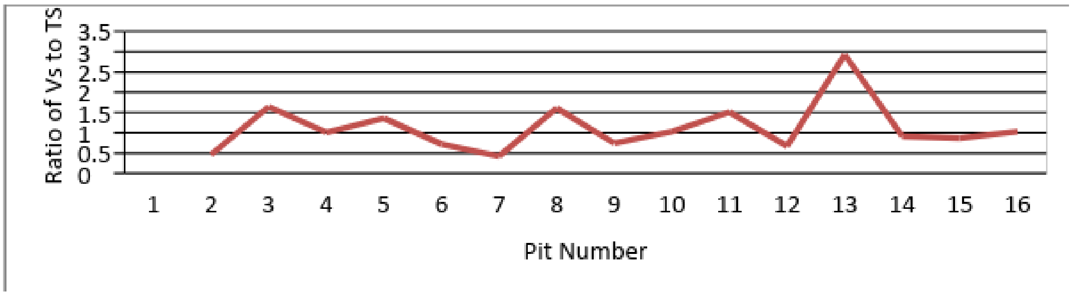

Figure 2: Variation of VS:TS ratio with Pit Number

4.3 Variation of COD: BOD ratio in sampled pit latrines

Figure 3 showed the variation of the ratio of COD to BOD in the various pit latrine sludges. The ratio indicated that 11 pits had values ranging from 0.90 – 1.34 and were high in organic content as against 4 pits that had values lower than 0.87. This means that most of the pit latrines studied in the reference community performed very well. However, all the pits performed above average.

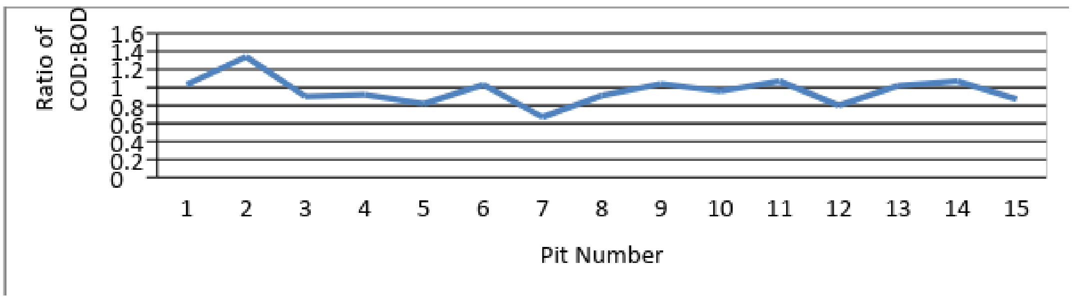

Figure 3: Variation of COD: BOD ratio with Pit Number

4.4 Variation of Biodegradability of Pit Sludge in terms of Moisture Content (MC)

Figure 4 showed the variation of moisture content in the pit latrines studied. Surface moisture content varied from 64.47% – 87.73% while the bottom values varied from 21.43% - 36.20%. The moisture content of Pit 11 was the lowest with 21.83% while Pit 8 had the highest with 87.73%. The moisture content was used to give an approximation of biodegradability characteristics of the material found in the different layers of the pit latrines. Excess moisture content slowed down the rate of faecal decomposition and this affected the flocking of microorganisms that fed on the faecal matter. Lay et al (1997) in their study of the influence of moisture content on the methanogenic activity in the anaerobic digestion of wastewater treatment plant sludge cake showed that methanogenic activity dropped from 100% at a moisture content of 96% to 53% of the maximum activity when the moisture content was reduced to 90%.

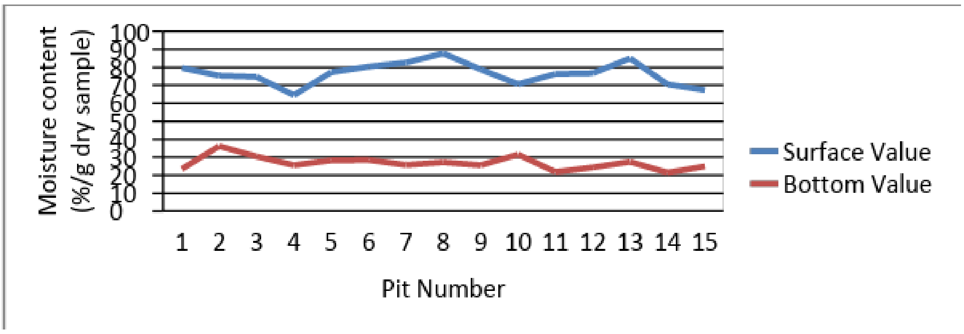

Figure 4: Variation of Moisture content in Pit latrines.

4.5 Variation of Microbial Density in Pit Latrine Sludge

Figure 5 showed the variation of plate count in the 15 pit latrines. The highest microbial density was recorded at the surface since the faeces was fresh and still undergoing aerobic decomposition. As the sludge aged, microbial density decreased. It was possible that the plate count was composed mostly of viruses and helminthes that inhibited microbial decomposition and so, volatile solids were low amidst moderate temperature of 38°C. However, with longer storage time obtained from field survey and increased microbial decomposition, pathogens in faecal sludge died off naturally under temperature higher than ambient, 25°C with the highest recorded in this study being 67°C. At temperatures between 23°C and 67°C observed in this study, most of the pathogens died off due to natural decomposition processes leaving the very few resistant viruses at the bottom of the pits. Overall, it means that when the pits were put out of use after filling up, there was no disruption in faecal sludge composition, thus allowing biodegradation to continue unhindered.

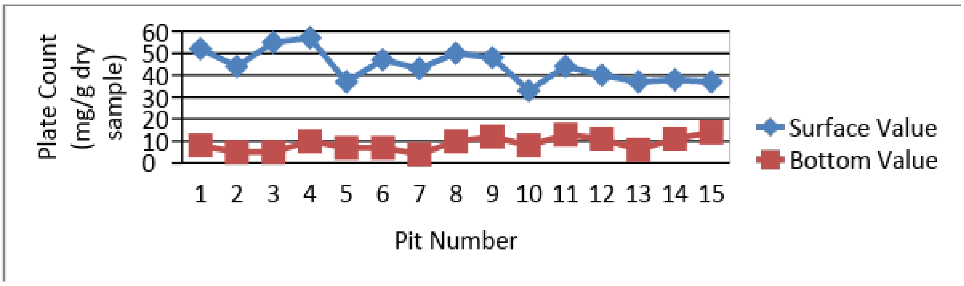

Figure 5: Variation of Plate Count in Pits Latrines.

4.6 Variation of Temperature in Pit Sludge

From Figure 6, the highest mean surface temperature recorded was 66.67°C in Pits 4 and 14 while the lowest mean surface temperature was 51.67°C in Pit 11. On the other hand, the highest mean bottom temperature was 52.67°C in Pit 12 while the lowest mean bottom value was 25.67°C in Pit 7. Temperature measured in the pit sludge favoured biodegradation process considering other factors such as moisture content, pH, soil conditions, amount of nutrients in the pit sludge and microbial density. This is within the thermophilic range established by LoK et al. (1985), whose own range was from 55°C – 65°C. Franceys et al. (1992) stated that residence time in the pit had sanitizing effect on pathogens since they were not able to survive during the decomposition processes due to changes in temperature and moisture. Most of the microorganisms exhibited a narrow range of temperature over which they were active. This is in line with the findings of Lopez et al (2004).

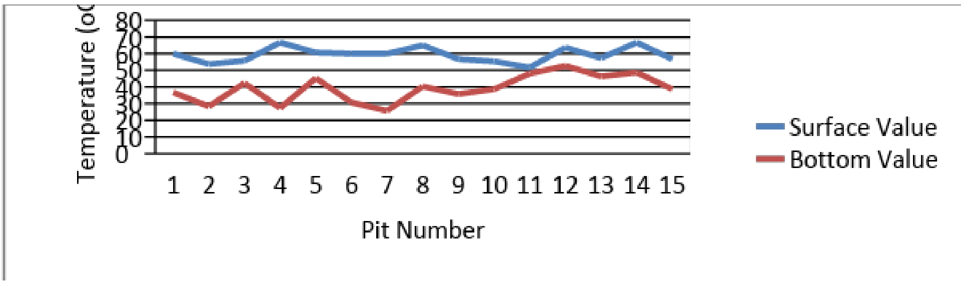

Figure 6: Variation of Temperature in Pit Latrine sludge.

4.7 Comparison of Biodegradability of other Faecal Parameters in Pit latrines

Figure 7 showed the comparison of sludge biodegradability in terms of BOD, COD, VS, TS and SS. In Pit 1, sludge parameters namely BOD, COD, VS and SS had biodegradability of at least 80%. In terms of TS, the biodegradability was below 60%. In Pit 2, the dominant parameter was COD with biodegradability above 80% while in Pit 3, BOD and VS had biodegradability values above 80%. VS and SS had values above 80% in Pit 4 whereas in Pit 5, sludge parameters namely BOD, VS, TS and SS had values above 80%. In Pit 6, BOD and COD dominated and in Pit 7, BOD and SS had biodegradability above 80%. In Pit 8, BOD, COD and SS had values above 80% while in Pit 9, BOD, COD, and VS were dominant, In Pit

10, BOD, COD, VS and SS were prominent. In Pit 11, COD, VS and SS were dominant whereas in Pit 12, BOD and VS were dominant. In Pit 13, BOD, COD, VS and SS had biodegradability above 80% while in Pit 14, BOD, COD and VS had biodegradability above 80%. Three parameters in Pit 15 namely BOD, VS and SS had values above 80%.

The choice of 80% biodegradability was to decide clearly high performing pit latrines since this would mean low filling rate and the longer lifespan for the pit latrines. The reduction in total solids content from surface to the bottom was a sign of sufficient microorganisms acting on the substrates.

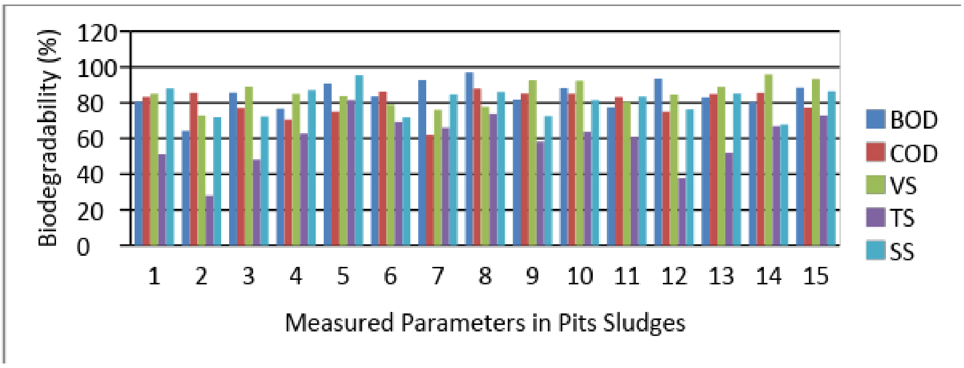

Fig. 7: Comparison of Biodegradability of Faecal Sludge Parameters in Pit Latrines.

4.12 Sewage Application for Agricultural purposes

Application of this organic fertilizer, based on the biodegradability of sewage from various pits, increased the growth of fluted pumpkin, pawpaw and banana in the community with control. Treatment with 5,000kg of faecal sample/ha out-performed other treatment levels. Application of 3,000kg faecal sample/ha had a similar effect on fluted pumpkin growth as 5000kg F/ha. Economic analysis also showed that 5,000kg F/ha gave high profit. The study has revealed the inert potentials of human faeces when used in correct proportion as a good source of organic fertilizer that could be harnessed to boost the on-going organic farming programme in Nigeria.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Human excreta may be attractive as fertilizer because of the high demand for fertilizer and the relative availability of the material to create night soil. In areas where native soil is of poor quality, the local population may weigh the risk of using night soil. The use of unprocessed human faeces as fertilizer is a risky practice as it may contain disease-causing pathogens. Nevertheless, in some developing nations it is still widespread. Common parasitic worm infections, such as ascariasis, in these countries are linked to night soil use in agriculture, because the helminths eggs are in faeces and can thus be transmitted from one infected person to another person (faecal-oral transmission of disease). These risks are reduced by proper faecal sludge management, e.g. via composting. The safe reduction of human excreta into compost is possible. Some municipalities create compost from the sewage sludge, but then recommend that it only be used for the planting of fluted pumpkins, banana, pawpaw, and flower beds, not vegetable gardens. The experiment has revealed the inert potentials of human urine and faeces when used in correct proportion as a good source of organic fertilizer that could be harnessed to boost the on-going organic farming programme in Nigeria.

It was found that faeces can be handled and re-used for agricultural purposes if treated with a combination of ash and sand after use and stored for 8 months.

The biodegradability of faecal sludge in the pit latrines studied has been determined and used to assess the performance of such pits. Biodegradability in terms of BOD could not be used to effectively assess the performance of pit sludge at the lower part of the latrine since aerobic biodegradation prevailed at the surface and minimally down the profile. Thus biodegradability in terms of COD is a better assessment.

5.2 Recommendations

- The biodegradability of sewage in pit latrines should be determined before sewage management option is discussed.
- Biodegradability and biodegradation rates are critical factors that should be measured for sewage before separate biological treatment or co-treatment with rural and municipal sewage is decided upon.
- COD should be adopted to assess the biodegradability and performance of any pit latrine.
- Methane production level of sewage should also be used to measure the biodegradability of sewage in pit latrines if the required equipment for such investigation is available.
- Rather than dwelling on real Ecosan urine diversion toilets for the production of humanure, the compost of already filled pit latrines should be used in right proportion for the planting of pawpaw, banana, fluted pumpkins, tomatoes and pepper with control.
- Other economic plants such as mango, orange, guava trees can be planted directly on filled compost pit latrines after 6 months of usage with the top covered with soil.
-

ACKNOWLEDGEMENT.

I very much appreciate the contributions and expertise of Prof. J.C. Agunwamba during this work. He has kept the fire burning by continuously encouraging me to write and publish papers to keep increasing my academic status. For all those who supported me in data collection and analysis, I say a bid thank you to you all. For my wife, I appreciate her patience and understanding.

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Table 1: Chemical Composition of Faecal Solid Fertilizer from a typical Sanplat pit latrine (compost ecosan).

A = Faeces + Ash, B = Faeces + sand; C = Faeces + Ash + sand, D = Faeces only

Parameters	Samples				Range	Mean
	A	B	C	D		
pH	6.85	6.80	8.40	6.90	6.80 – 8.40	7.24
Organic Carbon (%)	1.43	1.77	1.38	4.93	1.38 – 4.93	2.38
Total Nitrogen	0.12	0.16	0.09	0.43	0.09-0.43	0.20
C:N Ratio	12.44	11.43	15.28	11.66	11.43 – 15.28	12.70
Available P. ($mgkg^{-1}$)	167.44	225.44	110.31	230.94	110.31 – 230.94	183.53
Calcium ($cmolkg^{-1}$)	2.80	2.00	2.80	1.80	1.80 – 2.80	2.35
Magnesium ($cmolkg^{-1}$)	1.90	3.00	1.40	7.10	1.40-7.10	3.35
Potassium ($cmolkg^{-1}$)	0.13	0.13	0.12	0.12	0.12-0.13	0.13
Sodium ($cmolkg^{-1}$)	0.09	0.10	0.09	0.08	0.08 – 0.10	0.09

SUSTAINABLE COMMUNITY WASH GOVERNANCE APPROACH FOR SMALL TOWNS IN NIGERIA: A CASE STUDY OF ANAMBRA STATE.

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Abstract.

Small towns Water, Sanitation and Hygiene (WASH) are key strategic focus of World Bank, WaterAid Nigeria (an NGO) and European Union water Supply and sanitation Sector Reform programme (EU-WSSSRP) in Nigeria in line with the 2000 Water and Sanitation Policy. This case study focused on community governance approach in the implementation of small towns' WASH services delivery in Anambra State. The focus was on National and State WASH Policy directions with the support of the EU-WSSSRP in the state with intervention in 10 small towns. The study also looked at some implemented programmes and target areas including those seen as either successful or more challenging. Most interventions in the small towns studied lacked adequate community management process required for sustainability. The result also showed that some successes recorded were due to the adoption of well articulated and implemented process as against haphazard implementation that led to failure in most cases. Moreover, the study revealed opportunities and emerging lessons for scaling up future interventions.

Keywords: Strategic focus; Community governance; Small Towns; Water Consumers Association; Sustainability.

1.0 Introduction

According to OECD (2011), benefits of access to water, sanitation and hygiene far outstrip costs by a cost- benefit ratio of seven to one. It reported that the benefits include time savings from distances and/or queues at water sources, reduction in water borne diseases and other non quantifiable benefits such as social status, convenience, privacy, security, school enrolment, life expectancy etc. The report found that almost 10% of global burden of disease, especially, including 30% of deaths of children under 5 could be prevented through water, sanitation and hygiene intervention.

1.1 National water and sanitation policies and issue of access

Going by the Nigerian constitution, "except waters affecting more than one state" (FGN

1999) the responsibility of potable water supply and water-sanitation falls on each of the 36 states including Abuja. However, general support on policy formulation and direction is provided at Federal Level by the Federal Ministry of Water resources. In 2000, a National Water Supply and Sanitation Policy was developed which aims to contribute to the attainment of MDGs (Millennium Development Goals) and improve access to water and sanitation from 40% in 1999 to 100% by 2011 (FMWR, 2000). It classified water supply according to urban (populations above 20,000), small towns (5,000 to 20,000) and rural (less than 5,000). The National Water-Sanitation policy of 2004 covers water-sanitation issues related to disposal of household related waste water, faeces and hygiene (FMWR, 2004).
As at 2011 only 59% of the Nigerian population is using an improved source of drinking water - 73 percent in urban areas and 31 percent in rural areas (NBS-MICS, 2013). The national policy target on sanitation was to achieve 65% in 2010 and 80% coverage by 2015 (FMWR, 2004) but results from MICS(Multiple Indicator Cluster Survey) shows that access to improved sanitation was only 51% as at 2011 (NBS-MICS, 2013).
Community management of water supply and sanitation systems is increasingly seen as a fundamental part of national programmes for sustainable development. Various international fora on water have called attention to this topic. "Community management of services, backed by measures to strengthen local institutions in implementing and sustaining water and sanitation programmes", as one of the guiding principles adopted in the New Delhi Consultation in 1990.
In Anambra state of Nigeria, many development partners are involved in the implementation of water, sanitation and hygiene services. Among these are European Union Water Supply and sanitation Sector Reform Programme (EU-WSSSRP), WaterAid, United Nations Information and Children Emergency Fund (UNICEF) to mention a few. Prior to now, most of the partners did not lay much emphasis on implementation process and this caused the sector a fortune. Some WASH facilities constructed across the state were either abandoned after completion or left uncompleted due to failure to engage the beneficiary communities prior to implementation.
This case study took a cursory look at the processes employed by various implementing agencies with a view to proffering solutions for present and future implementation.

1.2 Overall objective

The overall objective of WASH programme is to improve health and livelihoods by increasing access to resilient facilities and services for good drinking water and improved basic sanitation on a sustainable basis.

1.3 Specific objective

The specific objective is to come up with sequential community governance approach that will ensure full participation of beneficiary communities leading to ownership, management and sustainability of WASH services.

1.4 Rationale for this study.

Some years back, early donors implemented WASH services in some states under Federal Ministry of Water Resources Small Town Water Supply and Sanitation Programme Implementation guidelines (FMWR-STWSSP (2000)).

. The emphasis then was on how many facilities that could be constructed. Little attention was paid to the type of facilities needed by the beneficiaries who were also not properly briefed nor participated in project implementation in terms of identification of sites, facilities design, delivery and management. There was little thought on how the facilities provided would be managed and sustained at the point of exit. Thus, so many WASH facilities were either uncompleted or abandoned or if successful, were instead of being owned, called either UNICEF or WaterAid or European Union (EU) projects.

Small towns are a key focus of European Union Water Supply and sanitation Sector Reform Programme (EU-WSSSRP) Phase II's Global Strategy 2012 -2017 extended. This Case study undertook a study of community governance approach in 2 namely Aguata and Anambra Local Government Areas (LGAs). Five small towns were selected from each LGA and this gave a total of 10 small towns for the study. Five (5) Small towns selected from Aguata LGA comprised Nkpologu, Oraeri, Uga, Akpo and Ekwulobia, while those of Anambta East LGA comprised Enugwu Aguleri, Mkpunando, Umuatuolu Umueri, Igboezunu Aguleri and Umuoba Anam. Importantly, the study focused on some implemented programmes and target areas including those seen as either successful or more challenging. The study also showed an interesting variety of interventions, from the pioneering capacity building initiative in small towns to the town-wide planning. In addition to this, there was also some level of successful school sanitation and hygiene intervention, supported with interventions and hard-ware. Moreover, there was also topping up of resource deficit, together with a rights-based approach, capacity building and citizens' fora.

2.0 Methodology

Key Research Questions developed to aid the study

- Identification: What were the motivations for site-selection? Has equity been factored in? What was the process adopted for project identification? What level of participation of local communities is the principle of subsidiarity (i.e. taking decisions closest to the ground by the ones affected most) in action? What is the theory of change applied? How has value for money been considered? How are decisions made on what approach to adopt (town-wide service delivery, slum-based project, local government capacity building, advocacy, or all of those)?

- Design: To what extent are WSSSRP II and WaterAid small town programme designed or aligned/realigned to meet the minimum commitments of the small towns' *framework*? How have the framework and report influenced the small town programming? Have the guiding principles been adopted or been adapted to the country contexts?
- Delivery: To what extent are WSSSRP II and WaterAid small town programmes able to support service delivery at scale? What is the status of service delivery across all the sub-sectors – water, sanitation and hygiene?
- Impact: What are the benefits of WSSSRP II and WaterAid small town programmes for poor communities and state/central governments and in-country systems? What is the impact of WSSSRP II small town interventions beyond the project area and beyond the limits of water and sanitation delivery?

2.1 Description of the Study Area

2.1.1 Anambra East LGA

Anambra East LGA is riverine. Agriculture is the predominant occupation of the residents which contributes significantly to the Gross Domestic Product (GDP) and internally generated revenue in the LGA, over 75% of the workforce is engaged in agriculture, about 10% in civil service while others are engaged in trading and in the informal sector of the economy. The LGA has a population of 153,331 people (2006 population census). The LGA has 11 autonomous communities (Aguleri, Umuleri, Nsugbe, Igbariam, Nando, Umuoba Anam, Eziagulu-Otu, Enugwu-Otu, Mkpunando, Ikem-Ivite and Igboezunu), with each comprising a mix of rural, small towns and urban settlements.

2.1.2 Aguata LGA

Aguata LGA is one of the oldest and largest LGA in Nigeria. The LGA boundary was adjusted when Orumba North and South were carved out of the old Aguata LGA in 1996. The 2006 National census put the LGA population at 192,760 male and 177,412 female making up a total LGA population of 370,172 people. In addition, the LGA has 14 autonomous communities (Agulu-Ezechukwu, Akpo, Amesi, Achina, Ekwulobia, Ezinifite, Igbo-Ukwu, Ikenga, Isuofia, Nkpologwu, Oraeri, Uga, Umuchu and Umuona), with each comprising a mix of rural, small towns and urban settlements. Most residents are Igbo. The communities operate a patriarchy head of households and ownership of property. In the LGA, the extended family system is strong and the men and women are predominantly traders.

In Aguata LGA, the predominant community based organisations were the Town Unions, Age Grades, Church societies and Parent Teachers Association. The LGA has some tourist centres such as Igbo Ukwu water museum and Obizi-Uga water wells

2.2. Data Collection

For the purpose of data collection and household sampling, the boundaries of Small Towns in the 2 focal LGAs were delineated from available satellite image data to avoid duplicating information gathered. This was to avoid duplication of data collection and analysis. However, sensitization/awareness creation among stakeholders on the study was conducted, targeting the follow up data collection activities in small towns. The targeted audience for data collection included the Programme Implementation Unit PIU), the Programme Recipient Agency (PIA), the Small Town Water Agency (STOWA), Rural Water Supply and sanitation Agency (RUWASSA), the LGAWASH Unit, the Water Consumers Associations, and notable Non-Governmental Organization/Civil Societies Organization (NGOs/CSOs including Women Organisations.

2.2.1 Stage one (Pre-field activities):

In this stage, the protocol on how the study would be carried out including the methodology was developed. Also, the instruments for data collection were developed, adapted, reviewed, pre-tested and amended prior to training of enumerators and data collection. In addition, the calculated minimum sample size of respondents was applied based on the number of small towns in the selected LGAs.

2.2.2 Field activities

A qualitative method was used to answer key research questions that were developed based on the focus of this study as well as what the Programme Support Unit hoped to achieve from this learning review. The questions were:

- How has the Anambra state *Small town water and sanitation delivery been successful, taking a wider view* report that informed the design/delivery of small town programmes?
- What have country programmes been doing in small towns (Identification; Design; Delivery; Impact)?

Semi-structured interview, focus group discussions and transect walks were used to answer the questions above. Informants included implementing partners, community members, local authorities, non-state providers and central governments/regulators. Interview questions and focus groups were designed around the programme cycle, described in detail below:

- Identification: What were the motivations for site-selection? Has equity been factored in? What was the process adopted for project identification? What is the level of participation of local communities is the principle of subsidiary (i.e. taking decisions closest to the ground by the ones affected most) in action? What is the theory of change applied? How has value for money been considered? How are decisions made on what approach to adopt (town-wide service delivery, slum-based project, local government capacity building, advocacy, or all of those)?

- Design: To what extent are water Supply and sanitation Sector Reform Programme Phase II.(WSSSRP II) and WaterAid small town programme designed or aligned/realigned to meet the minimum commitments of the small towns' *framework*? How have the framework and report influenced the small town programming? Have the guiding principles been adopted or been adapted to the country contexts?
- Delivery: To what extent are WSSSRP II and WaterAid small town programmes able to support service delivery at scale? What is the status of service delivery across all the sub-sectors – water, sanitation and hygiene?
- Impact: What are the benefits of WSSSRP II and WaterAid small town programmes for poor communities and state/central governments and in-country systems? What is the impact of WSSSRP II small town interventions beyond the project area and beyond the limits of water and sanitation delivery?
- Sustainability: How was sustainability factored into the overall process?

Eventhough school sanitation is a major component of the programme, community voices, including schools, got scanty representation in programme design specifics. As a result, there was little mention of equity and inclusion in the identification process, and little awareness of this generally. Most problems that arose were due to the neglect of beneficiaries ab initio.

3.0 Results and Discussion.

Semi-structured interview, focus group discussions and transect walks were used to answer the questions above. Informants included implementing partners, community members, local authorities, non-state providers and central governments/regulators. Interview questions and focus groups were designed around the programme cycle.

3.1 Response to research questions.

Identification: Sites were selected based on favourable geological disposition arising from geophysical investigations that the sites contain water bearing aquifers coupled with responsiveness of the communities to support WASH programme. Contributions towards provision of facilities were based on willingness to support the project by the beneficiary communities. Projects were identified based on people's needs and affordability. Another reason was the feasibility of the location on the projects to be sited considering the ability of the beneficiaries to support, own and manage such projects. The level of participation of the local communities was very high starting with decision-making on the type of facilities to be provided, coupled with planning, and contribution both materially and financially, implementation and handover process. The theory of change applied looked at the long-term goals such as improved access to WASH facilities, the service level considering the preconditions of community cohesion and the intention to own and manage the facilities at the long run, joint decision-making, financial outlay for the projects, and human resources available. The value for money looked at the success of projects implemented and the extent to which the facilities serve the beneficiaries. So, value for money is reflected in the service-life of the projects necessitating due to good workmanship and quality of materials used. The quality of supervision still adds to this service-life since poor supervision leads to low poor performance and short service life of the projects executed. Prior to intervention, there was a consensus to adopt the following approach to ensure successful implementation: carry out advocacy visits with the beneficiaries to local and state governments to support the projects implementation; local government to support capacity building of relevant personnel; sensitize and mobilize the communities for the works ahead and adopt town-wide service delivery.

Design: WSSSRP II and WaterAid small town programme have been well designed/aligned to meet the minimum commitments of small towns' framework in the following ways. The foremost is to improve water policy and institutional framework at federal level; improve water policy and institutional framework in the focal states; support urban and small towns water institutions in the focal states to deliver sustainable water supply and sanitation services, and support rural water supply and sanitation institutions in the focal states to deliver sustainable water supply, sanitation and hygiene services. The framework has helped in holding the stakeholders accountable to their roles and responsibilities, making maximum use of available human, financial and materials resources at each stage of the project. WASH programme is informed by key approved national policy and regulatory documents within the larger framework of Integrated Water Resources Management and Water Supply, Sanitation and Hygiene sector. In addition, WASH builds on proven approaches/strategies for small towns WASH sector such as CLTS; LGA-Wide approach to scale up WASH coverage, O&M; Water safety plan, harmonized procurement guidelines an work done in Sanitation Marketing.

Delivery: WSSSRP II and WaterAid small town programmes have successfully supported service delivery at scale in the small towns. All the institutions involved in the provision of WASH services in small towns have been assigned roles and responsibilities and it is envisaged that by the National Community Water and Sanitation Programme and all the sector players have the capacity to execute their respective roles and where these capacities are lacking, regular capacity building programmes could be the solution. The services of WSSSRP II and WaterAid provide lasting benefits to users. Federal government is ultimately responsible for ensuring that WASH services are delivered to their citizens and for deciding how these services should be delivered. This could be through local government, utilities, the private sector, community-based organisations or by households. Households and communities have a key role in demanding improved services and corresponding responsibilities in relation to management and current financing. In Anambra state, contracts were awarded for construction of WASH facilities in the 10 small towns. Construction of

Motorised Deep Boreholes (DMBHs) alongside sanitation facilities are nearing completion. Aguata LGA is 100% Open Defecation Free (ODF) within the 5 selected small towns only while Anambra East is 50% ODF in the 5 selected small towns only. Construction of deep motorized boreholes (DMBHs) and sanitation facilities in all the small towns are on-going and will be completed by the middle of this year. The success of the following was based on community management strategy/guidelines well documented and used as guidelines for the implementation of community works by the community management team (EU-WSSSRP Community Management Strategy Report, 2014)..

Impact. There has been increased access to portable water and sanitary facilities. There is poverty reduction and increased human activities as a result of increased water supply. Due to improved hygiene practices, there has been reduction in faecal related disease and other contagious diseases and increased productivity. There have been increases in school enrolment due to child friendly learning environment in place. Communities around small towns project areas have tremendously benefited from their WASH projects, not only in the utilisation of such facilities but have made internal arrangements to provide such facilities on their own. They have carried out advocacy visits to STOWA, Water Boards and governments for assistance and are yearning for enrolment into subsequent phases of the programme due to their limited human and financial capacities. In addition, management structures in small towns have been strengthened and positioned to manage projects handed over to them. In fact, these small towns have become very much responsive for any WASH donor funded or assisted projects that may want to come in and assist in such projects since they have the capacity to assist in the implementation, owning and managing them. At the end, and across all the focal state, access to safe water supply would have increased to 80% with drastic poverty reduction and improved health. .

3.2 Strength, Weakness, Opportunities and Threats (SWOT) Analysis through right implementation process

Involvement of the communities appeared to be the greatest strength of small town programme. Each project has been designed to suit the need of communities.

The processes followed by the partners have been similar. They have conducted a very detailed analysis of the situation and tried to identify strategies to improve access to services. It is also very clear that the partner CSOs/NGOs are playing the role of a facilitator and the small towns have been strategically involved in all the interventions by the partner. WSSSRP II has provided strategic training and programme inputs to strengthen partners' capacities to be able to manage and sustain their facilities well.

Community participation had been ensured right from the start of the project in all the small towns and throughout the project implementation period. A range of mechanisms and approaches were evident in the small towns to achieve this. For project identification purposes several rounds of meetings were held with equal participation of community members, male, female and the youth inclusive.

As communities have voted emphatically for prioritization of water services, the package on offer is water supply with focus on access, reliability, quantity, quality, sustainability and delivery at scale.

As far as **value for money** is concerned, both WSSSRP II and partners are conscious about value for money, which is frequently defined as the cost per user. This was achieved during intervention in these small towns.

3.1 Key community water governance approach in the state.

Lessons from the past revealed colossal economic wastes (humanly, financially and materially) due to failure by implementers to adopt community governance approach. Presently, the following processes are being adopted by implementers in WASH service delivery in various small towns in Anambra state of Nigeria. This is to enable the beneficiaries participate in the initiation, planning, funding, implementation, assume ownership at the point of exit of donors, management and sustainability of the WASH facilities bequeathed to them. These processes include inter alia:

- Undertake a process for selection of beneficiary small towns:
- Conduct baseline studies of the small towns;
- Establish a database on WASH facilities and services for the selected small towns and schools, including safe havens;
- Identify potential WASH interventions for the selected small towns and schools including safe havens.
- Assess on the ground characteristics in the small towns, schools, including safe havens, and propose resilient WASH solutions for locations that require resilient options.
- Review minimum standards for WASH interventions and indicators (with due focus on resilience) and propose measures for subsequent policy discussions and uptake.
- Establish relevant management structures such as Water Consumers Associations and Volunteer Hygiene Promoters' groups and build their capacities in relevant areas. Also ensure institution of Mentoring program.
- Establish Water Consumers Associations (WCAs) Coalitions at State, Zonal and LGA levels to coordinate the activities of constituent WCAs in the small towns.
- Build the capacities of these structures on Soft Skills and Leadership Qualities and other areas like Construction Monitoring, Operation and Maintenance (O&M).
- Set up Functionality Criteria on which the Water Consumers Association/Volunteer Hygiene Promoters (WCAs/VHPs) will be assessed.
- Institutionalize Community-Led Monitoring and Evaluation System.

- Establish a campaign to promote the social norms of using latrines and not defecating in the open with a focus on the disaster prone communities.
- Sustainable implementation of Community – Led Total Sanitation (CLTS) in Communities to ensure latrine uptake.
- Provide for WASH technology assessment, development and dissemination of manuals and guidelines.
- Provide institutional sanitation facilities in schools, communal facilities in safe havens and health centers.
- Provide access to resilient and safe drinking water facilities including construction of water kiosks for revenue generation with assurance on willingness to pay.
- Promote measures for the adoption of good hygiene practices.
- Ensure ownership at the point of exit of External Support Agencies (ESAs).
- Enhance capacity of field officers and National and Local government WASH authorities.
- Assist with measures to enhance preparedness to disasters by beneficiary communities as complement to other national efforts.

For the WSSSRP II Programme, one State Community Mobilizer was engaged at the state level to facilitate the implementation of Community management works in the small towns albeit in collaboration with the state Policy Implementation Agency (PIA), LGAWASH, and CSOs/NGOs Partners to implement in various small towns including capacity building of WCAs/VHP. Community Management Expert was engaged to provide technical support to the State Community Mobilizer to ensure quality in activities implementation in the small towns across the state.

Moreover, the small towns in the state also participate in the monitoring and supervision of WASH projects and make 5% counterpart contributions of the total project cost for operation, maintenance and management of constructed facilities after handover.

4.0 Conclusions.

The WASH Sector Programme is implemented within the framework of the Joint EU-WSSSRP II programming approach through collaboration with FMWR, States (MWR/STOWA), LGAs through LGAWASH Departments and beneficiary small towns, and partnership with CSOs/NGOs and other development partners in WASH Service delivery. In Anambra State, each participating body plays its own specific roles in the programme. On the whole, having a policy that focuses on small towns water supply is a good starting point in post MDGs planning. Developing a structure dedicated to support small towns water supply and sanitation at state level with a zonal or cluster arrangement would assist for better planning, management and improvement of access to safe water supply and sanitation in Nigeria in a more sustainable manner. Building the capacity of communities in small towns to own and make appropriate water supply and sanitation decisions as well as transferring operational responsibilities to skilled local operators is necessary to address some of the challenges.

Acknowledgement

The authors would like to extend thanks to European Union Supported Water Supply and Sanitation Sector Reform Programme Phase II (WSSSRP II) and the Anambra state partners that contributed to make this study a success.

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VULNERABILITY AND DRIFTS IN LIVESTOCK PRODUCTION IN A CHANGING CLIMATE- A REVIEW

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ABSTRACT
Livestock plays a very important role in the agricultural economy of the world. Its global demand is continually growing due to the increasing world population and the changing diet pattern of the rising middle class in the emerging economy. The contributions of livestock go beyond direct food production; it serves several other purposes such as skins, fiber, fertilizer and fuel production, provide income to farmers and the consumption of animal products such as meat and milk contributes to child's development. However, climate change is posing a serious threat to livestock production which if ignored might lead to extinction of some livestock in certain regions of the world. This work, reviews the various contributions of livestock to climate change, the effects of climate change on livestock production and a way forward towards sustainability of livestock production is proffered. It was found noteworthy that livestock production contributes to climate change by emission of methane during digestion of food and microbial activities in the dungs, increasing CO_2 in the atmosphere as a result of deforestation due to industrialization of livestock production to meet the increasing demand of livestock products, and emission of nitrous oxide from the application of herbicide to produce animal feeds. While climate change affects livestock production by increasing heat stress in animals, infections from pest and diseases, influence availability of water and affecting the structure of most livestock systems. This work advocates that as livestock farmers are continually developing farming techniques to adapt to climate change, animal behavior towards climate change should be monitored and studied. It was also recommended that livestock production should be enhanced while significantly reducing its contributions in greenhouse emissions through advanced studies and research.

KEYWORDS: Vulnerability, Livestock, global production, climate change, food security.

1.0 INTRODUCTION

Livestock contribution goes beyond direct food production; it also serves several other purposes such as provision of hides and skin, fiber, fertilizer, source of farm power and fuel production. It also serves as source of income to farmers especially in developing countries. Furthermore, the consumption of animal products such as meat and milk contributes to child's development (Marquis *et al.*, 1997; McMichael *et al.*, 2007). Unfortunately, the demand for livestock products outweighs its supply globally and this demand is expected to continue growing owing to the rapidly growing world's population. According to Kiaya (2014), by 2050 the world's population is expected to increase by one to three billion. Further trends like shift of lifestyle and diet patterns of the rising middle class in emerging economies along with climate change which put considerable pressure strain on the earth's resources, leading to decline of freshwater resources and biodiversity, loss of fertile land, etc. (Bank *et al.*, 2011; Hodges *et al.*, 2011; Nellemann *et al.*, 2009) have negatively influenced global livestock production.

Vulnerability is defined as the extent to which a system is exposed to hazards or negative impacts (Derner *et al.*, 2018). In this context, vulnerability looks into the direct effects of climate change (temperature changes, warming, change in rainfall pattern, accumulation of CO_2 in the atmosphere etc.) on global livestock production. It also involves indirect effects of climatic change, such as expansion of invasive plants, increasing wildfires, and increased incidence of pathogens and parasites; The vulnerability of a system can be seen as the combination of the exposure, sensitivity, and adaptive capacity of the system (Turner *et al.*, 2003). Exposure describes the direct and indirect effects of climate changes on livestock production; sensitivity describes the level of effects on the system including environmental and economic effects (Derner, *et al.*, 2018); while adaptive capacity deals with the level to which livestock can resist the effects of climate changes; it also involves the developed technologies for tackling these climate change effects. For example, cattle response to high temperature in the form of heat stress, which is a combination of sensitivity to heat (the temperature at which energy needs to be expended to maintain body function) and the capacity to dissipate excess heat (for example, sweating, coat reflectivity), will further depend on the availability of shade or water. Thus, vulnerability can encompass a wide range of complex intrinsic and extrinsic processes (Reeves & Bagne, 2016).

Since 2015, after the Global Climate Change Conference concluded in Paris, global warming and climate change is no longer a new thing but a problem staring at the world. According to Calvosa et al. (2009) evidence from the Intergovernmental panel on climate change (PFT, 2007) is convincing that climate change is real, and its effect will be worse on the poorest and most vulnerable people. The vulnerability of climate change will be seen in both developed and developing countries but its impact will be more in developing countries due to lack of resources, knowledge, veterinary and extension services, and research technology development. Sejian *et al.*(2016) stated that one of the major threats to sustainable livestock globally is climate change due to its global warming effects which influences temperature, rainfall pattern, pest and diseases infestation etc. Some livestock thrive well at hot climate while some do not and at extreme temperatures, some livestock dies. Therefore, the survival or adaption of livestock at extreme temperature or climate change may be a function of available resources, the ability of livestock producers to identify the effect of climate change on its environment at a particular period and take adequate action towards livestock sustainability. Some climate model projections have estimated that between the year 2010 and 2100, global temperature is going to increase by 1.1- 6.4°C (Sejian, *et al.*, 2016) which is about 18% increase in average global temperature. The various causes of global warming include burning of fossil fuels, transportation, coal generated electric power, bush burning, gas emissions from industries etc. in which transportation and energy generation are considered largest emitters of greenhouse gas, which are believed to be the major drive for climate change. Recently, there is an argument that greenhouse gas emissions from U.S., livestock production is comparable with that of transportation sectors in which the U.S., environmental protection agency have estimated the greenhouse gas emission from U.S., livestock to be 4.2% (Mitloehner, 2016). This article reviews the contribution of livestock production to climate change and the vulnerability of livestock production in the changing climate.

2.0 CONTRIBUTION OF LIVESTOCK PRODUCTION TO CLIMATE CHANGE

Livestock production is growing worldwide as the demand for livestock products is increasing owing to the world growing population. This increasing demand for livestock products have led to industrialization and improvement in technologies for livestock production since such practices can increase the number of livestock produced per area and consequently lead to increase in grazing area resulting in deforestation. Forests play important roles in preserving the world's ecosystem; they are involved in water cycle by returning water vapor to the atmosphere, which absorbs some of the CO_2 and other gases in the atmosphere that is causing global warming. Apart from the water cycle role forests play, they also absorb CO_2 direct from the atmosphere and produce oxygen which human beings and animals breathe, prevent soil erosion and keep soil moist by blocking the sun.

Methane is produced as a product of digestion in mostly ruminant animals that results from breakdown of feeds by microorganisms in the rumen, which the animals release mostly through belching. Different gases other than the popular CO_2, gases like methane, ozone, nitrous oxide etc. also causes global warming depending on their quantity in the atmosphere, ability to absorb heat and persistence in the atmosphere. In 2011, an estimated 137 million metric tons of methane (in CO_2 equivalents) was produced in U.S. by livestock, which comprises of about 70 percent of the total agricultural methane emissions (Smith, 2014). Cattles produce a greater quantity of the methane, producing close to 100 million metric tons of CO_2 equivalents annually in U.S (Smith, 2014). Most livestock farmers store dungs from livestock to produce manure for crops. These dungs are stored in an airtight container or pits to create enabling environment for microbial activities. The microbial activities on the dungs during digestion produce methane that is released to the atmosphere during manure application. Also during grazing, a small amount of methane is released to the atmosphere from the animal dungs. In 2011, about 52 million tons of CO_2 equivalents of methane were produced from animal manure deposition, storage, and application (EPA, 2013).

Due to industrialization of livestock production because of the increasing demand for livestock products, livestock farmers produce crops for feed. This has led to livestock farmers clearing more land areas for feed production, resulting to deforestation, manure, fertilizer and pesticide application. According to EPA (2013) report, soil management is the greatest emitter of nitrous oxide to the atmosphere, which normally occur immediately after application of fertilizer, herbicides and pesticides, hence resulting in accumulation of nitrous oxide in the atmosphere and probably global warming that is fueling climate change.

3.0 EFFECTS OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

Climate change is a problem that threatens livestock production globally. There is a convincing evidence by reviewers that climate change will affect livestock production negatively, if it does not lead to extinction of livestock in some part of the world (Baumgard *et al.*, 2012; Calvosa, *et al.*, 2009; Mitloehner, 2016; Rojas-Downing *et al.*, 2017; Sejian, *et al.*, 2016). Climate changes such as days and nights becoming warmer, retreating snow lines, increased evapo-transpiration and peak runoff, decreasing regular water discharge in streams and recharge of natural water stores, changing water table(s) and changing pattern of precipitation in terms of form, season, duration and intensity, and decreasing total rainy days (Pokhrel, 2011) are surely going to influence livestock production performance. Effects of climate change on livestock production are discussed under the following sub-headings:

3.1 Heat Stress

Heat stress is a situation where excess heat is absorbed by the body and causes stress, illness or even death. As the climate changes, it comes with a rising atmospheric temperature which will increase the heat absorbance of livestock. Although livestock like poultry may enjoy the rising temperature depending on the level of climate change because they thrive better at temperatures a little above room temperatures, livestock like pigs, cattle etc. are very sensitive to heat and their performance are easily affected by heat stress. According to Binsiya *et al.*(2017), pigs eat less when under heat stress which affects the performance of growing pigs and quality of meat. Heat stress reduces growth, alters carcass quality, and compromises efficiency of livestock, thus reducing chances for production of high quality protein for human consumption. Heat stress also weakens the immune system of animals, thus expose livestock to various illnesses. Heat stress models have predicted that by 2040 in the central US, swine may take additional 1.5 to 3.7 days to reach slaughter weight while cattle may take additional 2.8 to 4.8 days and milk production could be reduced up to 2.9 percent (CCC, 2013).

3.2 Pest and Disease

The effect of climate change on pest and diseases is uncertain; to some pest, high temperature is favorable and to others, high temperatures may lead to their extinction. For pests that thrive well in temperate regions, warmer and longer growing season increase the pest life cycle. Thus increased pest infestation may result to skin and other form of diseases for animals and possibly humans. High temperature fuels the transfer of diseases and infections. Thus climate change will increase the rate of transfer of diseases and infections causing various illnesses. Wittenberg & Boadi (2001) states that climate change will enhance insects development, create new diseases and alter animal husbandry techniques, thereby increasing the use of medications on sick animals which may potentially lead to more chemicals in food.

3.3 Animal Farming

Climate change is expected to affect the method or practices in which livestock is reared. For instance in most developing countries, extensive system of livestock production is the most dominant practice. In a high temperate environment caused by global warming, livestock needs to be kept in a controlled environment to enable adequate monitoring and necessary action towards the effects of climate change especially heat stress. In case of water scarcity, livestock needs to be kept in a place or house to reduce water loss by stress of going to fend for themselves as practices in extensive system of rearing animals. A similar situation may occur where there is adequate water supply which may have been contaminated by run offs due to increasing precipitation and rise in sea level, the practice of extensive system in such situation may lead to spread of water borne diseases among the animals and consequently affect livestock production and transfer of the diseases to humans. Though the animals may need to be kept in a place or house for easy monitoring, confined spaces and overcrowding indoors could lead to faster disease transmission. Overcrowding of livestock where there is adequate water supply may result in animal stress, greater pathogen output in one area of the paddock and reduced water quality (CCC, 2013). Therefore, the expected effect of climate change on animal farming is that livestock producers may need to pay more attention to the livestock to identify and take necessary action to the vulnerability of the changing climate on them.

3.4 Water Resources

Just like other factors, effects of climate change on water resources vary according to geographical area around the world. High temperature naturally increases the rate of evapotranspiration; this in some areas may increase the rate of precipitation while in some, the increasing evapotranspiration dries up the area and increase precipitation. Areas that experience increasing precipitation may have the advantage of having abundant water supply for water activities (Piao *et al.*, 2010). Depending on the volume of precipitation, such areas may face the risk of flooding as a result of rising sea level due to high precipitation, consequently leading to surface run offs and washing away of nutrients in the soil thereby affecting feed production in the areas. Also, fresh water in such areas may be contaminated or made unsafe for consumption due to run offs that wash soil nutrients, herbicides, chemicals etc. into their water bodies; salt water may rise to mix with fresh water due to high precipitation, hence there may be need for water treatment or sourcing other means of getting fresh and safe water for consumption (EPA, 2017). Where the aforementioned issue is neglected and water is consumed like that by humans and animals may lead to rapid spread of diseases and infections, consequently, death follows suit. Areas that experience dried environment as a result of global warming may face water scarcity risks. This will lead to drought severity and frequency, increasing demand on available water resources, which may affect water quality and quantity with the possibility of increasing toxin and pathogen concentration in water supply (CCC, 2013), lowering of underground water table, decreased precipitation and snow fall which may decrease water availability (PFT, 2007). Climate change may make prediction of precipitation difficult, as there may be alterations in precipitation patterns. This effects are already being experienced in some part of the world, like in Nigeria, raining season is usually experienced from the month of April to September while dry season starts from October to March (Amekudzi *et al.*, 2015; Omigbodun, 2013). Currently, raining season starts especially in the eastern and southern parts of Nigeria from February and sometimes last till December. A two weeks break in rainfall normally experienced in the month of August is now experienced in July and sometimes in September.

4.0 WAY FORWORD

Despite the contributions of livestock production to climate change, the economic benefit of livestock production cannot be ignored. The way forward is finding a way to strike a balance between livestock production and the greenhouse gasses it emits, and making adequate plans for adaptation of livestock to the changing environmental conditions. Herrero *et al.*(2016) revealed that global livestock sector can maintain the economic and social benefits it delivers while significantly reducing greenhouse gas emission. This can be achieved by modifying livestock production technologies and land use management. For instance, the feeding practice of livestock can be improved especially in the developing countries, ranching and improved manure handling systems may reduce the quantity of methane gas released to the atmosphere (Herrero, *et al.*, 2016).

Government policies and awareness will help in reducing global warming. Government enforcing policies that are targeted at reducing or stopping some activities such as deforestation that contribute to greenhouse gas emission in countries especially the developing countries will help. Government and agencies needs to work hand in hand in creating awareness of newly developed practices and possibly providing financial aids or programs that will easily key-in farmers who cannot afford the cost of implementing the developed practices.

Institutions and researcher should work more on possible ways of reducing global warming by not only livestock but also human activities while ensuring food security for the growing world population. Wollenberg *et al.*(2016) proposed that the global institutions concerned with agriculture and food security set a sectoral target to guide more ambitious mitigation and track progress toward a 2 ^{0}C warming limit while also assuring food security.
Another possible way of tackling this climate change effects is by reducing global livestock production by influencing the demand for livestock products. This can be achieved by reducing the quantity of meat and other livestock products consumed all over the world especially in the developing countries as proposed by some researchers (Hedenus *et al.*, 2014; Kim *et al.*, 2015). But the problem with this approach is that the world population is continually growing; likewise child birth as livestock products such as milk is needed for child's development. Also, questions such as who needs to eat meat?, who doesn't need meat?, when and where to eat it?, is there some alternatives to these products?, needs to be answered as to convince the populace to reduce meat consumption.

5.0 CONCLUSION

Livestock production has contributed to global warming that is fueling climate change. The ways livestock production have contributed to global warming include emission of methane during digestion of food and microbial activities in the dungs, increasing CO_2 in the atmosphere as a result of deforestation due to industrialization of livestock production to meet the increasing demand of livestock products, and emission of nitrous oxide from the application of herbicide to produce animal feeds. Climate change on the other hand is posing a serious threat to livestock production. Changes such as days and nights becoming warmer, retreating snow lines, increased evapo-transpiration and peak runoff, decreasing regular water discharge in streams and recharge of natural water stores, changing water table(s) and changing pattern of precipitation in terms of form, season, duration and intensity, and decreasing total rainy day may influence the performance and production of livestock. This climate changes can lead to heat stress, increase the infection of pest and diseases, influence availability of water etc. The vulnerability of climate change to livestock production may not be uniform globally; it will vary according to region, time and period.
Considering the social and economic benefits of livestock production globally, it can be deduced that, the need for livestock and its accompanied products and uses outweighs the contribution of livestock production to the changing climate. Therefore, all hands need to be on deck in resolving and solving the vulnerability of livestock production to the changing environments. There may be surprises down the lane as there are many uncertainties in climate predictions which the world have not experienced for millennia, so it may be difficult to determine how livestock production will react to the changing climate. As livestock farmers are continually developing farming techniques to adapt to climate changes, animals'

behavior to the changing climate should be studied. Further studies should be carried out on ways to enhance livestock production while significantly reducing greenhouse gas emission.

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THE PROSPECTS, POTENTIALS AND CHALLENGES OF BEEKEEPING IN NIGERIA

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ABSTRACT

Diversification of the Nigerian economy is the main agenda of the government now after the economy suffered a recession which was caused mainly by over dependence on crude oil as revenue generator of the country. There is increasing need to generate national revenue from other sources apart from crude exports. Beekeeping holds great promise as a potential source of national revenue. Demand for products of beekeeping is increasing worldwide. In spite of the challenges in apiculture, Nigeria has great potential for apiculture with its rich flora and fauna; with individual, corporate and government involvement in developing its apicultural industry; revenue can be generated from meeting some part of the worldwide demand for honey and other apicultural products.

Keywords: Apiculture, diversification, honey, demand, economy.

1. INTRODUCTION

Nigeria has a big potential for beekeeping owing to its diverse flora and fauna that provides nectar and pollen to foraging bees. This potential has been largely ignored as commercial beekeeping is relatively nonexistent in Nigeria. Different Nigerian tribes have their traditional beekeeping practices but when compared to world standards, the products of these traditional methods are substandard and are not fit for export. If concerted effort is put into developing and optimizing the abundant natural and human resources in our traditional beekeeping, Nigeria can generate revenue from export of beekeeping produce.

Bees are found around the globe, they are winged insects of the Apoidea family. So far, over 20,000 bee species have been recorded, most are found in Asia with a few others occurring in other parts of the world. Some bee species are solitary but of economic importance are the social species which include the honeybee. Four main species of honeybee exists: i. Apis mellifera (common). ii. Apis cerena (oriental). iii. Apis florea (dwarf). iv. Apis dorsata (giant). Of the four, two species are domesticated and used in beekeeping. *Apis cerena* in South East Asia and Apis mellifera world wide (Seeley, 2010). The Apis mellifera specie abounds in Nigeria and the West African region.

According to (Labe, 2017), Apiculture/beekeeping is the rearing, breeding and managing of honeybee colonies by humans in artificial hives for economic gains. Bees do well in natural, undisturbed forests and on integrated farms where there is abundant water and flowering plants since noisy environment can disturb the bees (Goulson., 2003). Beekeeping if properly exploited has a huge potential to generate foreign exchange for Nigeria. There is an increasing demand for honey and other bee products because of its great values in maintaining good health and in the treatment of various diseases. According to Anineme (2007), honey is highly useful and as a result, there is so much demand for it that it can be termed a money spinner.

Honeybees are of great economic importance because they do not only produce honey and beeswax but also act as primary pollinating agents of many agricultural and forest crops (Labe, 2017). It is due to pollination that crop yield increases, quality of seed and fruit improves (Moniruzzaman and Rahman,2009). The objective of this Paper is to review the potentials of beekeeping as a possible source of foreign exchange for the Nigerian economy and the associated challenges.

2. BEEKEEPING PRODUCE

2.1. HONEY

Honey is used as a food ingredient, as medicine, in the tobacco industry to improve and preserve tobacco’s aroma and humidity, in cosmetics as a skin treatment, moisturizer, and softener and in creams, soaps, shampoos and lipstick. Honey is a juicy, sticky substance with very sweet taste. It is produced from nectar, which is obtained from floral nectaries deep within flowers. Honey is one of the most important foods of our modern world taking into account the current trend in food consumption. In addition to it, honey has an important role in the so-called “healthy lifestyle”, since it can be consumed without any further processing. Worldwide production of honey amounts to around 1.4 million tonnes per annum. The European Union (EU) is an important producer of honey, in terms of production volume. Other leading producers according to their production shares are China (22%), the USA (6%), Argentina (6%) and Turkey (5%) (FAO STAT, 2010).

2.1.1. NUTRITIONAL VALUE OF HONEY

Honey is a mixture of sugars and other compounds. With respect to carbohydrates, honey is mainly fructose (about 38.5%) and glucose (about 31.0%), making it similar to the synthetically produced inverted sugar syrup which is approximately 48% fructose, 47% glucose, and 5% sucrose. Honey's remaining carbohydrates include maltose, sucrose, and other complex carbohydrates. As with all nutritive sweeteners, honey is mostly sugars and contains only trace amounts of vitamins or minerals. Honey also contains tiny amounts of several compounds thought to function as antioxidants, including chrysin, pinobanksin, vitamin C, catalase, and pinocembrin. Honey is primarily made of water and carbohydrates. It contains trace amounts of several minerals and vitamins. You can find niacin, calcium, copper, riboflavin, iron, magnesium, potassium and zinc in honey. Honey also contains a blend of flavonoids and phenolic acids. Honey is an amazing antibacterial substance which comprises sugars like glucose and fructose and minerals (like magnesium, potassium, calcium, sodium chlorine, sulphur, iron and phosphate), vitamins (such as B1, B2, C, B6, B5, B3), trace elements (like copper, iodine, and zinc) as well as amino acids. The nutritional properties or the specific composition of any batch of honey, the color and flavour of honey are determined by the types of flowers the bees pollinate. (Sampath Kumar, *2010).* The data in table 2.1 below shows the nutritional value per 100g of honey:

Table 2.1 Nutritional value of honey per 100g

Energy	1,272 kJ (304 kcal)
Carbohydrates	82.4 g
Sugars	82.12 g
Dietary fiber	0.2 g
Fat	0 g
Protein	0.3 g
Water	17.10 g
Riboflavin (Vit. B2)	0.038 mg (3%)
Niacin (Vit. B3)	0.121 mg (1%)
Pantothenic acid (B5)	0.068 mg (1%)
Vitamin B6	0.024 mg (2%)
Folate (Vit. B9)	2 μg (1%)
Vitamin C	0.5 mg (1%)
Calcium	6 mg (1%)
Iron	0.42 mg (3%)
Magnesium	2 mg (1%)
Phosphorus	4 mg (1%)
Potassium	52 mg (1%)
sodium	4 mg (0%)
Zinc	0.22 mg (0%)

Source: USDA Nutrient database 2007

Therefore, Honey is a supersaturated sugar solution with approximately 17.1 percent water. Fructose is the predominant sugar at 38.5 percent, followed by glucose at 31 percent. Disaccharides, trisaccharides and oligosaccharides are present in much smaller quantities. Besides carbohydrates, honey contains small amounts of protein, (including enzymes), vitamins and minerals.

Honey yields 64 calories per tablespoon, making it a more concentrated source of energy than other common sweeteners. While the amino acid content is minor, the broad spectrum of approximately 18 essential and nonessential amino acids present in honey is unique and varies by floral source. Proline is the primary amino acid with lysine being the second most prevalent. Other amino acids found in honey include phenylalanine, tyrosine, glutamic and aspartic acids. The glutamic acid is a product of the glucose oxidase reaction.13 Proline and other amino acids are contributed by pollens, nectar or bee themselves.

Table 2.2: Nutrient percentage in Honey

Nutrient	Percentage
Water	17.20 %
Fructose	38.29 %
Glucose	31.28 %
Sucrose	1.31 %
Maltose	7.21 %
Carbohydrates	1.54 %
Acid	0.57 %
Protein	0.26 %
Minerals	0.17 %
Enzymes, Vitamins etc	2.21 %

Source: USDA Nutrient Database 2007

2.1.2. MEDICINAL USES OF HONEY

Honey has a variety of medicinal and antibacterial properties, and has been used in ache comfort and healing of burn victims. The sugars in honey nourish healthy cells and help guide the improvement of new white blood cells. Honey's antioxidants, amino acids and nutritional vitamins play a function in reducing inflammation.The antibacterial activity of honey hastily kills the pathogens that cause typhoid fever,bacterial pneumonia, strep throat and bacterial dysentery. In fact, in 1998 honey was once proven to be more advantageous than silver sulphadiazine, the antibacterial ointment most broadly used on burns in clinic situations, in the remedy of burns (Kihwele et al,2001).

Other medicinal uses of honey include: Honey is used for the treatment of pimples in human faces, for hair loss or baldness treatment. It is also used for treating bladder infections and also for skin infection treatment. Honey serves as antibiotic and it serves effectively in treating patients who are obese. Honey that is not contaminated with other substances like extra sugar substances help in the treatment of cancer, eliminate bad breath and also treats arthritis which often is suffered by the elderly ones. Medically it has be proven that honey helps in restoring loss in hearing and most especially honey serves as a skin moisturizer. In households honey is used as an antiseptic and also it is used in the removal of acne and most especially for energy boosting in enhancing vitamin A and improves blood flow. Honey due to its versatile usage it is used for the treatment of sore throat, colon damage prevention and to remedy burns. Honey serves as antibacterial solution, as relaxant for nervousness, wound healing/treatment, tooth-ache treatment, reduction of cholesterol level, treatment of persistent cough and colds, upsets stomach problem, heart diseases treatment, indigestion treatment and Influenza germs destruction, etc. Honey/beeswax are used as preservatives, serves as a hair conditioner, and serves as a skin toner.

Honey is as its best as produced by the bees and no amount of processing can improve it. This implies that the less that is done to honey after harvesting the better. Production of good quality honey requires that the beekeepers and honey handlers do not inadvertent reduce the quality of honey by bad or careless handling, while the best time to harvest honey is normally late afternoon or early evening, so as to minimize the possibility of other bees in the area robbing the hives (Hisao, 2009).Increasing standards of living around the world has also seen increase in honey consumption. Industrialized countries are importing more honey providing developing countries like Nigeria with a source of foreign exchange from exporting honey.

2.1.3. DOMESTIC/COMMERCIAL VALUES OF HONEY

The main uses of honey are in cooking, baking, as a spread on bread, and as an addition to various beverages such as tea and as a sweetener in some commercial beverages. According to international food regulations, "honey stipulates a pure product that does not allow for the addition of any other substance. Honey barbecue and honey mustard are common and popular sauce flavors. Honey is the main ingredient in the alcoholic beverage mead, which is also known as "honey wine" or "honey beer". Historically, the ferment for mead was honey's naturally occurring yeast. Honey is also used as an adjunct in some beers. Baker's honey is suitable for industrial uses or as an ingredient in other foodstuffs. Honey is used for making vinegar**.** Vinegar made from honey is rare, although commercially available honey vinegars are produced in Italy, France and Spain. Choices and uses of honey varieties in cooking ultimately depend on personal tastes and preferences which can be rather subjective. But different honey varieties have great versatility in cooking and their own unique tastes which could influence the flavour of other foods substantially. The following are but a few of the applications or commercial importance of honey and beeswax: cosmetics and medicinal creams; foundation for new honeycomb in hives; slippage prevention for belt in vacuum cleaners and sewing machines; waterproofing shoes and fishing lines; lubricant for doors, windows and tools; wax for skis, toboggans, bow strings; polish making; soap making; glass etching; crayon making; wax production; reconstructive surgery; embalmment procedures; wood filler; dental floss; e.t.c.

2.2. BEESWAX

This is the material that the bees use in building their combs. Bees secret it as liquid from their wax glands and on exposure to air, the wax hardens and forms scales. All species of honeybees produce beeswax although the physical and chemical properties of the wax vary by species. Beeswax is valued according to its purity and color. The lighter the color, the more valuable the wax as dark colored wax tends to be contaminated.

Processing beeswax to export quality involves simply heating and filtering to ensure the wax is clean. This makes it an appropriate export crop for developing countries.

Over 200 industrial uses exist for beeswax with the cosmetic and pharmaceutical industries taking up to 70% of the total trade in beeswax. The price per kilogram of beeswax ranges from US$4 - US$8. Other applications of beeswax include furniture and shoe polish, crayons, candles, lip balms, lipstick, hand creams. candle makers, dentistry as temporary tooth filler, and chewing gum production, wood and leather industry as waterproofing agent.

2.3.ROYAL JELLY

Royal jelly is secreted and used in the nutrition of bee larvae, as well as adult queens. It contains about 67% water, 12.5% protein, 11% simple sugars, 5% fatty acids and 2-3% 10-hydroxy-2-deconoic acid. It is widely marketed as a dietary supplement and is by the most lucrative bee product selling at around 1200 USD per kilogram. It is produced in specialized colonies and requires expertise in its production, harvesting and storage as it is perishable. The Asian beekeepers produce a lot of royal jelly and offer training opportunities.

2.4.BEE VENOM

The production of bee venom is another lucrative venture in beekeeping. Bee venom is used in the pharmaceutical industry. It offers opportunity in generating revenue as the value of bee venom ranges from 100 – 200 USD.

2.5. BEE POLLEN

Bees collect pollen from plant anthers as shown in plate 4, mix it with doses of secretion from salivary gland and nectar and store them in special compartment in the hive. This mixture is called bee pollen/bread/cake. The characteristics of bee pollen vary a lot and depend on the plants the pollen is collected from as well as time of day. Bee pollen is known as an Apitherapeutic product because it contains groups of chemical compounds that are used for medicinal purposes.

One bee colony can produce about 1 – 7kg of pollen annually, daily production ranges from 50 – 250 grams. Countries like Australia, USA, Spain, Argentina, Mexico and some European countries have thriving markets for bee pollen with prices ranging from 4 – 15 USD per kilogram.

2.6. PROPOLIS

Propolis is made by bees mixing beeswax and other secretions with resins from the buds of conifer and poplar trees. Propolis production is very low in Nigeria. The value of propolis around the globe ranges from as low as 5 – 30 USD per kilogram. Table 2.3 below shows the range of price for honey and other bee produce.

Table 2.3 Price of Honey and other bee products.

Bee Product	**Market Price**
Honey	$12 - $25 per kg
Beeswax	$4 - $8 per kg
Royal jelly	$1200 per kg
Bee venom	$100 - $200 per g
Pollen	$4 - $15 per kg
Propolis	$5 - $30 per kg

3. PROSPECTS OF BEEKEEPING AS AN ECONOMIC DIVERSIFICATION TOOL

Honey is in great demand round the year especially for medicinal purposes. Many health conscious people consume it regularly. It is also used in making certain health food preparations. Market potential for honey and its by-products is expanding in the medicinal and cosmetic industries as a result of growing interest in natural ingredients. A growing market opportunity is honey with the essence of a specific wild flower, herb or special crop. These products are in demand for their nutritional, culinary and medicinal properties. The major four registered honey marketers in Nigeria as competitors: RQ pure honey-Kaduna, Adonai pure honey-Abuja, Abdulson honey-Kaduna and A & Shine pure honey-Abuja package a total of up to about 40,000 liters per annum valued at N52, 500,000. Domestic honey consumption data for key honey consuming countries are presented in Table 3.1 below. Approximately one-half of Canadian honey is sold to domestic consumers or processors, while exports average 9,000 to 14,000 metric tonnes annually.

Table 3.1: Domestic Honey Consumption for Selected Countries (tonnes)

	Canada	China	Germany	United States
1995	24,550	75,205	93,000	155,000
1996	25,144	85,760	88,950	151,526
1997	26,605	120,003	85,798	149,161
1998	26,900	123,100	88,000	151,000
1999	27,250	122,500	92,749	152,300
2000	27,500	123,300	87,800	153,200

Source: Canadian statistics, 2000

World honey trade has expanded steadily, having grown by 36 per cent from 157 kT in 1977 to 214 kT in 1982. The largest exporters are China and Mexico, which together account for close to half of the world exports. China's exports increased rapidly from an average of 18 kT in the three-year period 1976-78 to 60 kT in 1982. With this threefold increase, exports from China constituted a quarter of the world trade in honey in 1982. Also, exports of honey are an important segment of the total market in Australia. Exports of honey in Australia have averaged over 10,000 tonnes per annum over recent years, representing between 25% and 30% of estimated total production.

Honey has substantial medicinal properties and potentials. Procurement of natural or pure honey is becoming difficult due to urbanization and deforestation. Simultaneously, its demand is steadily increasing as medicines are becoming more and more popular. To facilitate rearing of honey bees to obtain natural honey, government agencies should provide assistance/incentives. Honey production activity has very good potential round the world, table 3.2 below shows world honey production and consumption as at 2005.

Table 3.2 World honey production and consumption for 2005.

World honey production and consumption in 2005				
Country	**Production (1000 metric tons)**	**Consumption (1000 metric tons)**	**Number of beekeepers**	**Number of bee hives**
Europe and Russia				
Ukraine	71.46	52		
Russia	52.13	54		
Spain	37.00	40		
Germany (*2008)	21.23	89	90,000	1,000,000
Hungary	19.71	4		

Romania	19.20	10		
Greece	16.27	16		
France	15.45	30		
Bulgaria	11.22	2		
Serbia	3 to 5	6.3	30,000	430,000
Denmark (*1996)	2.5	5	4,000	150,000
North America				
United States of America (*2006, **2002)	70.306	158.75	12,029	2,400,000
Canada	45 (2006); 28 (2007)	29	13,000	500,000
Latin America				
Argentina	93.42 (Average 84)	3		
Mexico	50.63	31		
Brazil	33.75	2		
Uruguay	11.87	1		
Oceania				
Australia	18.46	16		
New Zealand	9.69	8		
Asia				
China	299.33 (average 245)	238		7,200,000
Turkey	82.34 (average 70)	66		4,500,000
Iran				3,500,000
India	52.23	45		9,800,000
South Korea	23.82	27		
Vietnam	13.59	0		
Turkmenistan	10.46	10		
Africa				
Ethiopia	41.23	40		4,400,000
Tanzania	28.68	28		
Angola	23.77	23		
Kenya	22.00	21		
Egypt (1997)	16		200,00	2,000,000

Central African Republic	14.23	14		
Morocco (1997)	4.5		27,000	400,000
Source: Food and Agriculture Organization of the United Nations (FAO), August 2007.				

The Nigerian tropical environment and diverse flora is ideal for establishment of bee colonies having fewer pollutants that can adversely affect bees as in the industrialized nations. According to United Nations Conference on Trade and Development "UNCTAD (2006), it has been certified that honey from the tropics has a distinct attractive aroma superior to those from non-tropical regions of the world. In 2002, the world honey market was largely affected by EU ban on Chinese honey, following the identification of antibiotics in samples of Chinese honey. China was the largest supplier of honey to Europe. This ban led to a shortage of honey in Europe and honey prices increased rapidly (BBC News, 12th July, 2002). This condition presented an ideal opportunity for developing countries like Nigeria. The gap left by China could be filled by other Countries like Nigeria if they were organized to do so. African honey is absent in EU honey imports. The demand for chemical residue free honey, presents opportunities for honey producers in Countries like Nigeria. Beekeeping for honey production has been identified as one of the activities that could provide a means of livelihood and reduce poverty among rural dwellers in Nigeria (Babatunde *et al*., 2007).

Apiculture is a foreign exchange earner for countries that export bee products. China is the number one exporter of honey in the world, selling $246,550,000 followed by Argentina with $212,637,000 (Chibuzo *et al*., 2015).The market for honey beverages in the US is worth about $195million per year aside the processing and packaging of honey by-products such as pollen, propolis and royal jelly as food supplements, which generate more than $1billion annually (Adeola *et al*.,2011). The products are readily marketable and have long shelf-life: In Nigeria, the price of honey ranges from N100,000 – N120, 000 per ton. If Nigeria were to export 2,000 tons of honey produced annually, that will fetch the Nation 200 to 240 million naira per year (Adediji and Omoba, 2016).

The Nigerian beekeeping industry has majored mainly on honey production. For beekeeping to be a tool of economic diversification, apart from optimizing honey output, effort should go into large scale production of other beekeeping products: beeswax, royal jelly, bee venom, propolis, pollen. There are other business opportunities in the beekeeping industry that can boost the beekeeping and the economy as whole:

1. Crop pollination services

   Nigerian beekeepers can also generate revenue by offering pollination services to agricultural crop farms. This service will have a multiplier effect as it will at the same time increase crop production and bee products. This is practiced in most developed countries: Over $30million is made by American beekeepers from renting out bees for crop pollination. The use of bees in biological (non- pesticide) control of agricultural pests is also an industry generating $20millio in the US per year (Fabunmi, 2010). It requires about 2 – 4 bee colonies to service 1 hectare of crop.

2. Queen breeding

   This is a specialized process that involves the selection of stock based on genetic traits. The main goal of breeding is to improve selected traits like increase in honey production, resistance to disease and infections. These specially bred queens and their colonies are packaged and sold to beekeepers. As awareness in beekeeping is increasing, demand for these packaged colonies is also increasing.

3. Processing centers.

   Bee products for export must meet certain quality standards and must be uncontaminated by chemicals and residues from the environment or during processing. This puts Nigerian beekeepers at a disadvantage as they still employ crude traditional processing methods. Currently, only five African countries meet up with the requirement in the World Market. The countries include; Kenya, South Africa, Tanzania, Uganda and Zambia. Only four Asian Countries like China, India, Taiwan and Vietnam meet up with the requirement (UNCTAD, 2006). For our bee products to meet international export standards, opportunities exist for setting up processing centers for bee products. This will put make Nigerian honey fit for export and encourage exploitation of other bee products for exports.

4. Design and fabrication of beekeeping equipment

   Alongside setting up processing centres, to modernize beekeeping in Nigeria there is a market for locally manufactured beekeeping equipment.

   Quality of bee products is affected by the methods of harvesting and storage. Presently the Nigerian beekeeping is lacking good quality beekeeping equipment. Local manufacture of quality beekeeping equipment will improve market indices as beekeepers will not have to import equipment anymore and product quality will increase.

5. Research and development of beekeeping technology.

3.1. Current challenges of beekeeping in Nigeria:

1. Limited knowledge of modern beekeeping practices and low technical capacity: This includes poor hive management, limited knowhow on colonization and hive maintenance, crude product harvesting methods that decimate the bees, general lack of training and access to modern research information, lack of material and skill to monitor and improve bee health.
2. Lack of government regulation and policies: There is a big need for the government to provide an enabling policy framework and regulatory regime to provide market guidelines and directions for beekeeping in Nigeria.

3. Environmental factors: Deforestation, bush burning and introduction to the environment of pesticides and insecticides pose a great threat to the floral requirements for optimum beekeeping.
4. Finance: A major challenge to industrial level beekeeping and to establishment of product processing and packaging centres has been poor access to finance.
5. Lack of awareness: There is a lack of awareness of the business potential of beekeeping and most people involved take to it as a part time venture with minimum labour input. Therefore growth is limited. There is also lack of awareness on the existence of government support for beekeeping entrepreneurship development like those offered by the Raw materials research and development council.
6. Lack of quality management system: This also contributes to the prevalence of substandard and contaminated bee products in the market, thereby making it very difficult to market products for export.

4. Conclusion

Beekeeping in Nigeria has a high growth potential. The diverse floral conditions of Nigeria support industrial production of bee products for export. Beekeeping as an activity, which meshes well with other agricultural and rural development program offers great potential for development in almost all African countries. Regional development projects also offer possibilities of implementing beekeeping ventures. It is easy and cheap to start, it can provide valuable food/medicine for the family and honey and beeswax are important cash crops with ready local market. Beekeeping requires little land and therefore is an ideal activity for small scale resource-poor farmers. Beekeeping also enhances the environment and increases crop yields through pollination. It gives local people an economic incentive for the retention of natural habitats such as forests and therefore is an ideal activity in any forest conservation projects. Certain crops planted in such projects can yield honey for the beekeeper as well as benefit from the pollination activities of the bees. Beekeeping can provide additional income to small farmers who plant these crops or have their honeybees nearby. These challenges if effectively addressed will create a thriving beekeeping industry in Nigeria and will lead to increased production, greater market access and increased revenue.

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EFFECT OF CALCINATION TEMPERATURE, MIX RATIO AND CURING TIME ON STRENGTH CHARACTERISTICS OF CEMENT-PERIWINKLE SHELL ASH (PSA) LATERIZED CONCRETE

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Abstract

This work studied the effect of calcination temperature, mix ratio and curing time on the strength characteristics of cement-periwinkle shell ash laterized concrete. Periwinkle shell ash, an agricultural waste material was calcined at three different levels of temperature viz : 600, 800 and 1000 ˚C; two mix proportion of 1:1:2 and 1:2:4 were prepared using each level of PSA calcination as cement replacement in the concrete mix. Five replacement levels of 0, 10, 20, 30 and 40% of cement with periwinkle shell ash were used in the preparation of the specimen, while slump test in accordance with the requirement of BS EN 12350-2: 2009 was carried out to determine the workability of each mix. Moulds of 100 mm × 100 mm × 100 mm was used for moulding of compressive strength test specimen. Each replacement was replicated three times. Five levels of curing time were applied on the specimen namely 7, 14, 21, 28 and 56 days. Finally testing of the specimen for characteristic strength was carried out on the respective curing times using compressive testing machine. A total of 360 cubes were used for the experiment. The result shows that no significant differences were observed on calcination temperature on PSA laterized concrete but the calcination temperature significantly affect the physico-chemical properties of PSA. The curing ages were found to be significant exception of 56 days of curing, water/PSA-cement ratio met the specification of ASTM C618- (2008) across all level of replacement for 1:1:2 mix for 800 and 1000 ˚C calcined PSA while 20-40% and 30, 40% of 800 and 1000 ˚C, for 1:2:4 mix proportion satisfies the requirement. 10 and 20% of 800 and 1000 ˚C PSA laterized concrete met the requirement for characteristics strength of concrete for 1:1:2 mix proportion while the levels of replacement for 1:2:4 falls below the required design strength.

Keywords: Calcination temperature, characteristic strength, concrete mix ratio, curing time, laterized, periwinkle shell ash

I. INTRODUCTION

Concrete is define as a mixture of Portland cement, water, fine and coarse aggregates and admixture proportion to form a plastic mass capable of been cast, placed or moulded into forms that will hardened it into a solid mass Aitcin (2000). Its constituents include; cement,` sand (fine aggregate) and gravel (coarse aggregate). However, due to high cost of its constituent especially cement and sand, and the risk and hazard it pose to human and the environment, many researches has been carried out over the years to source for environmental friendly and cost effective construction materials.

Lateritic soil has been one of the major building materials in Nigeria for a long time. It is known that a large percentage of walls of residential and agricultural buildings in the rural areas have been built with lateritic soil in different forms without cement stabilization. However their usefulness as laterized blocks has been replaced with sancrete blocks today and widely use in urban settlement. Lateritic soils are known to be available in large quantities and in different types all over Nigeria as well as in most tropical countries of the world. They are essentially products of tropical or sub-tropical weathering, usually found in areas where natural drainage is impeded, though lateritic soils have been used in the construction industry as a substitute for fine aggregate in concrete, there have not been accepted standards as regards its performance characteristics, this may explain why there is still scepticism about their behaviour and hence acceptability continues to be a problem.

Various authors have investigated processes and methods of improving lateritic soil as a better engineering material in other to obtain its full use for engineering purposes and some interesting studies have been carried out in the field of laterite technology especially in the recent past. Most of the studies according to Kurmar (2002) focus on the stabilization and utilization of laterite and lateritic soils with the addition of lime, cement, or bentonite. Balogun (1982) under different studies considered the possibility of replacing sand in concrete with laterite and discovered that the most suitable mix of laterized concrete for structural purposes is (1:1½:3), using batching by weight with a water/ cement ratio of 0.65, provided that the laterite content is kept below 50 percent of the total fine aggregate content. According to Lasisi *et al.*, (1990) the durability of laterized concrete and laterite/cement mortar members can be enhanced by the low permeability characteristics of the lateritic soil contents of such specimens. Other factors such as mix proportion, grain size, moisture content of the mix which affect the performance characteristics of laterite soil has been investigated by Lasisi *et al* (1984), Osunade and Babalola (1991), Osunade (1994) and (2002). Olugbanga (2007) also look into the effect of curing age and water/cement ratio on the elastic properties of laterized concrete, the results of these investigations did confirmed the suitability of lateritic soil as an engineering material. Aguwa (2009) concludes in his work that stabilized lateritic soil can compete favourably with cement-sand mix.

According to BS EN 197-1: 2009, cement is an hydraulic binder which when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which after hardening, retains its strength and stability even under water. Due to its property of setting and hardening by virtue of a chemical reaction with it, it is known as hydration cement. Pozzolanic materials have been investigated over the years as a possible replacement for cement partially or wholly. Mehta and Monteiro (2006) stressed that for a pozzolan to function properly; it must be amorphous and glassy and have particle sizes comparable with Portland cement which is to be replaced. He added that when finely ground, it attains higher specific surfaces which hasten the silica content to combine with the lime to form cementitious materials, these secondary compound leads to increase in the strength of the mix. Table 1 shows the physical properties of pozzolanic material which according to ASTMC618 (2008) is comparable to that of cement. The challenges posed on the construction of structures that are to be of quality standard and functional under service life have led to the resurgence of pozzolan as one of the mix. The employment of pozzolan in the construction industry is for economical, technological and environmental reasons. Technologically, it can modify the properties of cement, increasing or decreasing its durability with respect to its aggressive strength; economically, active pozzolan promote utilization of our natural resources (Bhanja and Senguptab 2002), while Hendelberg (2013) submit that pozzolan reduces the effect of global warming. Periwinkle shell ash is obtained by burning the periwinkle shell which is the by-product of periwinkle. Badmus *et al* (2007) charred periwinkle shell in a muffle furnace at a temperature of 300˚C and the ash obtained was found to be pozzolanic. The use of shell ash as pozzolan to replace cement in concrete has been investigated by Job (2003), Koffi (2008), Umoh and Femi (2013). Offiong and Akpan (2017) carried out an assessment on the physico-chemical properties of periwinkle shell ash and concluded that it satisfy the classification of ASTMC618 (2008) for a good pozzolan. Dahunsi and Bamisaye (2002) incinerated periwinkle shell in a muffle furnace at an unspecified temperature and ground it to a pulverized stage, and use it to replace cement in concrete production. Hence this paper seeks to investigate the effect of calcination temperature, mix ratio and curing time on the strength characteristics of cement-periwinkle shell ash laterized concrete

Table 1 Physical Requirement of Pozzolans

Properties of Pozzolan	**ASTM Requirement**		
	Classes		
	N	**F**	**C**
Fineness (Amount retained when wet-sieved in 45μm sieve, %)	34	34	34
.Strength activity index			
With Portland cement at 7- days min. percent of control	75	75	75

Water requirement max. percent of control	115	115	115
Soundness autoclave e	0.8	0.8	0.8
Autoclave expansion or contraction, max, percent			
Uniformity requirement			
The density and fineness of individual sample shall not vary from theaverage established by the ten preceding tests if the number is less than ten or more than:	5	5	5
Density, max. variayion from average, %			
Percent retained on 45µm (no 325), max. variation percent point of average	5	5	5

Source: ASTM C618-2008

II. METHODOLOGY

a. Sample Collection

Periwinkle shell used for the study was sourced from Odiok Itam, a riverine community in Itu Local Government, Akwa Ibom State. The fine aggregate (lateritic soil) was sourced from a borrowed pit in Ajebandele along ife-Ibadan express road, granite chippings from a quarry along Ondo road Ile-Ife Osun State while Portland cement was purchased from a cement store in Ile-ife, Osun State

b. Calcination of Periwinkle Shell

Periwinkle shell were washed, dried before subjecting to heat for calcination. 15kg each of periwinkle shell were calcined at temperature level of 600, 800 and 1000˚C in a gas furnace at the Firing Chamber of the ceramic Section of the Department of Fine and Applied Art, Obafemi Awolowo University Ile-Ife Osun State, the ashes obtained were ground and sieved into the required particle sizes.

c. Proportioning and mixing of constituents

The mix proportions were carried out in accordance to IS 456-2000 mix-design approach of 28-days characteristics strength of 25 N/mm^2 for mix ratio of 1:1:2 and 15 N/mm^2 for mix ratio of 1:2:4 with (0% PSA and 100% cement) as control. Two mix proportions of 1:1:2 and 1:2:4 were used for each of the level of periwinkle shell ash replacement. The choice of these mix proportions is based on the envisage use to which they could be put in actual practical application, the 1:1:2 mix proportion is mainly use for farm storage structures while the 1:2:4 mix proportion is used for general reinforced concrete work. Portable water was used in mixing the concrete. Five replacement levels of 0, 10, 20, 30 and 40% of cement with periwinkle shell ash were used in the preparation of the specimen, while slump test in accordance with the requirement of BS EN 12350-2: 2009 was carried out to determine the workability of each mix.

d. Casting and curing of test specimen

Moulds of 100mm × 100mm × 100mm was used for moulding of compressive strength test specimen,. The moulds were thoroughly cleaned and coated with mould oil before casting to ensure easy de-moulding and smooth surface finish, casting was done in accordance to the requirement of BS 12390 – 2: 2009, the cubes specimen were de-moulded after 24 hours and immersed in water curing tanks for 28 days.

e. Compressive strength test

Compressive test was carried out at the Material Testing Laboratory in Department of Building, Obafemi Awolowo University. A total of 360 cubes specimen were used for the experiment. Testing of the specimen was carried out at 7, 14, 21, 28 and 56 curing days using compressive testing machine.

III. RESULTS AND DISCUSSION

a. Effect of Curing Age on Strength Characteristics of PSA-Cement Laterized Concrete

The compressive strength values of PSA-cement laterized concrete at 7 days, attained percentage of design strength of 52.15, 40, 40 and 40%, 73.32, 38.68, 36.80, 36% and 66, 54, 34 and 25.32%, respectively, for PSA calcined at 600, 800 and 1000 ˚C for 10 to 40% replacement level. 10% replacement level for all calcined temperatures and 20 % for 600 and 1000 ˚C met the requirement of normal concrete strength development as stipulated by BS 8110 Part 2, (1985), At 14 days, values at 10 and 20% for 600 and 1000˚C and 10% for 800 ˚C met the BS 8110 part 2 (1985) requirement. At 21 days of curing, the compressive strength of the control mix met the design strength with a value of 25.33 N/mm^2, while at various replacement levels of 10, 20, 30 and 40%, the values obtained is below the desired characteristic strength of 25 N/mm^2 as it ranged between 8.50 -21.65 N/mm^2, 9.5– 24.33 N/mm^2, and 7.65 – 19.83 N/mm^2

for 600, 800 and 1000 ˚C respectively. On the other hand, the compressive strength at 28 days of curing for the control mix was 28 N/mm^2 whereas on replacing cement with PSA at 10, 20, 30 and 40% the result obtained were 22, 20.5, 15 and 9.35 N/mm^2 for 600 ˚C calcined PSA, 25.6, 24, 13.67 and 12.67 N/mm^2 for 800 ˚C calcined PSA and 24.5, 23.75, 15, 9.17 N/mm^2 for 1000 ˚C calcined PSA respectively. This shows that 10 and 20% replacement of cement with PSA calcined at 800 and 1000 ˚C met the requirement for characteristic strength of concrete. This is in line with the findings of Umoh and Femi (2013) that PSA calcined temperature at 800 ˚C and above reaches its amorphous characteristics of a good pozzolan, and found to be suitable for use as a replacement for cement in concrete. At 56 days hydration period, the control mix recorded a compressive strength of 29.3 N/mm^2 while for 10, 20 30 and 40% replacement levels, the strength values were 26.33, 25, 18, 9.00 N/mm^2; 25, 24.83, 14.50, and 12 N/mm^2, 27.33, 25.33, 15.50 and 12.50 N/mm^2 for 600, 800 and 1000 ^{o}C respectively. These results obtained for 10 and 20% replacement levels at 56 days of curing confirms the report by Umoh and Femi (2013) that with longer curing days, concrete with pozzolan has the potential of achieving high strength values.

b. Effect of Water-PSA/Cement Ratio on PSA-Cement Laterized Concrete

The water requirements for PSA-cement blended mix use in preparation of the specimen are presented in figures 1 and 2. According to ASTMC618 (2008) which states the standard water requirement range of 105% to 115% of the control mix, Fig. 1 shows that for mix ratio of 1:1:2, PSA calcined at 800 and 1000 ˚C met the standard requirement as it ranges from 107% to 113% at all level of replacement, while that of 600 ˚C is less than 105%. For mix ratio of 1:2:4, figure 2 shows that ash at 800 ˚C with 20, 30, 40% replacement and ash at 1000 ˚C with 30 and 40% replacement met the standard water requirement.

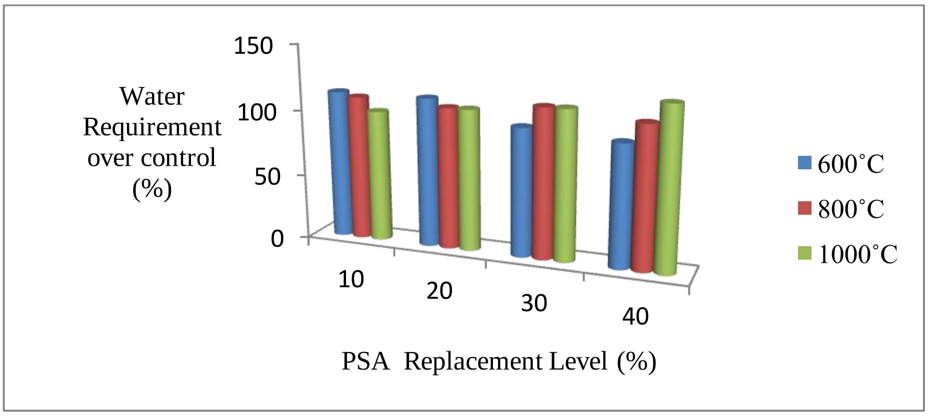


Figure 1: Water requirement for Cement-PSA Laterized Concrete for Mix Ratio of 1:1:2

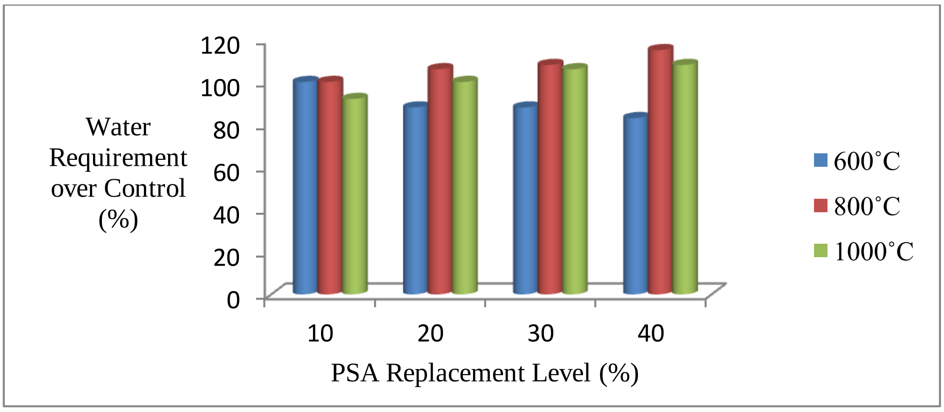
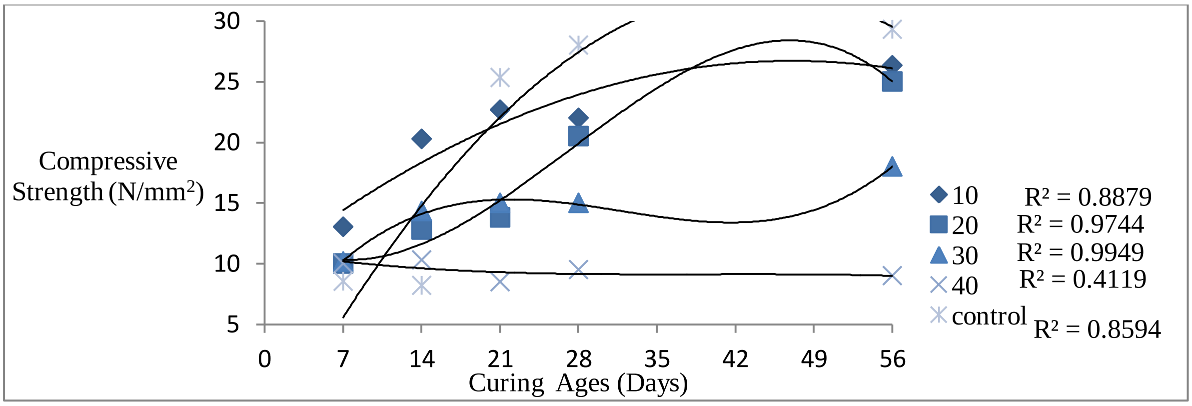


Figure 2: Water requirement for Cement-PSA Laterized Concrete for Mix Ratio of 1:2:4

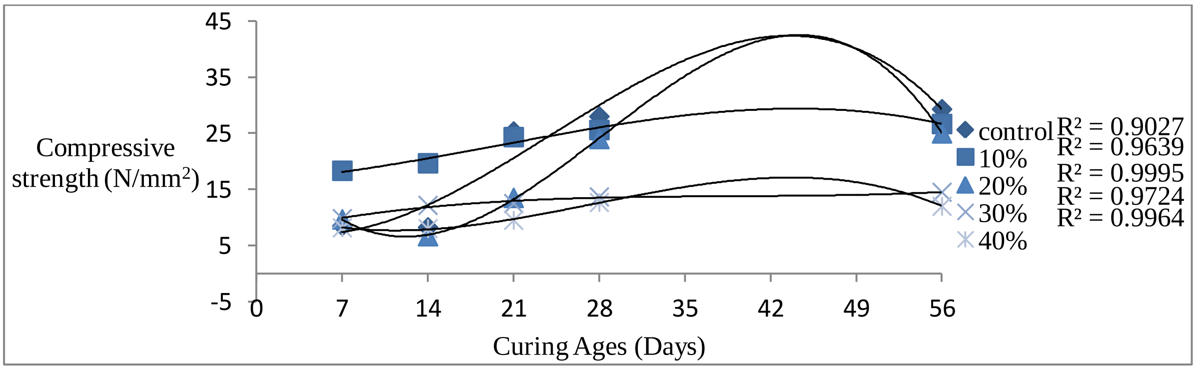
c. **Effect of Replacement Level on the strength Characteristics of PSA - Laterized Concrete**

Across the three temperature levels of PSA calcination (600, 800 and 1000 ˚C) and replacement levels (10, 20, 30 and 40%) for 1:1:2 mix ratio, at 28 days of curing being a measure for the characteristics strength of PSA-cement laterized concrete, compressive strength test values of 22, 20.5, 15 and 9.35 N/mm^2, 25.6, 24, 13.67 and 12.67 N/mm^2 and 24.5, 23.75, 15, 9.17 N/mm^2 for 1000 ˚C calcined PSA respectively were attained for 600, 800 and 1000 ˚C, while for control mix 28 N/mm^2 was obtained. For 1:2:4 mix proportion, 9.67, 8.5, 7.5 and 6.17 N/mm^2; 10.67, 9.67, 8 and 8 N/mm^2 and 13, 10.5, 8.17 and 7 N/mm^2, for 600, 800, and 1000 ^{o}C respectively were obtained, while the control mix recorded a strength of 18.0 N/mm^2. According to IS 456-2000 which specifies concrete characteristics strength of 25 and 15 N/mm^2 for 1:1:2 and 1:2:4 mix ratios respectively, this shows that 10 and 20% of 800 and 1000 ˚C for 1:1:2 mix ratios met the required characteristics strength. On the other hand, none of the replacement levels for 1:2:4 satisfy the IS 456-2000 requirement. ANOVA result shows that for 1:1:2 mix proportion, the p-values obtained are 0.521, 0.287, 0.086 and 0.001 for 10, 20, 30 and 40% respectively. Only 40% replacement level is significant whereas for 1:2:4 the p-value obtained are 0.0434, 0.0254, 0.015 and 0.015 for 10, 20, 30 and 40% replacement level. It could be observed that all level of replacement are significant at 0.05 significant level. For tensile strength, Only 10 and 20% replacement levels recorded strength values for 1:1:2 mix, while only 10% replacement level recorded strength values for 1:2:4 mix. This could be attributed to the initial filling of voids by PSA at lower replacement levels of 10 and 20%. while at higher replacement levels of 30 and 40%, the voids is already filled and the excess PSA causes reduction in tensile strength of the specimen, this is in line with the findings of Bhanja and Senguptab (2002) which states that filling of voids with less percentage of silica fumes significantly improve the tensile strength of concrete, while at higher level, the strength reduces drastically. **Effect of Mix Proportion on Compressive Strength of PSA Laterized Concrete**

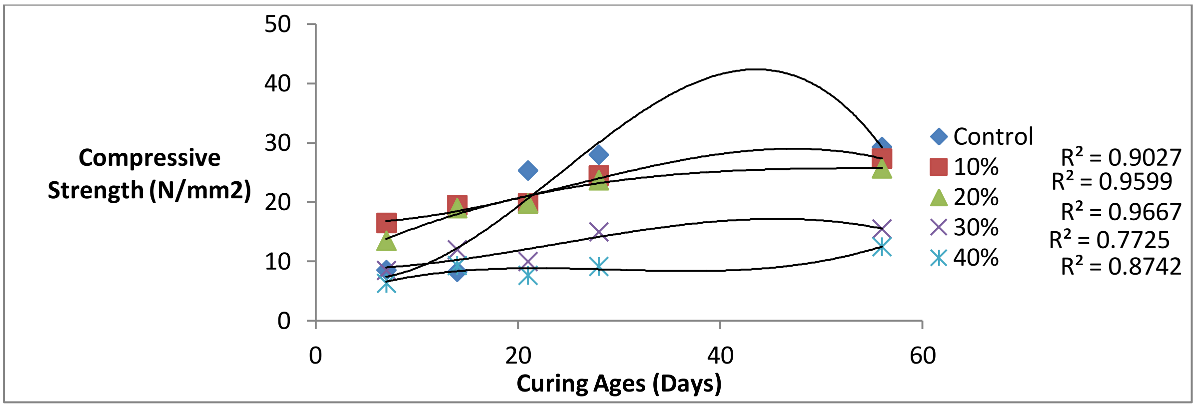
Figures 3 (a, b, c) and 4 (a, b,c), shows compressive strength as affected by mix proportion (1:1:2 and 1:2:4) at all calcination temperatures (600, 800 and 1000 ˚C). For 1:1:2 mix, for 7 and 14 days, all percentage replacement levels tends to have higher strength than the control specimen, while at 21 days of curing, the control became more stronger with value of 25.33 N/mm^2; however, both 10 and 20% replacement level increased appreciablly in strength close to that of the control specimen. 30% replacement level specimen also increased cosiderably while 40% records low strength value. Whereas for 1:2:4 acrross all level of replacement (10, 20 30 and 40%) and temperature of calcination (600, 800 aand 1000 ˚C), a steady and slow increase in strength was observed with the control specimen recording a high strength values. At 28 days of curing 1:1:2 mix proportion met the required design strength of 25 N/mm^2 for 10 and 20% replacement level of 800 and 1000 ˚C calcined PSA while for 1:2:4 mix proportion, none of the replacement level met the required strength of 15 N/mm^2. Only 10% of 1000 ^{o}C calcined PSA recorded a close value of 14 N/mm^2.



(a) 600˚C Calcined PSA

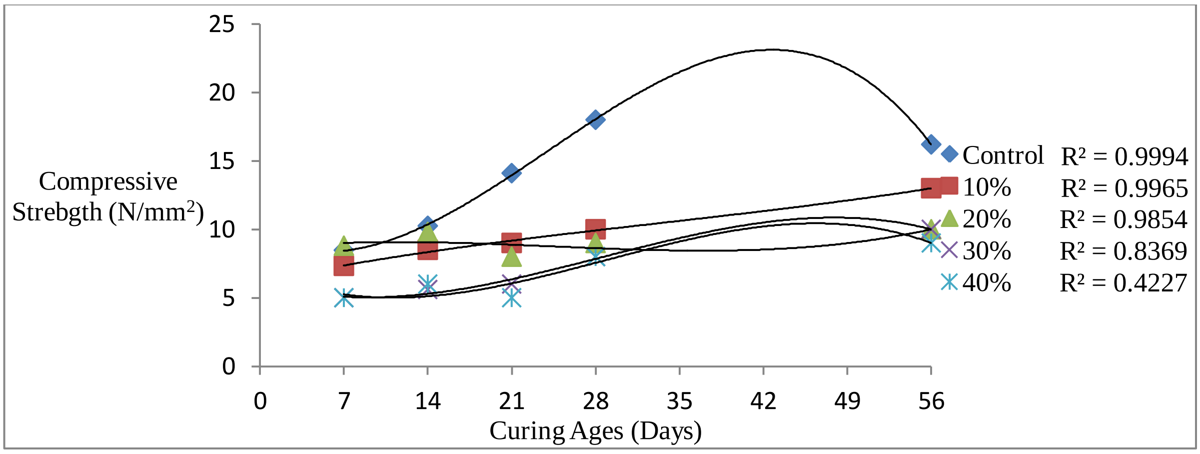


(b) 800 ˚C Calcined PSA

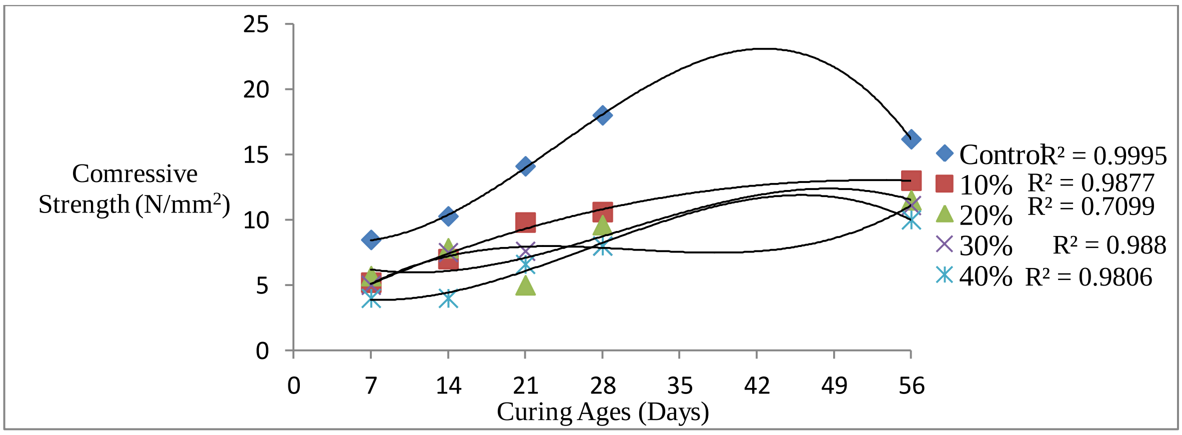


(c) 1000 ˚C Calcined PSA

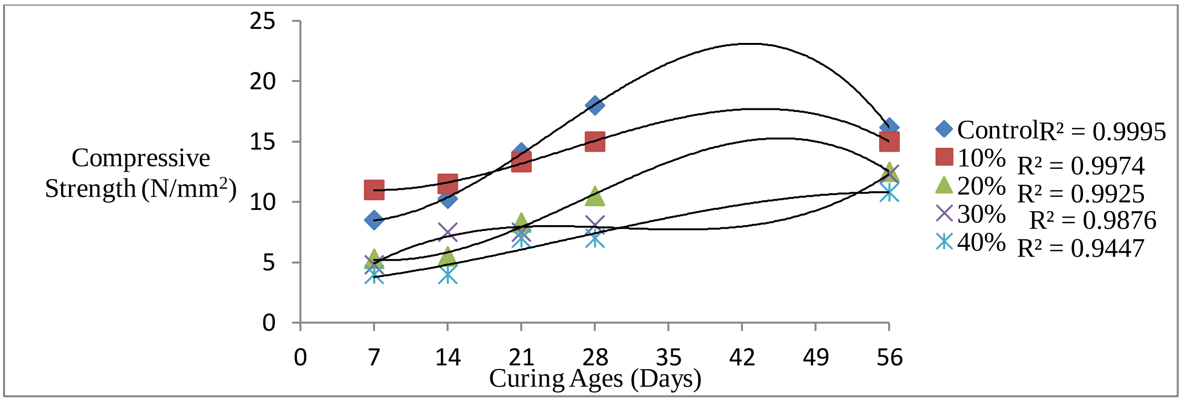
Figure 3 Effect of Curing Age on Compressive Strength of PSA Laterized Concrete for Mixed Ratio 1:1:2



(a) 600 ˚C calcined PSA



(b) 800 ˚C Calcined PSA



(c) 1000 ˚C Calcined PSA

Figure 4 Effect of Curing Age on Compressive Strength of PSA Laterized Concrete for Mixed Ratio 1:2:4

d. Effect of Calcination Temperature on the Strength Characteristics of PSA-Laterized Concrete

Figures.4 and 5 show plots of compressive strength of PSA–laterized concrete at different temperature of calcination. For mix proportion of 1:1:2, the correlation coefficients for 600 ˚C calcined PSA are 0.9985, 0.9744, 0.9947, 0.4119, for 10, 20, 30 and 40% replacement level with the control specimen having a coefficient of 0.9019, while for 800 ˚C the correlation coefficients are 0.9639, 0.9995, 0.9724 and 0.9964 for 10, 20 30 and 40% level of replacement, while the control has 0.9027. Also for 1000 ˚C, the correlation coefficients obtained are 0.9599, 0.9667, 0.8742 and 0.7725 with the control recording 0.9027. It could be observed that across all temperature of calcination, 10 and 20% replacement level has a correlation coefficient higher than that of the control specimen. This is confirmed in the ANOVA result as seen in Table 2 in which none of the temperature of calcination of PSA significantly affect the compressive strength of laterized concrete at 0.05 significant level. Whereas for 1:2:4, the correlation coefficients are 0.9994, 0.9599, 0.9667, 0.7725 and 0.8742 for 600 ˚C, 0.9995, 0.9877, 0.7099, 0.9888 and 0.9806 for 800 ˚C and 0.9995, 0.9974, 0.9925, 0.9876 and 0.9447 for 1000 ˚C for 0,10, 20 30 and 40% replacement levels. The correlation coefficients for the replacement levels are lower than that of the control across all temperature of calcination. The AVOVA result in Table 2 shows a p-value of 0.012, 0.049 and 0.031 for 600, 800 and 1000 ˚C, these shows that the three temperature of calcination are all significant at 95% confident level, implying that mix ratio 1:2:4 irrespective of the temperature of calcination is not suitable for PSA- laterized concrete. In terms of tensile splitting strength, Across all curing ages it was observed that calcined PSA at 800 and 1000 ˚C records higher tensile splitting strength than 600 ˚C for 1:1:2 and 1:2:4

CONCLUSION

Factors affecting cement-PSA-laterized concrete were investigated and it was found that:

- Calcination temperature has an effect on the compressive and tensile strength of periwinkle shell ash.
- Curing ages of 7, 14, 21 and 28 were significant as their effect on PSA-cement laterized concrete were observed across the different levels of replacement.
- For water/cement-PSA mix, 800 and 1000 ˚C across all levels of replacement met the ASTMC618-(2008) requirement for 1:1:2 mix proportion while for 1:2:4 mix ratio, 20, 30 and 40% and 30 and 40% of PSA calcined at 800 and 1000 ˚C respectively satisfies the requirement.
- For levels of replacement, 20% of 800 and 1000 ˚C for mix ratio of 1:1:2 met the characteristic strength of concrete with only 40% found to be significant while none of the replacement levels measured up to the required strength characteristics but all levels were significant at 0.05 significant level.

Table 2 Anova for the effect of parameters affecting PSA Laterized Concrete for Mix Ratio 1:1:2

Sources of Variance	Df	Sum of square	Mean Square	Std. Error	p-Value
Intercept	1	60090.34	60090.34	0.837	0.951
Control	4	934,27	233.56	0.798	0.473
Replacement Level					
10%	3	934.27	311.42	0.798	0.521
20%	5	467.135	186.85	0.798	0.287
30%	2	934.27	467.135	0.798	0.086
40%	4	932.27	233.56	0.00	0.001*
Temperature, ^{o}C					
600	2	1.04	0.52	0.618	0.642
800	1	1.04	1.04	0.618	0.834
1000	2	1.04	0.52	0.52	0.798
Curing Age, Days					
7	1	361.34	361.34	0.798	0.001*
14	2	361.34	180.67	0.798	0.001*
21	2	361.34	180.67	0.798	0.001*
28	3	722.67	361.35	0.798	0.009*
56	2	722.676	361.35	0.798	0.156

*Factors that are significant at p<0.05

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IMPORTANCE OF RENEWABLE ENERGY RESOURCES FOR SUSTAINABLE AGRICULTURE

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Abstract
The importance of renewable energy resources in Agricultural activities cannot be over-emphasized. The use of fossil fuels, as energy resource contributes to greenhouse gas emissions and, in turn, accelerates climate change. Such environmental damage can be mitigated by the promotion of renewable energy resources such as small-scale hydro, wind, solar, biomass and geothermal. These renewable energy resources have a huge potential for the agriculture industry. The farmers should be encouraged by the application of renewable energy technology in the practice of agriculture. Sustainable agriculture also depends on replenishing the soil while minimizing the use of non-renewable resources, such as natural gas, which is used in converting atmospheric nitrogen into synthetic fertilizer, and mineral ores, e.g. phosphate or fossil fuel used in diesel generators for water pumping for irrigation. Hence, there is a need for promoting use of renewable energy systems for sustainable agriculture, e.g. solar photovoltaic water pumps and electricity, solar dryers for post-harvest processing, and solar hot water heaters. This paper x-rayed the importance of renewable energy resources for sustainable agriculture. The data for renewable energy sources used in this paper was an extract from the report of 2018 World renewable energy generation statistics (2010- 2017). Renewable energy resources used include hydro, wind, solar, biomass(bioenergy and bagasse) and geothermal. The simulation of the result was done using Scilab software. From the study, hydro energy resource contributes the highest renewable generation throughout the world, including Africa and Nigeria.

Keyword: Sustainable, agriculture, renewable energy resources, greenhouse gas emissions, fossil fuel.

1.0 Introduction

Sustainable agriculture is an alternative for solving fundamental and applied issues related to food production in an ecological way [1]. It involves design and management procedures that work with natural processes to conserve all resources and minimize waste and environmental damage, while maintaining or improving farm profitability. Corwin et al .[2] established that the concept of sustainable agriculture is predicated on a delicate balance of maximizing crop productivity and maintaining economic stability, while minimizing the utilization of finite natural resources and detrimental environmental impacts. According to [3] as reported [4], a sustainable agricultural system is based on the prudent use of renewable and/or recyclable resources. Ikerd [4] defined sustainable agriculture as ―capable of maintaining its productivity and usefulness to society indefinitely. Such an agriculture must use farming systems that conserve resources, protect the environment, produce efficiently, compete commercially and enhance the quality of life for farmers and society overall. A system which depends on exhaustible (finite) resources such as fossil fuels cannot be sustained indefinitely. A sustainable system would use renewable energy sources such as biological, geothermal, hydroelectric, solar or wind. Sustainable economic development is clearly an objective and indisputable requirement of the present society. An important element of this transition to another type of economy, more efficient and friendlier to the environment, new green economy, which seeks to improve living conditions and to reduce social inequalities in the long run, to reduce negative external and market failures. Green agriculture could nutritionally feed the global population if worldwide efforts are immediately initiated and the transition carefully managed. This transformation should particularly focus on improving farm productivity of smallholders and family farms in regions where increasing population and food insecurity conditions are most severe. Rural job creation would accompany a green agriculture transition, as organic and other environmentally sustainable farming often generate more returns on labour than conventional agriculture. According to the United Nations, green agriculture incorporates ideas and guidelines from different conceptual areas. Green Agriculture means empowering managers to the widespread use of natural fertilizers, to improve the crop rotation, to improve efficiency of the water consumption, to improve the storage methods and the supply production chain. More specifically, this means green agriculture uses adaptable local farming techniques and practices that will increase farming yields. This will also reduce waste and inefficiency problems in our food chain, offer improved and sustainable services for the ecosystem, and also provide a higher return on labour. Basically, green agriculture uses well-developed modern farming and sustainability concepts to improve natural agricultural techniques dealing with things such as weed and pest management and organic fertilizers and seeds. It also draws on technology to push farming forward. These technologies will complement and expand upon natural methods, and include things such as new, synthetic fertilizers. Green agriculture fuses both sustainable environmental practices with better labour usage on agriculture farms to reduce poverty. It is also something that small-scale farmers can introduce. The transition to a more sustainable form of agriculture will mean local farms will change their practices, drawing upon best practices from the green agriculture toolbox. Conventional and traditional farmers can take on these sustainable practices and methods for maximum results. The greening of agriculture presents an enormous innovation challenge of producing more food and fibers without relying on most of the technological mainstays of productivity gains of the past. The challenges posed by climate change to agriculture and food security require a holistic and strategic approach to linking knowledge with action. It is increasingly clear that climate change as the dominant global scale environmental concern will have a profound influence on the agro-ecological conditions under which farmers and rural populations need to develop their livelihood strategies, manage their natural resources and achieve food security and other ends. Some major challenges to the sustainability of the world‘s agriculture are: pollution, water scarcity/ salinity, carbon foot-print and natural resource depletion. In the late 1950s and early 1960s scientists began to record increasing levels of carbon dioxide (CO2) in the atmosphere which occur due to human-induced emission of CO2 and other ―greenhouse gases‖ into the atmosphere. By the early 1980s, a fairly broad consensus had emerged in the climate change research community that energy production and consumption from fossil fuels could, in the foreseeable future, result in a doubling of the atmospheric concentration of CO2, a rise in global average temperatures and a complex pattern of worldwide climate change [5]. A greener agriculture has the potential to substantially reduce agricultural green house gas emissions (GHG). The cumulative effect of green agriculture in the long term will provide adaptive resilience to climate change impact.

This paper discusses the importance of renewable energy resources for sustainable Agriculture. The objective is to understand how to use renewable energy technologies knowledge in agricultural production systems.

1.1 Renewable Energy in Agriculture.

Renewable energy systems are the cornerstones and the foundation of a truly sustainable energy future. Renewable energy sources are literally found in sunlight, in the air, deep underground and in our oceans. They are part of the planet’s physical structure, which means they are constantly being renewed by natural means. They simply cannot run out. These sustainable energy sources are often called “alternative energy” because they’re considered to be an alternative to traditional fossil fuels such as oil and coal. Renewable energy also includes generation of power to do a number of farm tasks: pumping water for irrigation, for livestock or for domestic use; lighting farm buildings; powering processing operations and others. These forms of renewable energy include solar energy, wind and water power, oil from plants, wood from sustainable sources, other forms of biomass (plant material), and biogas (gas produced from fermentation of manure and crop residues). It is a clean form of energy with little or no environmental pollution. They are from natural occurring sources like; water, sun, wind, the earth crust and biological materials. A natural resource qualifies as a renewable resource if it is replenished by natural processes at a rate comparable with or faster than its rate of consumption by humans. Renewable sources of energy for agriculture are a green option for cutting back on energy consumption in developed countries or even providing energy in developing countries, where electricity supply in rural areas is intermittent at best. In rural communities of developing countries this often results in encroachments into natural ecosystems — for example the cutting down of forests for fuel —

leading to major sources of emissions. Renewable energy technologies are ones that consume primary energy resources that are not subject to depletion. Examples of renewable technologies include solar energy, wind energy, geothermal energy and biomass. Given this definition and the fact that water supplies are replenished in the annual hydrologic cycle, hydropower is considered part of the mix of renewable technologies [6].The various sources of energy, e.g. solar, wind, hydraulic, biomass, organic wastes, biofuels, and combined heat and power provide a simple, sustainable, effective solution for the conservation of valuable non-renewable fossil resources without resulting in environmental pollution. Solar energy can be utilized in its varied forms, e.g. solar PV, direct solar thermal and renewable fuels and wind can offer the solution to the world’s energy problems and ultimately make the environment sustainable for future generations by reducing environmental pollution from fossil fuel energy usage.

Agriculture, as a sector, was viewed in the post-World War II era as a sector from which resources could be extracted to fund development in the industrial sector — success of the latter being seen as key to the economic well-being of Organization for Economic Cooperation and Development, OECD countries[7]. While growth in agricultural production was viewed almost as an essential precondition for growth in the rest of the economy, the process(es) by which agricultural productivity was increased did not come under much scrutiny from policy-makers, agricultural researchers and scientists, development practitioners or even environmentalists at the time [8].

Renewable energy can address many concerns related to fossil energy use. It produces little or no environmental emissions and does not rely on imported fuels. Renewable resources are not finite (as fossil fuels are) and many are available throughout the country.

1.1.1 Hydropower

Worldwide, hydropower is the most widely used renewable energy resource due to its significant advantages over other renewable resources: It has high energy density, low cost and reliability in particular. Hydropower plants are available from very small sizes of only few Kilowatts (kW) to multi-Gig watts (GW). Small hydropower plants, generally in kW range, are used for rural electrification in many countries and have high potential to be integrated into the agriculture value chain in those locations. Hydroelectric power comes from the natural flow of water. Hydro-power equipment harvests kinetic energy from moving water to produce mechanical power and to generate electricity. The energy is produced by the fall of water turning the blades of a turbine. The turbine is connected to a generator that converts the energy into electricity. The amount of electricity a system can produce depends on the quantity of water passing through a turbine (the volume of water flow) and the height from which the water ‘falls’ (head). The greater the flow and the head, the more electricity produced. Hydropower is a clean, domestic, and renewable source of energy. It provides inexpensive electricity and produces no pollution. Unlike fossil fuels, hydropower does not destroy water during the production of electricity. Hydropower is the only renewable source of energy that can replace fossil fuels' electricity production while satisfying growing energy needs.

Hydroelectric systems vary in size and application. Micro-hydroelectric plants are the smallest types of hydroelectric systems. They can generate between 1 kW and 1 MW of power and are ideal for powering smaller services such as processing machines, small farms, and communities. Farms often have easy access to lakes and ponds as well as naturally occurring streams and rivers.

1.1.1.1 Water use for irrigation

Agriculture is by far the largest water use at global level. Irrigation of agricultural lands accounted for 70% of the water used worldwide. In several developing countries, irrigation represents up to 95% of all water uses, and plays a major role in food production and food security.[8] Water used for agriculture comes from natural or other alternative sources. Natural sources include rainwater and surface water (lakes and rivers). These resources must be used in a sustainable way. Rain water resources rely on the atmospheric conditions of the area. Surface water is a limited resource and normally requires the construction of dams and reservoirs with a significant environmental impact.

Alternative sources of irrigation water are the reuse of municipal wastewater and drainage water.

1.1.2 Solar

Solar energy is one of the renewable energy resources widely used in the agriculture sector for various applications [9]. Sunlight is a renewable resource, and its most direct use is achieved by capturing the sun's energy. A variety of solar energy technologies are used to convert the sun's energy and light into heat: illumination, hot water, electricity and cooling systems for businesses and industry. Widespread use of solar energy for domestic, agricultural and agro-industrial activities has been practiced almost since the development of civilization. Increasing threat of acute shortage of the commercial sources of energy coupled with serious environmental pollution problems has accelerated interest in the scientific exploitation of renewable sources of energy. For many agriculture needs, the alternative is solar energy. Solar technologies produce electrical or thermal energy. Photovoltaic (PV) cells (or "solar cells") that convert sunlight directly into electricity are made of semiconductors such as crystalline silicon or various thin-film materials. Solar thermal technologies collect heat from the sun and then use it directly for space and water heating or convert it to electricity through conventional steam cycles, heat engines, or other generating technologies (concentrating solar systems). Electrical conductors attached to the positive and negative sides of the material allow the electrons to be captured in the form of a direct current. This electricity can then be used to power a load, such as a water pump, or it can be stored in a battery. It is a simple fact that photovoltaic modules produce electricity only when the sun is shining, so some form of energy storage is necessary to operate systems at night. Photovoltaic systems are very economical in providing electricity in remote locations on farms, ranches, orchards and other agricultural operations. PV systems can be much cheaper than installing power lines and step-down transformers in applications such as electric fencing, area or building lighting, and water pumping either for livestock watering or crop irrigation. In fact, water pumping is one of the simplest and most appropriate uses for photovoltaic. From crop irrigation to stock watering to domestic uses, photovoltaic-powered pumping systems meet a broad range of water needs. Most of these systems have the added advantage of storing water for use when the sun is not shining, eliminating the need for batteries, enhancing simplicity and reducing overall system costs. Powering electric fans for air circulation is another application of photovoltaic. Modern pig and poultry farms double and even triple production by raising the animals in enclosed buildings. Another good use of photovoltaic is for lighting in agricultural buildings and enclosures. Other solar applications include greenhouse heating and solar crop drying. Modern, well-designed, simple-to-maintain solar systems can provide the energy that is needed at the given location and for the given time period. These are systems that have been tested and proven around the world to be cost-effective and reliable, and they are already raising levels of agricultural productivity worldwide [10]. The advantages of solar energy applications are as follows: no fuel, low running costs; long life, reliability, low maintenance, clean energy, avoids greenhouse gas emissions.

1.1.3 Wind Energy

A renewable energy source such as wind energy can also be used in agriculture. Small wind systems can provide power that can be used directly or stored in batteries. Wind technologies provide mechanical and electrical energy. Wind turbines operate on a simple principle: Wind turns rotor blades, which drive an electric generator, turning the kinetic energy of the wind into electrical energy. Turbines are often grouped into wind farms, which provide bulk power to the electrical grid. Wind turbine has significant benefit in the areas where there is a shorter rainy season and hence demand for pumped water. After installing wind turbine water pumps in a farm, one can raise higher value crops throughout the year and also supply water to the livestock. There is the requirement of appropriate training for the local farmers to use wind turbine based water pump irrigation. At present, mostly fossil fuel powered water pumps are used in the farms. However, very few wind-powered water pumps are installed in the world, e.g. a wind turbine water pump in Nigeria in Goronyo in Katsina State, Kedada in Bauchi State and in Sokoto State. Presently, a 5 kW pilot wind turbine/generator is installed in Sayya Gidan- Gada village in Sokoto State, Nigeria. Other applications of wind power using water pumps are: domestic water supply, water supply for livestock, drainage, salt ponds and fish farms [3]. Wind power technology is already in widespread use due to substantial progress in reducing costs for areas with consistently high wind speeds. Small wind systems can serve agriculture in traditional ways, such as using mechanical energy to pump water or grind grain. Decentralized wind systems can be combined with other energy sources to create a hybrid energy system, where the low cost and intermittent wind resource is supplemented by more expensive small generators such as diesel generators or batteries, to provide power that is both relatively inexpensive and reliable [10]. As technological improvements continue to increase the economic efficiency of wind energy, agricultural producers are likely to increase their use of wind power to lower energy costs and become more energy self-sufficient.

1.1.4 Geothermal

Geothermal energy is derived from the heat of the earth. This heat can be sourced close to the surface or from heated rock and reservoirs of hot water miles beneath our feet.

Geothermal technologies produce electrical or thermal energy. The heat from geothermal energy can also be utilized directly. Geothermal fluids can be used for such purposes as heating buildings, growing plants in greenhouses, dehydrating onions and garlic, heating water for fish farming, and pasteurizing milk. Generally, low-to-medium temperature resources (between 70°F and 300°F) are used. Another technology, geothermal heat pumps, can provide space heating and cooling. This technology does not require a hydrothermal (hot water) resource, but instead uses the near-surface ground as a heat source during the heating season and as a heat sink during the cooling season. The geothermal resource base for low-to-medium temperatures is much more plentiful and widespread than the high-temperature resource base. Low-and medium-temperature geothermal resources exist throughout the western United States. Geothermal energy has many agricultural applications. Vegetables, flowers, ornamentals, and tree seedlings are raised in 43 greenhouse operations heated by geothermal energy. Forty-nine geothermal aquaculture operations raise catfish, tilapia, shrimp, alligators, tropical fish, and other aquatic species. Agric-industrial applications include food dehydration, grain drying, and mushroom culture. The drying of onions and garlic is the largest industrial use of geothermal energy [11]. Ground source heat pumps can be applied in most rural areas. In the future, new technologies such as enhanced geothermal systems (EGS) promise to reduce the cost of geothermal power. These can be developed by fracturing rock to increase underground fluid flow and permit heat extraction. Projects underway in Europe and Australia are advancing knowledge on how to use EGS for power production.

1.1.5 Biomass

Biorenewable resources, sometimes referred to as biomass, are organic materials of recent biological origin [12] as cited in [13]. Biomass is organic matter produced by plants, both terrestrial (those grown on land) and aquatic (those grown in water) and their derivatives

[14]. It includes forest crops and residues, crops grown especially for their energy content on "energy farms," and animal manure [15]. It is considered a renewable energy source because plant life renews and adds to itself every year. Biomass also includes wood waste and baggase, and can be converted to liquid or gaseous fuels, thereby increasing its energy density and making feasible transportation over long distances. Biorenewable resources are generally classified as either wastes or dedicated energy crops. A waste is a material that has been traditionally discarded because it has no apparent value or represents a nuisance or even a pollutant to the local environment. Dedicated energy crops are plants grown specifically for production of bio-based products i.e. for purposes other than food or feed. The process of new technologies to extract energy and other valuable products from biomass resources is termed "biorefinery." Like oil refineries, biorefineries are envisioned as industrial facilities that convert a stream of raw material into a varied slate of products, maximizing value by shifting the mix of output to match dynamic market conditions. Potential biorefinery products include liquid fuels, such as ethanol and biodiesel, electricity, steam, and high-value chemicals and materials. Many of these products have the potential to replace petroleum, either as a vehicle fuel or as a chemical feedstock, resulting in increased energy security and reduced environmental emissions. In a sense, biorefineries already exist. They process corn into ethanol, corn syrup, animal feed, and other products, or transform trees into a variety of wood products, electricity, and heat, to name two examples. Biorefineries, researchers are developing processes for exploiting the large amount of energy contained in plant cellulose — a difficult but potentially rewarding goal. In one biochemical process (referred to as the sugar platform), enzymes are used to break apart cellulose molecules, creating sugars that can be fermented into ethanol or processed further to create industrial and consumer products. A thermochemical process involves heating biomass to turn it into a gas composed of a few basic molecules, then processing this raw material into fuels and products through chemical or biological techniques. Researchers are also pursuing ways of turning biomass resources into useful products by using advances in plant genetics and biochemistry to develop crops designed for specific biorefinery end products.

An example of a product made with biorefinery technology is Toyota Motor Corporation's bioplastics, used to make automobile components. Already used in the Toyota Raum (sold in Japan), this plastic is made from sweet potatoes and other plants. Another example is DuPont's Sorona, a family of polymers made from 1, 3-propanediol (PDO) that can be used in fabrics, plastics, and in other applications. PDO can be made from sugars derived from corn. The United States has significant biomass resources. It has been estimated that the cellulose available from just forest land and agricultural land, the two largest potential biomass sources, could amount to 1.3 billion dry tons per year. While this quantity is six times greater than current production, researchers believe that it could be achieved with relatively modest changes in land use and agricultural and forestry practices [16]. Another biomass resource with significant potential is municipal solid waste, a byproduct of modern life.

2.0 Material and Method

2.1 Source of Data

The data used for analysis in this paper was an eight year period (2010- 2017) extract from International Renewable Energy Agency (IREA) Renewable Capacity Statistics report 2018. The figures extracted were - renewable energy sources such as hydropower, wind, solar, geothermal, biomass (bionergy and bagasse) as shown in Tables 1, 2 and 3. The data so extracted were analyzed using SCILAB software code,[17] to determine each of the renewable energy contribution to the global energy generation capacity.

2.2 Model Equations

The model equation for the computation of the difference in annual percentage for each renewable energy resource is given by equation 2.1.

$$y_i = \frac{x_2 - x_1}{x_1} \times 100 \qquad (2.1)$$

Where y_i is the annual percentage contribution of each of the renewable energy resource $x_2 - x_1$ is the difference between the base year and the succeeding year and x_1 is base year.

The average annual percentage for each of the renewable energy resource is given as equation 2.2.

$$y = \frac{\sum y_i}{n} \qquad (2.2)$$

Where y is the average annual percentage contribution of each of the energy resource, $\sum y_i$ is the summation of annual percentage contribution within the period and n is the number of years. The result of the average annual percentage contribution of each of the renewable energy resource is shown in Table 4. The model equation for the percentage contribution (z %) of a particular renewable energy resource to the total renewable energy resource in a particular year is given by equation 2.3.

$$z = \frac{x}{x_{total}} \times 100 \qquad (2.3)$$

z is the percentage contribution of a particular energy resource to the total renewable energy resource, x is the quantity of renewable energy resource generated in a particular year and x_{total} is contributions of the energy resource in a particular year. The result of the percentage contribution of all the renewable energy resources considered in this work for the World generation capacity (2010- 2017) is shown in Table 5, and Figure 4 is the pie chart of the energy resource allocation for the year 2017.

3.0 Result and Discussion

The Tables (1, 2 and 3) containing data on renewable energy resources capacity statistics (2010 – 2017) for some renewable energy resources (hydro, wind, solar, bioenergy, geothermal and bagasse) for the World, Africa and Nigeria were analyzed using SCILAB software code,[17] .and the result summarized in Figures 1, 2 and 3. In table 1 and figure 1, the world generation capacity of hydro energy resource increased from 1 028 901 MW in the year "2010" to 1270496 MW in "2017" representing average annual percentage increase of 3.06 % for the years under consideration. The wind energy resource generation capacity rose from 180 719MW in "2010" to 513939MW in the year "2017" indicating average annual percentage increase of 16.20%. For the solar renewable energy resource, the generation capacity in "2010" was 39 844 MW and increased to 390625MW in "2017" representing 39.37 average annual percentage increase. The biomass (bioenergy and bagasse) energy resource which was 66 462MW and 10419 MW respectively in "2010" rose to 10913MW and 17941 MW in "2017" indicating average yearly percentage increase of 7.36 % and 8.14% respectively. Also, the geothermal energy resource capacity in "2010" was 10118 MW and rose to 12894MW in "2017" indicating average annual percentage increase of 3.55%. Similarly, for the Africa renewable energy statistics, the average annual percentage increase of hydro, wind, solar, biomass and geothermal energy resources from 2010 to 2017 were 4.13%, 27.20%, 48.04%, 7.84%, 22.78% and 7.55% respectively as shown in table 4. Also, the Nigeria renewable energy resource statistics as contained in the International Renewable Energy Agency (IREA) 2018 statistical report indicate that the Nigeria hydro energy resource was 1941MW in 2010 and 2011 and increased to 2042MW in 2012 and remained constant throughout the period indicating zero percent average annual increment. The wind renewable energy resource for Nigeria from the report was constant at 2 MW for 2010, 2011, 2012 and 2013 periods; it increased to 3 MW in 2014 and remained constant throughout the period under review with average annual zero percent. There was zero solar energy resource generation capacity for 2010 and 2011; 15 MW generation capacity for 2012 and 2013; 16MW, 17MW, 18MW and 19MW for 2014, 2015, 2016 and 2017 respectively with 3.48% average annual percent increment. The report had no information on other renewable energy sources such as biomass and geothermal. The percentage contribution of all the renewable energy resources considered in this work for the World generation capacity (2010- 2017) is shown in table 5, and the pie chart for 2017 shown in figure 4.

Conclusion

The management of energy consumption in agriculture is a worldwide concern because of the adverse effects of CO2 emissions from fossil fuels, which are generally used as an energy source for various applications in agriculture such as water heating, irrigation and so on.

Sustainable agricultural system is based on the prudent use of renewable and/or recyclable resource capable of maintaining its productivity and usefulness to society indefinitely. Such an agriculture must use farming systems that conserve resources, protect the environment, produce efficiently, compete commercially and enhance the quality of life for farmers and society overall. Renewable energy technologies are promoted in many parts of the world for various agriculture applications for mitigating CO2 emissions associated with fossil fuels. In comparison to non-renewable energy resources such as fossil fuels, renewable energy resources are clean form of energy with little or no environmental pollution. From the study, the hydro power renewable energy resource is most significant used resource owing to its abundance and low cost.

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Table 1: Extract of World Renewable Energy generation statistics (2010- 2017)

CAP(MW)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Hydro	1 028 901	1 059 551	1092 567	1137 079	1 175 437	1210225	1 248 048	1270496
Wind	180 719	220 013	269 642	301 551	349 188	416798	467227	513939
Solar	39 844	70 495	98 423	137 102	174 361	224345	296873	390625
Bionergy	66 462	72 601	78 382	85 001	90 356	96488	104274	109213
Geothermal	10 118	10 008	10 468	10 736	11 192	11789	12249	12894
Bagasse	10 419	11 537	12 649	14 450	15 498	16 837	17 600	17 941
Total	1336463	1444205	1562131	1685919	1816032	1976482	2146271	2315108

Source: *IREA Statistics 2018*

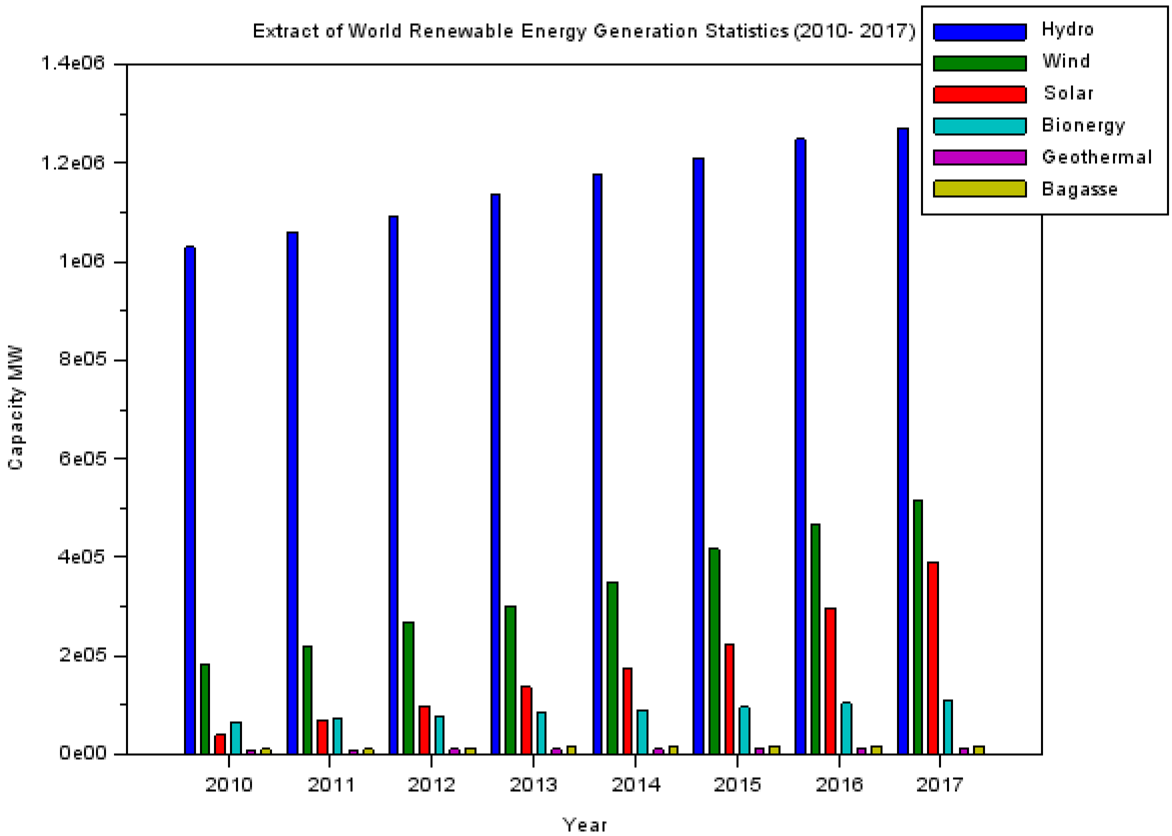

Figure 1: Extract of World Renewable Energy Generation Statistics(2010 -2017)

Table 2: Extract of Africa Renewable Energy generation statistics (2010- 2017)

CAP(MW)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Hydro	26 680	26 691	27 528	28 701	28 816	29155	33076	35195
Wind	894	1 035	1 157	1 772	2 432	3353	3864	4611
Solar	271	404	480	754	1 687	1986	2930	3585
Bionergy	753	847	971	1 063	1 221	1254	1259	1263
Geothermal	198	198	206	206	366	619	663	673
Bagasse	718	796	914	1 005	1 160	117 8	1 181	1 181
Total	29514	29971	31256	33501	35682	37545	42973	46508

Source : ***IREA Statistics 2018***

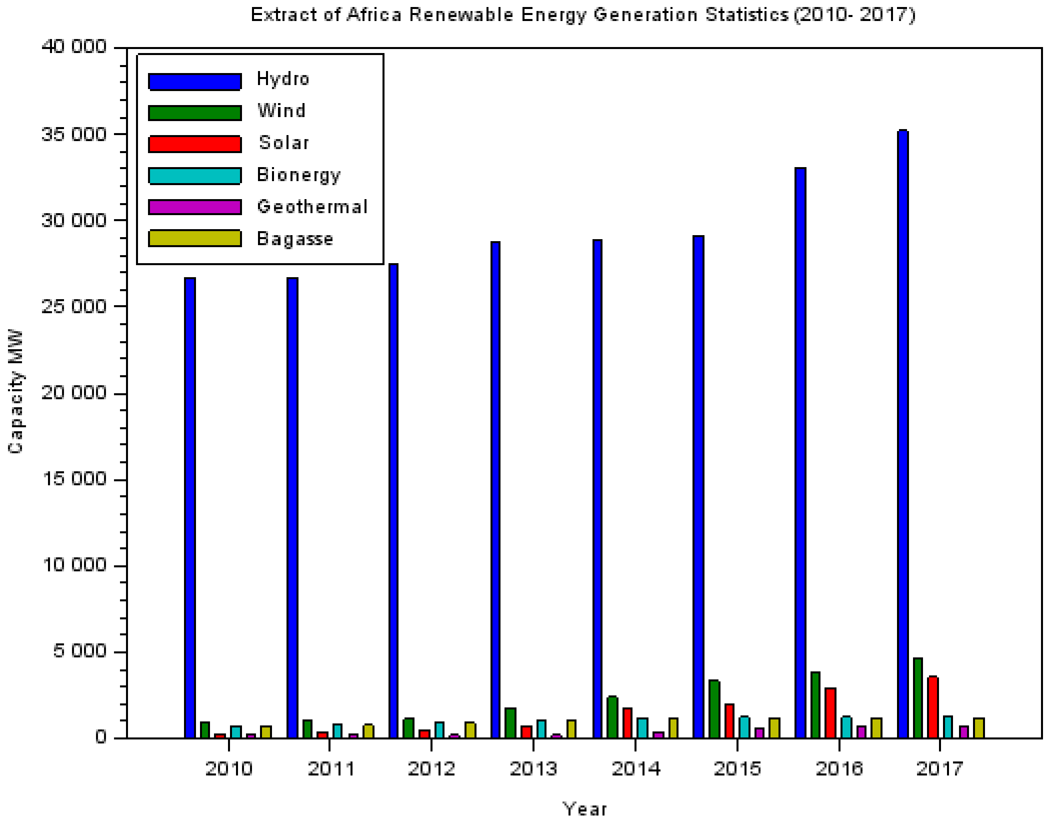

Figure 2: Extract of Africa Renewable Energy Generation Statistics(2010 -2017)

Table 3: Extract of Nigeria Renewable Energy generation statistics (2015- 2017)

CAP(MW)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Hydro	1941	1941	2 042	2 042	2 042	2042	2042	2042
Wind	2	2	2	2	3	3	3	3
Solar	0	0	15	15	16	17	18	19
Bionergy	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-
Bagasse	-	-	-	-	-	-	-	-
Total	1943	1943	2059	2059	2061	2062	2063	2064

Source : *IREA Statistics 2018*

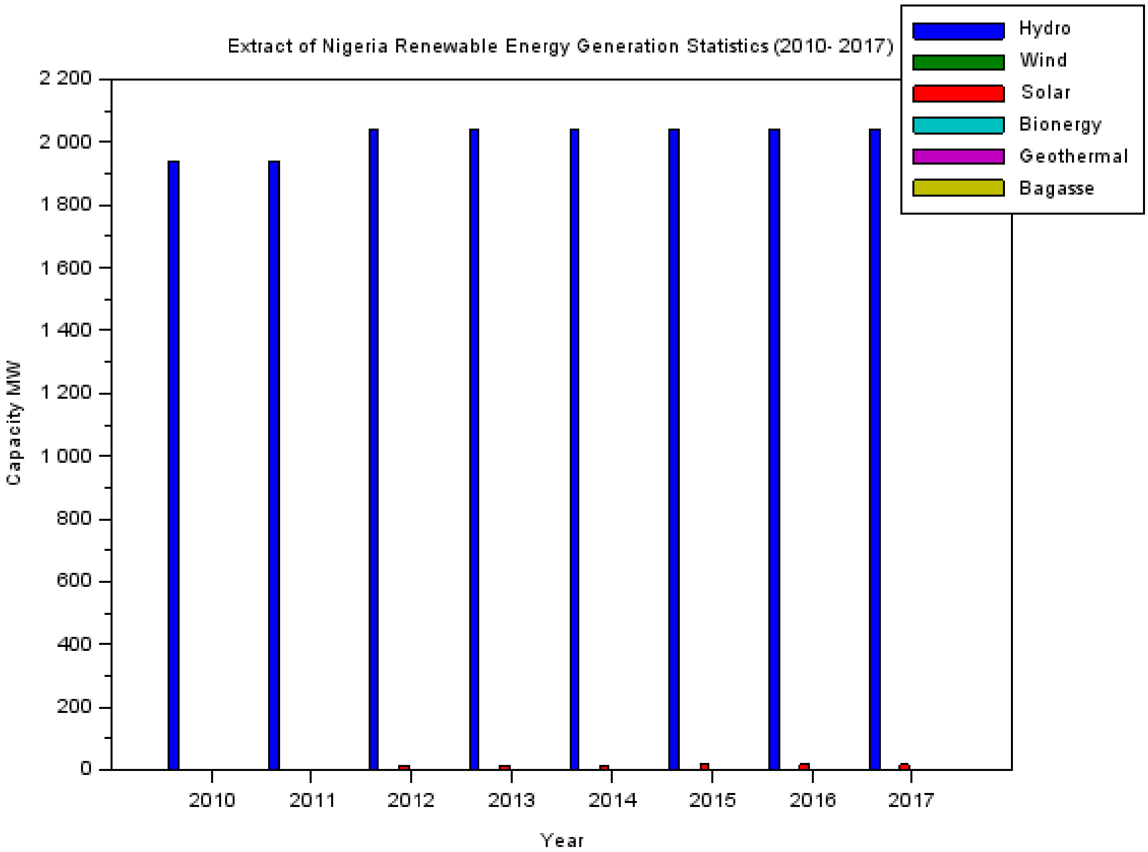

Figure 3: Extract of Nigeria Renewable Energy Generation Statistics(2010 -2017)

Table 4 : Renewable Energy Resource Average Percentage Yearly Increment (2010 – 2017)

World Renewable Energy Resource Average Annual Percentage						
Energy Resource	**Hydro**	**Wind**	**Solar**	**Bioenergy**	**Geothermal**	**Bagasse**
Average Annual percentage increment(%)	3.06	16.20	39.37	7.36	3.55	8.14
Africa Renewable Energy Resource Average Annual Percentage						
Energy Resource	**Hydro**	**Wind**	**Solar**	**Bioenergy**	**Geothermal**	**Bagasse**

Average Annual percentage increment(%)	4.13	27.20	48.04	7.84	22.78	7.55
Nigeria Renewable Energy Resource Average Annual Percentage						
Energy Resource	**Hydro**	**Wind**	**Solar**	**Bioenergy**	**Geothermal**	**Bagasse**
Average Annual percentage increment(%)	0	0	3.48	-	-	-

Table 5 : The percentage contribution of all the renewable energy resources considered in this work for the World generation capacity(2010- 2017)

Renewable Energy Resource	**Annual Percentage Contribution**							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Hydro	76.99	73.37	69.44	67.45	64.73	61.23	58.15	54.88
Wind	13.52	15.23	17.26	17.89	19.23	21.09	21.77	22.20
Solar	2.98	4.88	6.30	8.13	9.60	11.35	13.83	16.87
Bioenergy	4.97	5.03	5.02	5.04	4.98	4.88	4.86	4.72
Geothermal	0.76	0.69	0.67	0.64	0.61	0.60	0.57	0.56
Bagasse	0.78	0.80	0.81	0.85	0.85	0.85	0.82	0.77

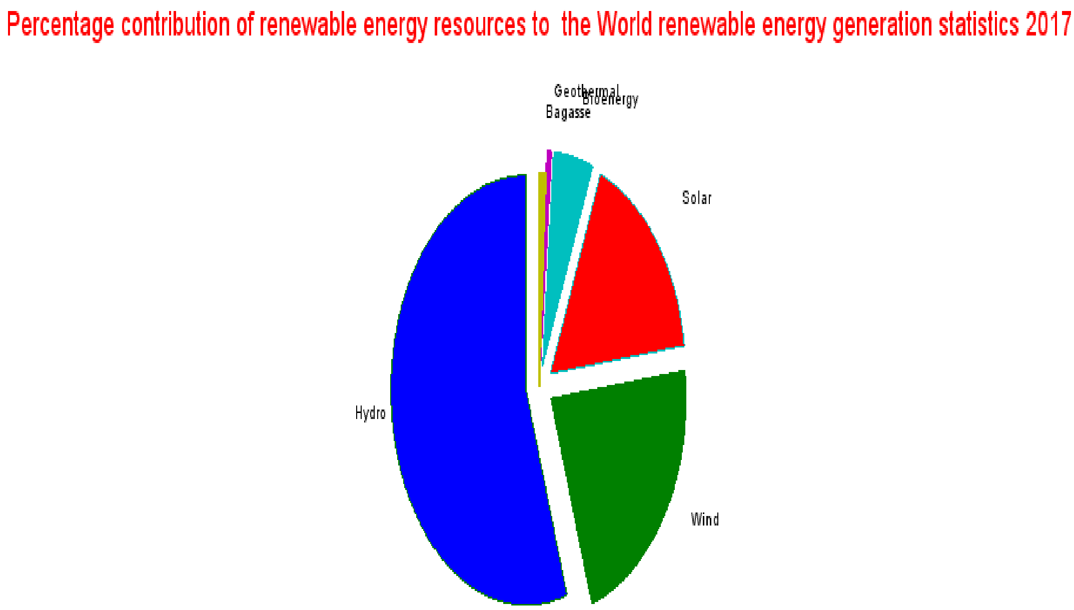

Figure 4: Percentage contribution of renewable energy resources for 2017

DESIGN AND CONSTRUCTION OF ELECTRIC WOODEN BROODER FOR SMALL SCALE FARMS IN IMO STATE

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ABSTRACT

Remote causes of high mortality remains a great concern in the agricultural sector. Construction with quality materials such as bottom and top rails with ends and plywood cutting materials with top and short side walls were used for small scale electric wooden brooder for poultry farming, which could enhance the rural poultry farmers' net profit and encourage poultry farming in Nigeria. A minimum of 25 to 40 lux (2.5-4ft candles) lighting, average maintained illumination E_{wp} 1500 lumen and light loss factor LLF of 1, produced 651.58 candela (cd) between 7 to 10 days of age. The brooding capacity or bird population considering 95cm^2/ bird space, 4.1 feeder ratio, 8890.30, 541.936 and 433.79cm^2 of brooding box (A), feeder (A_f) and drinker (A_d) areas respectively, had 60 to 62 birds. Inadequate environment during brooding periods might reduce profitability, Incidence of stunted growth and development, poor feed conversion, disease infestation and mortality.

Keywords: Wooden brooder, E_{wp}, LLF, Bird population and Net Profit

INTRODUCTION

Family poultry keeping by household is a process which involves rearing of birds by the rural poultry farmers to produce meat or egg. The poultry may range freely in the household compound and find much of their own food, getting supplementary amount from the house-holder. Participant at a workshop in Ile-Ife, Nigeria, defined rural poultry as a flock of less than 100 birds of unimproved or improved breeds, raised in either extensive or intensive family, (Sonaiya, 2000). Family poultry is rarely the sole means of livelihood for the family but is one of a number of integrated and complementary family activities contributing to the overall well-being of the household. Poultry constitutes a major income generating activity from the sale of birds and eggs. Occasional consumption provides a valuable source of protein in the diet. Poultry also plays an important socio-cultural role in many societies. Poultry keeping is traditionally the role of women in many developing countries such as Nigeria. In sub-Saharan African, 85 percent of all households keep poultry, with women owning 70 percent of all households. Income generation is the primary goal of family poultry keeping. Eggs can provide a regular, albeit small, income while the sale of live birds provides a more flexible source of cash, e.g. the Dominican Republic, where family poultry contributes 13 percent of the income from animal production, (Raven et al.,1990; Gueyo, 1998; Branckert, 2013).

Food and Agricultural Organization of United Nations (FAO, 2010), Sonaiya and Swan (2010), recognized the important contributions of poultry in poverty alleviation program on small-scale and low input family based poultry production.

The product of poultry farming is a good source of protein and it is also a source of income for business opportunity and entrepreneurship that aids poverty alleviation in the lives of rural dwellers. According to FAO (2013), small-scale poultry farming activity has been experiencing high mortality rate at the brooding stage of chicks ranging from a day old to three weeks old due to predators, thieves, harsh weather conditions and diseases which bring about a decrease in protein consumption and income. These necessitated the importance of designing and construction of an electric brooder, of 40 birds' capacity for the small-scale poultry farming in Imo State and Nigeria. Failure to provide adequate environment during the brooding period will reduce profitability resulting to stunted growth, poorer feed conversion, increased disease infestation and mortality, (Alemu, 1995).

Brooding period is a period from hatching until the chickens no longer require supplementary heat. During this period the chickens need warmth, shelter, fresh air, proper food and clean water. Therefore, maintaining the correct temperature is crucial in chick brooding, especially during the first seven to ten days of the chick's life. Early in life, the chick is poorly equipped to regulate its metabolic processes to adequately control its body temperature. As a result, the young chicks are dependent on environmental temperature to maintain optimal body temperature. If the room temperature decreases, the Chicks body temperature will decrease and vice versa, (Awudu et al., 2011).

Chilling or overheating during the crucial period can result in poor growth, poor feed conversion and increased susceptibility to disease. Proper brooding practices must maintain the chick body temperature so that it does not have to use energy to loose heat by panting or generate heat through metabolism.

Research has shown that the chick develops the ability to regulate its body temperature around 12 to 14 days of age. The chick can be easily stressed if its body temperature decreases or increases by as much as one degree. Once the body temperature changes, the bird will try to compensate it and in most cases will have negative effects on performance.

Extreme temperatures (high or low) often result in chick mortality, but even mild chilling or overheating can cause poor growth of chicks without causing death. While chicks are more tolerant of high temperature than adult birds, high temperatures for extended periods of time increase mortality and have negative impact on performances. As a result, cold stressed chicks have reduced growth and increase susceptibility to diseases, higher incidence of ascents that is a metabolic disorder that results in reduced performance, increased mortality and contamination at the processing plant or researching machine. In research studies where groups of chicks were brooded at either 26.67 or 32.22˚C (80 or 90˚F), the chicks reared under the warmer temperature had better weight gains, feed conversion and livability, (May and Lott, 2012). Temperatures are preferred as a guide, because the best way to adjust the temperature for the comfort of the chicks is to observe their behaviour, if they crowd near the heat source and chirp loudly, the temperature is too low, if they move well away from the heat source and start panting, they are too hot. Ideally, they should be fairly quiet and spaced evenly under and around the heat source. During brooding, good observation skills and routine attention are essential to ensure bird growth, health and low mortality, (Czarick and Fairchild, 2001).

One of the goals during brooding is to maintain chick within their comfort zone, which is where they are not using energy to gain or lose heat to maintain body temperature. When birds are kept in environmental temperature above or below their comfort zone, more energy must be expended to maintain body temperature. The extra energy will ultimately be supplied by the feed consumed. Therefore, the energy from the feed will be used to maintain body temperature instead of growth and development resulting in poorer feed conversion, (Czarick and Lacy, 2000). Thus the environmental temperature plays a major role in determining the cost of producing a kilogram (weight) of meat or pullet. Proper brooding not only consists of maintaining proper temperature but also the use of good husbandry practice.

Brooding temperature will vary, depending on whether the heat source is air furnace, conventional or radiant. When brooding chicks, floor temperature is crucial, that average floor temperature should be 90˚F (32.22˚C) on the day that chicks are placed in the house. Forced air furnace requires higher temperature setting for air and floor heat conduction. A conventional pancake brooder directs approximately 40% of its heat to the floor and 60% to the air, while radiant brooder projects approximately 90% of their heat to the floor and 10% to the air temperature. In commercial broiler grazing operations, broiler houses are equipped with mechanical ventilation systems insulated to maintain house temperature within 50% of the desired temperature regardless of external temperature, (Czarick, 2001).

Relative humidity which is the ability of air to hold moisture, depends upon its temperature and the percentage of water saturation of air at any given temperature. The level of humidity influences the ability of the bird to cool itself through panting and influences ammonia production, due to the microbiological breakdown of feacal material in the litter. Increased relative humidity improves environmental conditions for microbial growth in the litter. As the microbial population increases, more ammonia is generated from nitrogen sources found in bird faecal material, while ammonia exhibits negative impact on bird health and performance. According to Carlile (2010), research shows that increased ammonia impairs the immune system and increase respiratory disease in birds. High ammonia levels during brooding reduce growth rate, which could not be gained back during the remaining days of their growth. A relative humidity level of 50 to 70% is recommended to minimize ammonia production and dust.

Furthermore, ventilation regulates temperature and removes carbon dioxide, ammonia, greenhouse gases, moisture, dust and odour. If the mixing of the inlet opens too much or speed of the air entering through the inlet is too low, then the cool air will fall on the floor more quickly. Not only will this cause a problem of bird chilling, but can create cool spots on the walls and floor. These wet spot can lead to increased litter caking as well as more ammonia production. Circulating fans can be used to equalize temperature stratification and maintain uniformity throughout the poultry house. The conveying warmer air not only helps maintain bird body and floor temperatures, but removes moisture from the litter, (Czarick, 2001; Czarick and Fairchild 2004).

Lighting during brooding is an important factor that cannot be ignored. Light systems should be designed to produce a minimum of 25 lux (2.5 ft candles) or more at bird level. Many broiler houses being built today are more at bird level and capable of providing up to 40 lux (4 ft candles) at chick level in the brood area.

2.0 DESIGN AND CONSTRUCTION

The parameters used to determine the efficiency of the brooding box were: death rate at various stages, weight gain, growth rate and unexpected stunted growth of chicks at their tender age. Care was taken to recondition the environment in order to maintain low mortality rate.

The brooding box was tested using two different species of chicks, broiler and pullet within the ages of 1 to 21 days, administration of necessary vaccinations on its arrival and proper balanced diet. The brooding box design had an advantage as it is portable, less expensive, and affordable. It provides optimum environment and attack of rats and snakes, which is one of the preventive measures against chicks brooding. Bird (chick) is one of the most important vertebrates on earth, its meal is a good source of protein to human being, its droppings are very useful as an organic fertilizer, animal and fish feed and raw material for methane gas generation in biogas plants.

2.1 Materials and Methods

The area of study (Imo State) lies within latitude $4°45'01''N$ $7°15'01''N$ and longitude $6°50'01''E$ with ground area of $5{,}100$ km^2 bordered by Abia, Anambra and Rivers States.

2.1.1 Materials/tools procurement

2.54 x 5.08 x $91.44(cm)$ Galvanized wire mesh; $1\mathrm{m}^2$mosquitoes net; 4 pcs electric lamp (incandescent bulbs); 4 Lamp holder; 1 plug; $11m$ electric wire; 3-way and a single control switches; 1 junction box; 1 pkt clip and one inch nail; 4pcs $2.54 \times 6.35 \times 365.76(\mathrm{cm})$wood;

5pcs $2.54 \times 5.08 \times 365.78(\mathrm{cm})\mathrm{wood}$; $2pcs\ 1.905 \times 121.92 \times 243.84(\mathrm{cm})\mathrm{plywood}$; $2.54\mathrm{cm}$ wood joiners; 2 pd weight; Draw key 2 pcs draw key; 4 pcs of roller; $30\mathrm{cm} \times 9\mathrm{cm}$ sand paper (rough and smooth); $1\ t$in solo-gum spray; medium cup of bond gum; and 4 pcs of $91.44 \times 365.76(\mathrm{cm})\mathrm{feeders}$. The tools include: 5m measuring tape; square 25.4cm; jack plane; work bench; chisel; pliers; hammer; bar; spoon shave; saw; pinches; and G-cramp.

Methods/design procedure

The brooder was designed in rectangular shape and the area was determined using S.I units of cm^2, m^2, or mm^2

$$A = L \times W \qquad 2.1$$

Where: A = Area of the brooder = (180.44 x 49.27cm) = 8890.30 cm^2

L = Length of the brooder = (180.44cm)

W = Width of the brooder = (49.27cm)

2.1.3 Light level at a point

For planes perpendicular to the direction of candle power (inverse square law)

$$\text{Foot candles (Fc)} = l/D^2 \qquad (2.2)$$

Where: l = candle power in candelas (cd)

D = direct distance between the lamp and light level.

Many work planes (animal height) are not perpendicular to the direction of light intensity, therefore calculating light level at a point becomes useful for such applications to light levels on animal height not horizontal, perpendicular, titled, or even vertical are described in the following equation:

$$\text{Horizontal foot candles } (f_{ch}) = 1/D^2H \qquad (2.3)$$

$$\text{Vertical foot candles } (f_{cv}) = 1/D^2L \qquad (2.4)$$

Where: 1 = candle power in candelas (cd)

D = direct distance between the lamp and the light level i.e. $H^2 + L^2$

H = Distance between the calculated point and light level

Alternatively, applying illumination law or inverse square law by Rea (2005), which states that illumination is the intensity of light in a unit area or flux received in a unit area surface i.e.

$$E \quad \alpha \quad 1/D^2 \qquad (2.5)$$

where E = Illumination; D = Distance between light source; and 1= Constant

2.1.4 Average maintained illumination E_{wp}

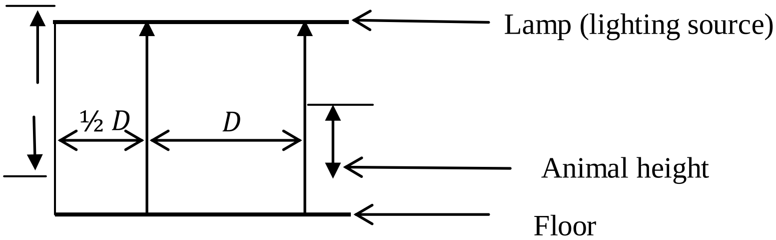


Figure 2.1: Lumen method of E_{wp} derivation

Average maintained illumination E_{wp} for candled power using lumen method Figure 2.1 becomes;

$$E_{wp.} = \frac{\text{ILL x Cu x LLF}}{.A_{wp}} \qquad (2.6)$$

and average maintained illumination (ft candela) becomes;

$$= \frac{\text{Total no.of lamps x lumen x light loss factor}}{\text{Area in square (ft}^2)} \qquad (2.7)$$

where: ILL = Total Initial lamp, Lumens

Cu = Coefficient of utilization

LLF = Light Loss factor

A_{wp} = Area of animal or work plane (ft^2)

E_{wp} = Average maintained Illumination or ft candles

Given an A_{wp} of 6.90627 ft^2 with 3 total number of lamps, 1500 lumens and LLF of 1. To show an average maintained illumination (E_{wp}), applying Equation (2.7) and noting that 1500 lumens = 100W will give:

$$(E_{wp}) = \frac{\text{Total no of lamps x lumen x light loss factor}}{\text{Area (ft}^2)}$$

$$E_{wp} = \frac{3 \times 1500 \times 1}{6.90627}$$

$$= 651.58\text{cd}$$

2.1.5 Spacing of the Lighting Sources

This is shown in Figure 2.2, where a and a_1 is half of b and w respectively.

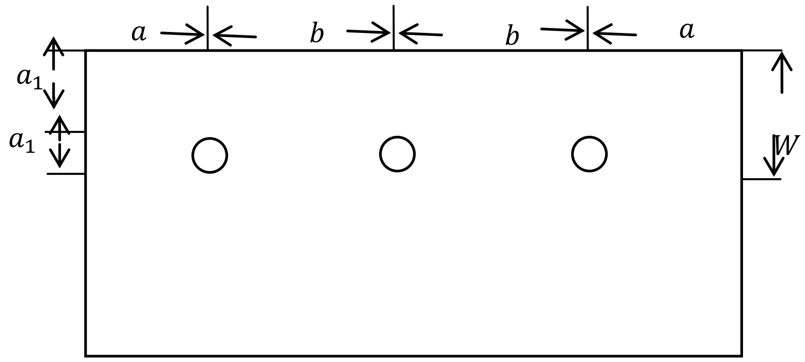


Figure 2.2: Spacing of the lighting sources

a = Distance of lighting source from the wall in row

a_1 = Distance of lighting source from the wall in column

b = Distance between the two lighting sources

w = Width of brooding box.

2.1.6 Determination of the heat source.

The heat was introduced by electric lamp and wood shaving within the box and it was regulated with thermometer. Heat was majorly measured at the floor or animal base-level. If the heat tends higher than the body temperature of bird especially during the day, the source will be turned OFF to suit their body temperature and turned ON at nights to suit the heat needed within the brooder.

2.1.7 Determination of the brooding capacity (bird population)

The steps to be taken for the brooding capacity include:

(i) Determination of brooding area based on accurate internal measurement, using area $(A) = \text{L x W}$

(ii) Determination of feeder area i.e. four (4) pcs, one (1) feeder (4:1), i.e.

$$4 \times A = 4A$$

(iii) Determination of area of drinker (two pcs), $A = \pi r^2$; $\pi = 3.142$, $\text{r} = \text{radius}$, while for two drinkers $2 \times A = 2A$

The capacity of the brooder therefore is:

$\text{the internal area of the brooder} - (\text{area of feeder} + \text{sum of drinkers})$ i.e.

$$A - [(L \times W) + 2(\pi r^2)] \quad (2.8)$$

Thus, bird population in the brooding box is the remaining area of the brooder divided by area of each bird (chick) from 1 - 7 days old. Thus, the total number of birds in the brooding box (bird population) is calculated viz.

Area of the brooding box 'A'= $180.44 \times 49.27 = 8890.30\text{cm}^2$

Area of feeder (A_f) 60.96×8.59 = 541.936cm^2

Then for four (4) pcs of feeders = 4×A_f=4×541.934=2167.9cm^2

Area of drinker (A_d) =πr^2, $r = 11.75$, = 3.142×11.75^2=433.79cm^2

Therefore two (2) drinkers = $2 \times A_d = 2 \times 433.79cm^2 = 867.58cm^2$

From Equation (2.8) actual capacity of the brooding box is shown as:

8891.36 – (2167.94+867.03) = $5856.39cm^2$

Then the bird population in the brooding box, if each bird occupies about $95cm^2$ from 1-21 days, should be the remaining area divide by $95cm^2$

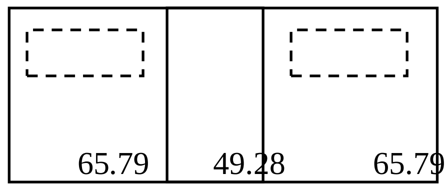
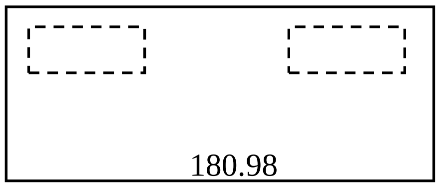
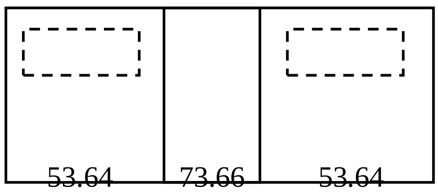
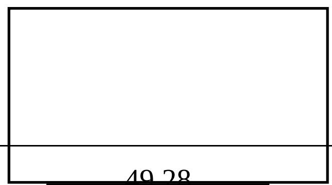
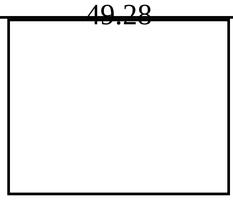
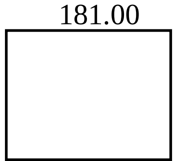
i.e.$5856.39/95$ = 60 to 62 birds

3.0 CONSTRUCTION PROCEDURES

Table 3.1: Cut list materials.

S/N	Quantity	item (cm)	Description
1	Top end and top bar		
i	2	2.54 x 6.33 x 180.44	Bottom rails
ii	4	2.54 x 6.35 x 49.28	Bottom ends
iii	4	2.54 x 6.35 x 56.39	Corner post
iv	8	2.54 x 6.35 x 56.39	Corner post
2	Post and door frame top		
i	4	2.54 x 6.35 x 56.39	Wall
ii	2	2.54 x 6.35 x 176.48	Top rail
3	Door frame		
i	2	2.54 x 5.08 x 38.60	Side door
4	Aperture frame (vent halls)		
i	8	2.54 x 5.08 x 54.86	Frame length
ii	8	2.54 x 5.08 x10.41	Frame width
5	Top door and screen frame		
i	5	2.54 x 5.08 x 46.48	Width
ii	4	2.54 x 5.08 x 74.17	Length
6	Small aperture		
i	2	2.54 x 8.89	Rubber clip

Table 3.2: Plywood cutting materials

S/N	Quantity	Type (cm)	Description
1.	1		Frontwall and kitchen door
2.	1		Back wall
3.	1		Bottom floor
4.	1		Top side
5.	1		Short sides wall
6.	1 1	 	Side door (kitchen door) Top door

7.

steps involved in assembling the electric brooder are shown in plate 3.1 (a -d)

(a)

(b)

(c)

(d)

Plate 3.1 (a and b): Construction materials in process using screens, frames and bar tops.

Plate 3.1 (c and d): Assembled brooding box with floor, galvanized wire mesh and vent.

4.0 RESULT AND DISCUSSION

The result of the technical detail of constructed electric brooder is shown in table 4.1

Table 4.1: Technically detailed electric brooder

S/No.	Parameters	Values
1.	Floor area of the brooder	8,891.36cm^2
2.	Area of one (1) feeder	541.93cm^2
3.	Area of four (4) feeders	2,167.72cm^2
4.	Area of one (1) drinker	433.52cm^2
5.	Capacity of the brooder (birds in population)	60-62 birds
6.	Illumination of the lighting source	695.02cd
7.	Height of the lighting source from the floor	42.42cm
8.	Thickness of the wood shave spread on the floor	0.3cm
9.	Lighting sources (100 watt bulbs)	3

The brooding box is used to regulate the behaviour of the chicks and create their conductive environment. The design parameters include the brooding box temperature which regulates the degree of hotness or coldness required to maintain adequate body temperature guaranteeing the survival of the chicks. If they crowd near the heat source and chirp loudly, the temperature is too low, if they move well away from the heat source and start panting, they are too hot. Normally, they should be fairly quiet and spaced evenly under and around the heat source.

According to Czarick and Fairchild (2001), during brooding, good observation skills and routine attention are essential to ensure bird growth, health and low mortality. Its temperature can be regulated periodically, using thermometer at six hours intervals to provide the mean ambient temperature 39° - 41°C. If the temperature is above the required temperature two or more lighting sources are turned OFF and vice versa according to the heat loss or gain. Lighting sources are connected in parallel with switches for independent control system. In addition, vent holes are positioned to ascertain cross ventilation within the brooder. Care should be taken to protect the brooder from theft confined in a porch.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the project design and construction of the electrically powered brooder, lower mortality rate of chicks was recorded compared to that of other boxes without conventional heat. In areas, where there is adequate source of electric supply, the electric brooding box can contribute immensely to the enhancement of poultry business.

However, further experiments should be carried out to determine the mortality rate of chicks during brooding; the equipment recorded a drastic reduction of about 90%, in mortality rate and chicks are healthy and very active which makes it a better option for farmers use. Also, the interior heat regulation needs less technical knowledge to operate as it entails turn ON or OFF, of lightening sources, when the mean temperature is exceeded.

5.3 Recommendation

Government should improve on public power supply which they have started by privatizing the electric power transmission and distribution companies, thus promulgating electricity regulatory laws and agencies. It is envisaged that, if power supply is made available to rural society at a constant rate, these will make the cost of acquiring the technology by rural farmers affordable and increases its acceptability among the farmers.

Government should assist rural poultry farmers with credit facilities to enable them acquire the technology. This is because majority of the rural poultry farmers are passant farmers with low purchasing power.

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COMMUNITY PARTICIPATION IN AGRICULTURAL SETTLEMENT PLANNING IN NIGERIA

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Abstract

Agricultural settlement refers to a planned community where agriculture and agro-related activities such as fishing, hunting and forestry are the predominant means of livelihood of the inhabitants. Although it was popular in Nigeria during the first republic and was indeed the main driver of the agricultural revolution of that period, most of them collapsed with the end of the Nigerian civil war. One of the reasons for the collapse may not be far from the fact that many of the stakeholders concerned were hardly involved in any of the stages of the planning process of the settlements. This paper outlines the procedures to be adopted in ensuring active involvement of the participating communities in the planning process to ensure the sustainability of the project.

1. Introduction

Agricultural settlement, in the context of this paper, refers to a planned community where agriculture and agro-related activities such as fishing, hunting and forestry are the predominant means of livelihood of the inhabitants. During the first republic, especially in the then Eastern Nigeria, there were a number of such settlements established mostly for specific agricultural production activities. They were mostly public sector owned and managed. Examples include the Uzo-Uwani and Igbariam Farm Settlements which were devoted to rice production, Ikom Farm Settlement which was for cocoa production and Bonny Farm Settlement which was for coconut production (Eastern Nigeria Ministry of Agriculture, 1964; Floyd and Adinde, 1967) Some were privately owned such as Ikwo Agricultural Settlements in Ebonyi State which were established by the Norwegian Church Agricultural Project (NORCAP). Some were established to serve as resettlement centres for internally displaced persons such as the Equatorial Guinea returnees who were resettled in various centres created by the government for the purpose. These settlement schemes helped to drive the agricultural revolution of that era which made agriculture the mainstay of the economy of that period.

Following the creation of states and the end of the Nigerian civil war, most of the settlements collapsed. One of the reasons for the collapse may be traced to the fact that the participating communities were hardly involved during the planning or implementation stage of the settlement an so their dreams, aspirations and fears were not taken into consideration

(Kottak, 1991). With the recent interest by some states in setting up agricultural settlement (Fadire, 2016: Premium Times, 2018) based on the Songhai farm model (where emphasis is laid on effective utilization of agricultural waste for sustainability), there is a need to involve the prospective inhabitants of the farm settlements during the conception, implementation and post implementation stages of the planning process. Outlined in this paper are the procedures to be adopted in ensuring the active involvement of the community in the planning process.

2. Importance of Community Participation

One of the fundamental principles in rural planning is to let the people themselves take the driver's seat in identifying their needs and/or setting the objectives to which the plan is to respond. With the help of experts, these needs/objectives are prioritized and the steps to be taken towards actualizing them determined. There are better chances of any rural project succeeding if such a project is initiated by the people instead of it being initialed somewhere and forced on the people (Thompson, 1995; NSPFS, 2001). Corollary, many development projects have failed, not because they were not laudable or that their objectives lacked in nobility, but because the project did not reflect the wishes and perceptions of the people and hence lacked their active support and commitment.

There are many ways of getting people to participate in community project planning (Pretty, *et al.*, 1995). It is important that the people participate effectively at every stage of the project. Effective participation can be achieved through the use of informal meetings involving different groups in the community. At such meeting it is important to stress that the expert coordinating the meeting should be a facilitator and not a leader. He should not assume authority or believe that he knows what is best for the people; he should rather only try to guide the people to "take the right decision" which of course is not the one that necessarily agrees with his own ideas. He should know different ways of tackling a given issue and use the decision which the people own and will implement and not his own decision.

Participatory method when applied to solving the problems of a group engenders a common understanding of the groups problems in a bid to solve them (Pretty, *et al.*, 1995; Igbokwe and Enwere, 2001). It enhances creativity in the people, instills a sense of responsibility on participants and catalyses corporate thinking.

3. Sequences in Participatory Planning Process

There are four sequences in participatory planning processes (NIRADO, 1996). They include:

3.1 Dreams &Visions

At this stage, the future dreams and aspirations of the community are articulated by the group. The underlying question to be answered at this stage is *"What do you want your community to be in the next few years?"*

3.2 Constraints & Obstacles

At this stage the current realities in the community is articulated with particular emphasis on the hindrances and underlying problems militating against the achievement of the community's corporate dreams. What are the strengths and weaknesses of the community? What are the opportunities? And most importantly: "*What can keep the visions of the community from being a reality – the dangers?"*

3.3 Strategies & Actions

The actions to be taken to overcome the obstacles and achieve the goals of actualizing the dreams are identified at this stage. The actions follow from the identified and prioritized visions and a careful analysis of the obstacles. As before the question to be answered is: *"What actions need to be taken to deal with the obstacles and make the vision come true?"*

3.4 Implementation

The specific action to be taken within a specified time frame is articulated. Teams are formed, time allocated and tasks assigned to the teams. The resources needed are identified as well as method of sourcing them. Again the question is: *"What sequential steps should be taken within a given time frame, by whom and with what?"*

For each of these stages, there are procedures for eliciting ideas from the participating groups. The steps are as follows:

(a) *Introduction and Concept Operationalization:* Under this step, the stage to be discussed is introduced, i.e. vision, obstacles, action or implementation. All contextual issues and concepts relating to the topic under discussion are made clear and well defined to ensure that each participant in the group is operating within the same wavelength. For example, if obstacle is being discussed, it may be necessary to identify other synonyms for obstacles that will help the group members to understand the issues better such as barrier, block, hindrance, etc. It may be necessary to make them realize that obstacle is something that gets in the way which in the context of this discussion is something in the community which has to change before the collective dream of the community can be realized.

(b) *Brainstorming:* Having understood the issue in question in its proper context, the group is asked to think out answers individually to the posed contextual questions. Each member of the group is encouraged to think adventurously and to include everything; even the most outlandish and wild ideas! In fact, emphasis at this stage is on quantity and not quality – the more ideas, the better. If the group is literate, cards may be provided for members to put down their ideas as they dream; one idea per card. Where they are not literate, they should be advised to commit their ideas into memory until when asked to present them.

After a reasonable time, a recorder should be appointed by the people from amongst themselves. The group should then be asked to call out their ideas and as they do so, the facilitator should write each idea in a card and placed on a board. There should only be one idea per card. Only few words should be used and the writing should be bold and easy to read. Only hard ideas – i.e. ideas that are specific and not ambiguous to any member of the group – should be entertained. For example "provision of agro-service centre" is an example of a hard idea while "improved cooperation" is not.

No comments on or evaluation of the ideas should be entertained at this stage. All judgments should be ruled out until all the ideas have been collected. For a community that is planning to embark on the development of a new agricultural settlement, some of the ideas that may be generated under the vision stage may include: good roads, more vehicles, tractors, fertilizers, seeds, agro-chemicals, water supply, electricity supply, waste disposal, good sanitation, market, primary schools, health clinic, planned layout, comfortable homesteads, security, more jobs, agro-industries, flood control, erosion control, good drainage, agro-service centre, etc.

(c) *Grouping, Naming and Prioritization:* The next step is to group all ideas that will lead to the similar results together. This should be done with the full active participation of the group. Cards containing ideas which are exact duplicates may be removed at this stage but all other cards must remain no matter how outrageous the idea they contain may be. Next the groups of ideas should be given a name. for examples for the vision ideas earlier generated, the groupings and the group names may be as follows (Table 1):

Table 1. Sample grouping of generated ideas.

Improved Transportation	**Improved Utility Services**	**Better Social Services**	**Increased Agricultural Productivity**	**Improved Economy**
Good roads More vehicles Good drainage	Water supply Electricity supply Sewage disposal	Primary school Health clinic Security	Fertilizer Seeds Agrochemicals	Market Agro-industries
Erosion control	Telephone services	Planned layout	Tractors	More jobs
		Comfortable homesteads	Agro-service centre Flood control	

Finally the identified groups should be prioritized using a number of participatory methods such as preference ranking, seed counting (Pretty, *et al*., 1995*;* Igbokwe and Enwere, 2001), etc. Actions should then be prepared in line with the priority ranking of the needs and objectives. The above method was successfully used in eliciting information on cash cropping survey in Enugu Urban and Peri-Urban, Enugu State Nigeria by a group of researchers assembled by the British Natural Resources Institute (Schippers, *et al.*, 1996).

Interviews can also be used to elicit ideas from groups provided that the interview schedule is well formulated and that the interviewer adopts the right attitude that will not inconvenience or put off the person being interviewed.

These procedures should not only be done at the inception of the project but the peoples' reactions should be sought again after the first stage since they may not have been conversant with the issues during the initial stage. And after the completion of the planning stage, it should be discussed again with the community to get their final reaction before the implementation of the plan.

4 Community Management Plan

In the forgoing discussions on agricultural settlement planning, the emphasis has been on the location of the various facilities in the settlement to ensure order and good neighbourliness in the community. The policy guidelines for the settlement, which is normally embodied in the planning strategy for the community, will normally state the type of development that are to be allowed in the various parts of the settlement by dividing the settlement into sections and assigning different land uses to the various areas. Thus, while some areas may be reserved for residential and public facilities others may be for crop or livestock farms. Such policy guidelines, therefore, state the direction in which development of the settlement is to take without stating how the development is to be achieved. A *Management Plan,* on the other hand, spells out a set of objectives, based on the study of relevant developmental issues of the settlement, and makes recommendations for achieving the objectives after careful analysis of the various options. Thus, while policy guidelines are static, management plans are dynamic.

Management plans may come up at any stage of the development process as issues related to development in the settlement arise. Such issues may vary from settlement to settlement and from time to time.

5. Community Management Planning Process

The process will normally start with the assembly of a team of experts at the instance of the settlement. A preliminary visit will then be made by the team to the settlement to identify the issues, relevant resource materials and stakeholders that will need to be consulted during the process of developing the management plan.

A community profile is then prepared detailing all the demographic and agricultural production statistics for the community using identified relevant resource materials. In Nigeria, such materials may be the national Population Commission, the Federal and State Ministry of Agriculture and Natural Resources, State Agricultural Development Programmes (ADP), State Fadama Coordinating Units, State Planning Commission, Agricultural Research Institutes, Federal Office of Statistics, etc. It must be emphasized that in many developing countries, these statistics are hard to come by and sometimes they are not very reliable if available. Some of the information to be gathered as part of the community profile are listed in Table 2. A transect walk of the settlement is also taken and plotted as part of the preliminary visit.

Based on the preliminary interactions, the potential issues are identified. Such issues may include soil erosion problems, flood control and drainage problems, need for diversification of production, agricultural input supply and distribution, chemical farming problems, extension education issues, non-resident land ownership as a source of non compatible land use, pest and disease control, agricultural mechanization, tourism, forestry development and management, fishing rights, taxation structure and reward for active farming, etc. In the identification of these issues, the community participation procedure earlier discussed is applied.

Having identified the issues, the first public hearing should be held with the stakeholders to review and prioritize the issues and set the goals and objectives for tackling the issues. For example for the resources sector issue, the goal would be “to provide the best way to manage, protect, strengthen and effectively utilize the resources of the community” and the objective would be “to promote the effective utilization of the resources of the community to the highest potential while minimizing any negative impact of such utilization on the community.

In setting these objectives, it is important that in the process of utilizing any of these resources, no burden (environmental or ecological) should be imposed on any section of the community; neither should the resource base be depleted without regards to future continued need for the resources.

The next stage is to determine the feasible scenarios for the achievement of the objectives. In order words, various options for achieving each objective are identified, analyzed, and adopted as recommendation if found feasible. At the end of the process, an open house is held in the settlement where the draft management guidelines are presented, reviewed and fine-tuned.

Table 2: Relevant Community Profile statistics.

Sector	Item	Detailed statistics
Resources	Land distribution by class	Total area, areas of arable and non arable lands, total cleared, total forested, etc
	Land distribution by land use	Total land (area and nos), total farm area under crops, areas under pasture, area for public facilities, residences, etc.
	Land tenure	No of land owners, tenants, part owner and part tenants, etc.
	Ownership structure	Individual or family farms, partnerships, legally incorporated companies, institutions, community, etc.
	Types of farms	No of farms for different crops, livestock and poultry.
	Fishery	No and capacity of fish farms,
	Forestry	No, size and ownership pattern of forest reserves.
Demography	Population	Total population – males, females, youths, children, etc
	Occupation	No of farmers, fishermen, nos employed and unemployed, etc
	Dwelling characteristics	Owned, rented, household size, etc
	Farm operators by age	Population of different age groups involved in farming from 25 to 70+ years.
Production statistics	Crop production statistics	Production figures for cereals, roots, tubers, fruits and vegetables, cash crops
	Livestock and poultry production statistics	No of cattle, pigs, poultry, sheep and goats, micro-livestock, livestock and poultry products, etc.
	Fishery production	Annual production figure for fish and fishery products.

Sector	Item	Detailed statistics
	Forestry production	Production figures for forestry products – timber, firewood, tungia farming products, etc .
Inputs	Fertilizer and agrochemicals	Total area fertilized, total quantity of fertilizer used, total area spread for weed and pest control, quantity of agro-chemical used, etc.
	Farm machinery and equipment	Inventory of farm machinery and equipment including tractors, trucks, tillage equipment, planters, harvesters, etc.
	Capital	Sources of funds, no and value of loans secured, % repayments, etc
Tourism	Tourism facilities	No of restaurants and bars, bed and breakfast, etc.
Organizational	Organizational structure	Agencies involved in development in the settlement.

Finally, the adopted issues, objectives and guidelines are compiled as the management plan for the community. The procedure and organizational structure for implementing the plan must be specified.

6. Conclusions

Agricultural or farm settlement schemes played a vital role during the first republic in driving the agricultural revolution of that era especially in Eastern Nigeria. Following the creation of states and the end of the civil war in Nigeria, these farm settlements collapsed. Among other reasons, the non-involvement of the stakeholders in the planning and implementation of these schemes may have played a vital role in their demise. The potential inhabitants of the settlements should have been made to share their dreams and visions, identify their constraints and map out implementation strategies that would have ensured the success of the scheme. There is also a need to develop a Management Plan for the settlement which spells out a set of objectives (based on the study of relevant developmental issues of the settlement) and makes recommendations for achieving the objectives after careful analysis of the various options. When stakeholders participate actively during the planning process as discussed in this paper, their fears, dreams and aspirations are taken into consideration and this helps to ensure the success and sustainability of the scheme.

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COCONUT SHELL ACTIVATED CARBON (CS-AC)- AN EFFECTIVE MEDIUMFOR WATER TREATMENT

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ABSTRACT

Various works have been done to remedy the effects of anthropogenic and industrial pollution of surface and groundwater. Adsorption and filtration have been widely employed by water engineers. Activated Carbon is a very good adsorption material which has been employed in the treatment of water. In this work, activated carbon was produced from coconut shell under various carbonization temperature and activation time, using Hydrochloric acid (HCl) as activating agent. Water treatment analyses were carried out on the products and results showed that the optimum conditions for production to be; 500^{o}C carbonization temperature for 2hrs and 180mins activation time at 800^{o}C. This sample gave 66.9% Chemical Oxygen Demand (COD) removal efficiency and 86.7% Biochemical Oxygen Demand (BOD) removal efficiency at a carbon dosage of 0.2g/60ml.

Keywords: Coconut Shell, Activated Carbon, Water Treatment

1. INTRODUCTION

It has been long recognized that tiny concentrations of both natural and synthetic organic substances can in some cases produce serious taste and odour problems in water (Tebbutt, 1999). Consumers object to waters having noticeable tastes or odours both because they are objectionable and because many tastes and odours are interpreted as evidence of pollution or of unwholesomeness of water. For instance, the odour of hydrogen sulphide (H_2S) is associated with dead fish in a reservoir. Therefore, the control of tastes and odours should not be neglected; otherwise the consumers will lose confidence in the quality of an actually safe supply and use any available substitute as long as it is attractive.

Most taste and odours in surface water are organic and derived from algae blooms. Algae growths can be influenced by the pollution from domestic waste, run-off from fertilizer, animal waste, domestic and industrial waste. If taste and odour must be controlled at the treatment plant, oxidation, aeration and adsorption can be effective in reducing taste and odour, and improved coagulation filtration. Activated carbon has the capacity to remove these problematic chemicals from water sources (Ami et. al, 2012).

Coconut-based agricultural wastes have gained wide attention as effective biosorbents due to low-cost and significant adsorption potential for the removal of various aquatic pollutants. The various parts of coconut tree such as coir, shell and pith have been extensively studied as biosorbents for the removal of diverse types of pollutants. Also, coconut shell-based carbons tend to be harder, more resistant to abrasion and lower in ash than similar grades of coal-based carbons (Shilpa and Nimisha, 2014).

Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification or treatment of industrial and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons (Chengwen et. al., 2014).

Activated carbon has been produced from various materials and under various conditions. However, the objective of this work is to produce activated carbon from coconut shell at carbonization temperatures of 300oC, 400oC, 500oC, 600oC and 700oC for 2hrs in each case. The resulting carbon from each would further be activated with Hydrochloric acid (HCl, 75% conc.) at activation times of 60mins, 100mins, 140mins, 180mins and 220mins. Theresulting products of the activated carbon would be tested for efficiency. The activating agent and range of carbonization temperature and activation time makes the work unique.

Ifinditneedfultoinvestigatethecarbonizationandactivationconditionsinproducingactivatedcarbonfromcoconutshellusinghydrochloricacidasactivatingagentthatwouldyieldthemosteffectiveoutput.Thecarbonizationtemperaturewouldbevaried(300,400,500,600and700oC)with2hrscarbonizationtimeconstant.Thechoiceof2hrscarbonizationtimeisbasedonestablishedresultsbyYusufuet al.(2012)thatshowsmaximumincreaseinweightlossforcarbonsamplesatcarbonizationtimeof2hrs.Also,Olafadehanetal.(2012)afterapplyingarangeofcarbonizationtimeshadresultsthatshowedoptimumcarbonizationtimeof1-2hrs.SusheelaandRadha(2015)alsocarbonizedat1-2hrs.

2. MATERIALS AND METHOD

The materials for this work include: Coconut Shell, Grinding stone, Muffle Furnace (Carbolite-CWF 1200), Oven, Crusher (Mortar and Pestle), Draining Tray, distilled water, Sieve (350µm), Weighing balance, Tong, Crucibles

The coconut shells were carbonized at 300^{o}C, 400^{o}C, 500^{o}C, 600^{o}C and 700^{o}C for 2hrs each and crushed using a laboratory mortar and pestle. The samples of carbonised coconut shells were soaked in hydrochloric acid (75% conc.) for 60, 100, 140, 180 and 220 minutes after which the resulting slurry formed from each sample was stirred and reinstated into furnace at a final temperature of 800^{o}C for activation. The choice of 800oC was guided by the assertion of Okoye (2010) that activation is best at temperatures between 700^{o}C-1000^{o}C.

Each activated carbon sample was washed in distilled water until the mixture got to a pH within the range of 6.8 to 7.2, after which it was further dried in the oven at 110^{o}C for 1hr to remove water from the activated carbon and enhance storage.

Analyses were carried out on the raw water and treated water samples to determine values of Turbidity, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) using a dosage of 0.2g/60ml (0.2g of each sample was added to

60ml of raw water in the absence of any other filter material). Turbidity was determined using a turbidimeter (Hack Model) and the results were appropriately recorded. Total dissolved solids (TDS) was also determined with a TDS meter (MettlerToledo). The chemical oxygen demand (COD) and biochemical oxygen demand (BOD) were determined using Benchwork.

3. RESULTS AND DISCUSSION

The following results were obtained after tests:Table 1 shows the summarized results of the raw water treatment using 500oC and 600oC activated carbons both at 180mins activation time. This comparison was done as both activated carbons showed good water treatment capabilities.Figure 1 shows the effect of the produced coconut shell activated carbon on total dissolved solids. Figure 2 shows the effect of the activated carbons on turbidity. Figure 3 shows the effect of the activated carbons on chemical oxygen demand while figure 4 shows the effect of the activated carbons on biochemical oxygen demand.

Table 1Water treatment using 500^{o}C and 600^{o}C; 180mins Coconut Shell Activated Carbon

Temperature ^{o}C	TDS (ppm)	Turbidity (NTU)	COD (mg/l)	BOD (mg/l)
500	22.1	59.2	47	0.33
600	21.05	56.9	38.9	0.15
Commercially Produced	25.6	60.3	45.8	0.15
Raw Water	149	150.8	142	2.49

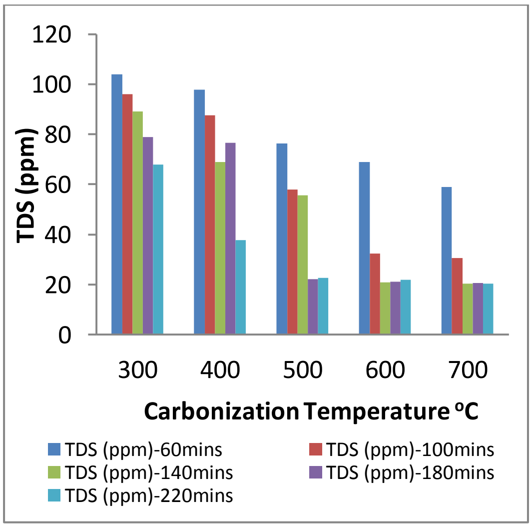

Fig. 1 Effect of produced Coconut Shell Activated Carbons on TDS.

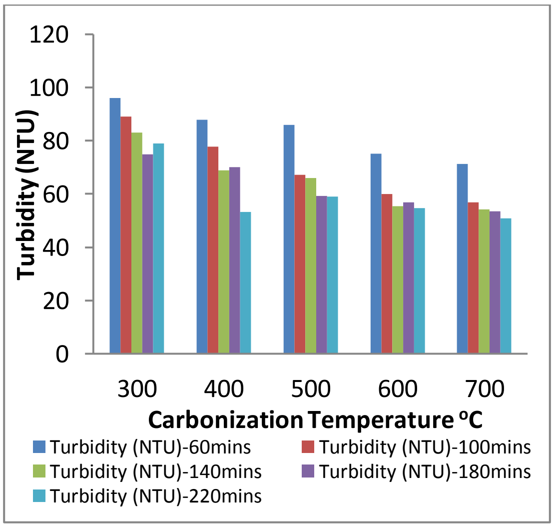

Fig.2 Effect of produced Coconut Shell Activated Carbons on Turbidity.

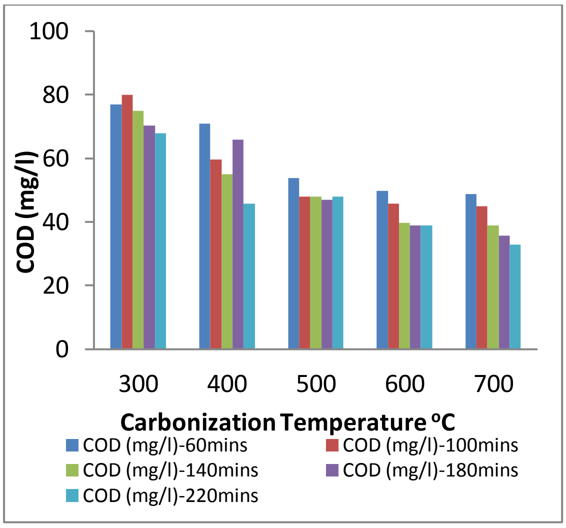

Fig. 3 Effect of produced Coconut Shell Activated Carbons on COD.

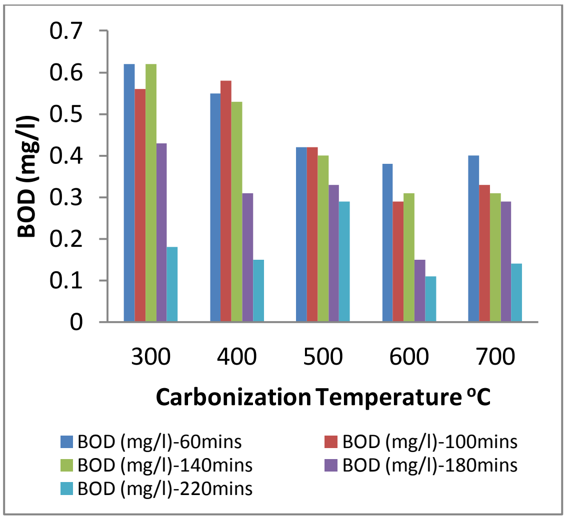

Fig.4 Effect of produced Coconut Shell Activated Carbons on BOD.

There was a significant reduction in the Total Dissolved Solids (TDS). The TDS of the raw water was 149ppm and results showed a highest value of 104ppm for *300^{o}C; 60mins* activated carbon and least value of 20.3ppm for *700^{o}C; 220mins* activated carbon. The values of TDS reduced with increase in carbonization temperature and also with increase in activation time. It was discovered graphically (fig. 1) that the activated carbon produced at 500^{o}Ccarbonization temperature and 180mins activation time had TDS value of 22.1ppm which is just a little higher than the least value of TDS in the test results (20.3ppm) and even less than that of the commercially produced activated carbon with 25.6ppm.

The result of turbidity after treatment of raw water with produced activated carbons is shown in figure 2. It could be deduced that the turbidity reduced significantly after treatment with the produced coconut shell activated carbons. The raw water sample had a turbidity value of 150.8NTU and after treatment the highest value was 96NTU for *300^{o}C; 60 mins* activated carbon and the least value was 50.9NTU for *700^{o}C; 220 mins* activated carbon. The turbidity also reduced with increase in carbonization temperature and activation time. *500^{o}C; 180 mins*activated carbon had 59.2NTU (60.5% removal efficiency) which is again less than the commercially produced activated carbon with 60.3NTU. At 140mins activation time and 500^{o}C carbonization temperature, the turbidity was 66NTU having 56% removal efficiency.

From figure 3, it was discovered that the Chemical Oxygen Demand (COD) also reduced remarkably after treatment with the produced activated carbons. A steady decrease was also noted with increase in carbonization temperature and activation time. The raw water had a COD value of 142mg/l and after treatment the highest value was 80mg/l for *300^{o}C; 100 mins* activated carbon and the least value was 32.8mg/l for *700^{o}C; 220 mins* activated carbon.

Figure 4 shows that the Biochemical Oxygen Demand (BOD) also generally reduced with increase in carbonization temperature and activation time. The raw water had BOD of

2.49mg/l and after treatment with the produced coconut shell activated carbons, the highest value was 0.62mg/l for *300^{o}C; 60 mins* and *300^{o}C; 140 mins* activated carbons (both had the same value). The least value was 0.11mg/l for *600^{o}C; 220 mins* activated carbon.These values further buttress the fact that removal efficiencies of the activated carbons increase with increase in carbonization temperature and activation time.

Plate 1: Coconut shell just gotten from the market

Plate 2: Carbonized coconut shell before crushing

Plate 3: Carbonized coconut shell after crushing and sieving

4. *CONCLUSION*

The results of this study show that it is very possible and economical to produce activated carbon (having well developed pore structure and adsorption capacity) from coconut shell (which is an abundant agricultural waste material in Nigeria) for water treatment. Experimental results showed that increase in carbonization temperature and activation time resulted in better activation as demonstrated by the characterization and water analysis conducted. Results also showed that the optimum carbonization temperature/time is 500^{o}C/2hrs and activation temperature/time is 800^{o}C/180 minutes (3hrs). The results obtained in this study further showed that produced activated carbon from coconut shell can be used for contaminated surface water treatment, achieving 66.9% COD removal efficiency, 86.7% BOD removal efficiency and 85.17% TDS removal efficiency at a carbon dosage of 0.2g/60ml of contaminated surface water. This would be of immense benefit to the water treatment industry and also in the aspect of renewable energy.

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DEVELOPMENT OF A WEB BASED LIVESTOCK ORDERING AND DELIVERY

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ABSTRACT

A branch of Agriculture known as Livestock Farming is making tremendous contributions to the growth of the Nigerian economy in line with the government's efforts to diversify the economy. The sector faces major challenges of enhancing sales and delivery of its products causing a situation on its sales and profitability. Information and Communication Technology (ICT) plays an important role in improving the system by making it easier for one to buy livestock and get them delivered to their locations of request. The aim of this paper is to develop a system that enables the ordering and delivery of livestock using web technologies. This helps to solve problems normally encountered in the process of buying and selling of livestock. The online system features customers' ability to make orders, select special description of choice of livestock, pay using credit cards and have the livestock delivered to them conveniently, Certain distinctive factors were collated to arrive at a model that is used to generate the price of livestock available for sale online. A web based system is designed and implemented which helps the users of the system achieve the afore-mentioned objectives.

Keywords: Agriculture, Livestock buying and delivery, ICT, model, profitability, Web Based System.

1. INTRODUCTION

Due to economic diversification, Nigerian Government is working towards migrating from non-oil economy to agriculture; livestock farming is gradually becoming the next oil. Livestock Farming or Animal Husbandry can be described as the breeding of animals for the sole purpose of consumption. Livestock Farming is a rapidly growing arm of farming in Nigeria, the primary reason why more entrepreneurial farmers are venturing into livestock farming is because of its profitability (Olorun, 2016). Agriculture is a branch of Nigeria economy, providing employment for about 30% of the population as of 2010 (NBS, 2015). As long as humans exist there will be need for food and the major source of food for mankind is crops and animals. Meat in Nigeria is an important part of daily meals and a good proportion of Nigerian household food budgets are expended on meat and people buy livestock for social function purposes.

Several opportunities are coming up on the web. So many businesses and agricultural institutions now venture into their business with ease because of the Internet (Mccown. 2001). One of such business that the Internet introduced is the possibility for anybody to order any product via Internet and have the goods delivered to his or her doorstep. In today's age, many farmers have been chosen to focus on quick sales and delivery of livestock to anywhere in the country, rather than restricting their sales only in their farms. This was possible because of availability of Internet technologies (Jehsan, 2012).

This system is one of the latest technologies services being rendered in the agricultural livestock sector with countries in the western world adopting this new technology (Schaendoff, 2017). However, farmers can now boost sales, make wide range of publicity and advertisement on their farms and increase profits by using technology in agriculture to improve operation (McDonald, 2015). With this system livestock is ordered and delivered to the customer in convenience of their homes. This is made possible through the farmer's interest in advertising their commodities on the Internet. This work aims at enabling farmers to advertise their products online where customers can order for it via Internet and have the goods delivered to his or her desired location. Farmers advertise their livestock available for sale online by providing detailed information about them on the Internet e.g. animal's weight, breed, age, gender etc. Through the available information on this system, prospective customers can describe the choice of livestock they desire buying in the system, this system based on this livestock description including the customers' location will display the total cost of the livestock. Customer can make payment using their credit cards or other payments modes like cash payments etc, and the commodity will be delivered to them. So the system designed in this project will enable costumers go online and place order for their livestock and have it delivered to them.

The remaining part of this work is organized as follows: section 2.0 reviews related literature; section 3.0 details a high-level set of requirements that the web based system must satisfy and the database of the system. Section 4.0 outlines the implementation of the system and presentation of results. Finally, section 5.0 presents summary and conclusion.

2. REVIEW OF RELATED LITERATURE

This section deals with review of related literature in the subject matter "Online livestock Ordering and Delivery System" and was found out that researchers have made a good number of contributions.

Companies have been delivering goods to customer homes for years with many kinds of delivery systems. Instances runs from mail ordering catalog shopping to online ordering and delivery services such as those provided in (Borders & Arvinal, 2013). In (Hirschberg et al, 2016) a technique for effecting electronic commerce for livestock using a data network usually called Internet, includes a plurality of subsystems which together forms an integrated system for receiving customer's orders for selected items, via a data network or Internet, fulfilling the customer's orders and delivering the ordered products to the customers. Describing the system's architecture in (Hirschberg et al, 2016), it is of integrated nature allowing the online seller to provide a guarantee to the customer that the ordered system will be available to be delivered to the customer at the specified delivery date, time and location. The system described has some potential problems pointed out such as: customers' inability to cancel orders made, the customer must first receive the livestock then submit a separate request to the online seller for delivering the livestock, this process consumes a lot of time to achieve one transaction. Another problem is the inability of the farmer to showcase available livestock for customers to view to ensure the specific livestock they will order for. This results to some case where a farmer will receive an order without having the available livestock in stock.

In response to some problems in delivering support to agricultural activities, a system in (Lowell & Lindsay, 2012) was established to develop a vision statement and conceptual design for such a system based on a national need assessment. It involves support planning for farms and catchments such that farmers could implement activities in their properties that may contribute to the achievement of catchment wide environmental outcomes. The strength of this system is that it was available at no charge via the Internet, it was built on existing knowledge and application of SWOT (Strength, Weakness, Opportunities, and Threats) analysis. Problems encountered in the system is limited data coverage and little or no opportunity for two-way information sharing i.e. farmer's feedback, customer's suggestions and feedback.

Online ordering is a game changer for livestock farms that offer delivery. One of such livestock farm named in (EFC, 2018) runs an online order and delivery web system called everythingfarm.com. It was created because of the need to boon the use of technology trend in agriculture. As a result of this they have been dedicating their time and resources to provide tools and service that will allow farmers to prosper. They have built a farming community that values buying remotely which promotes a healthier way of life. This system permits users to display, offer, buy and sell livestock and agricultural equipment in accordance with the terms of use. The website is merely a facilitator/agent between a buyer and seller. The company does not have possession of the items offered for sale. This idea can be related to this project work. Some technologies featured on this site that can be related with this work includes; A buyer and seller form, Adverts and publication corner, Explicit item listing (information on livestock for sale). Limitations found in this system is that this company does not have any control over the legitimacy or quality or the ability of the sellers to sell or deliver items, payments for such items by the buyers and they do not also guarantee that any buyer or seller will complete a transaction.

(Awinle, 2013) also talks about the system in Nigeria which also makes use of ICT to aid the aspect of marketing known as shopping cart. It has been seen as a means of improving the societal way of life.

This project work has been able to make reasonably modification and added more exiting features to the existing systems that have been reviewed such as: A model to allocate prices to every livestock, customers description column, whereby customers can fill in livestock description of their choice if not satisfied with the ones listed on the sale corner, after the description, the system will automatically check for availability of the livestock from its database. The administrator takes full control over the payment for livestock, every payment is directed to the administrators account and in turn gives part payment to the farmer/seller who is also in charge of delivery, full payment is given to the farmer/seller pending confirmation of delivery by customer. It is hoped that the result of this system will be used as a marketing tool amongst the livestock farmers in Nigeria.

3. SYSTEM ANALYSIS AND DESIGN

This section deals with the analysis and design of the proposed system. This looked at the concepts, skills, methodologies, techniques, tools, and perspectives essential for the proposed system.

System analysis and design deal with planning the development of information systems through understanding and specifying in details what a system should do and how the components of the system should be implemented and work together. System analysts solve business problems through analyzing the requirements of information systems and designing such systems by applying analysis and design techniques. Object Oriented Analysis and Design methodology (OOADM) was used in developing this system. This methodology is viewed as a technical approach to analyzing and designing a system or application by applying the object oriented paradigm and visual modeling through the development lifecycles to foster better stakeholder communication and product quality (Jawahar, ND).

3.1. Requirements Definition for the Proposed System

The design of this system satisfies a number of sometimes competing criteria. These requirements are:

1. Availability: The system is readily available to users through the Internet, mobile phones, among others.
2. Multi-user: A number of farmers and both customers can access the system simultaneously through the Internet.
3. Accessibility: The system can be accessed by farmers and customers from any location using secure internet and mobile devices.
4. Security: The information stored in the system cannot be tampered with unless by the administrator when the need for update arises.
5. Integrity/accuracy: Every livestock product in the system comes from sellers (those farmers and intending sellers). Prices can't be altered due to the integrity of the model that generates the prices.
6. Verifiability: Farmers and customers can also verify that the information they got is correct by going back to the website the second time or more.
7. General: All farmers and customers must be able to have access to the Web based livestock ordering and delivery system.

3.2. System Architecture

Figure 1 shows the architecture of the system is designed in three tiers. These tiers are Presentation tier, Middle tier and Data tier. The presentation tier is the user interface and it is designed using HTML, CSS, and JavaScript. The middle tier connects the presentation tier and data tier together, it is designed using PHP and runs on the server. The data tier also called database is responsible for storing the data. The database management system used in developing this system is MySQL database.

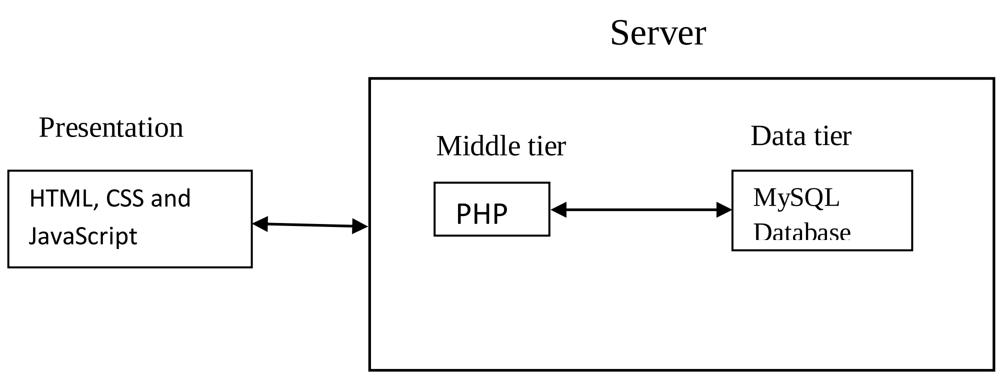

Figure 1: System Architecture

3.3. Database

Database has the core service for storing, processing and securing data. The database server provides controlled access and rapid transaction processing to meet the requirements of the client tier. Information on all users, livestock, livestock breed records and each crop variety requirements record resides in this server as shown in Tables below. The server is also responsible for authenticating administrator's authorization and the system when the need be. The relationships between the entities in the Tables mentioned below are also shown in Figure. 2. Table 1 shows is a record of a new user when added into the table.

Table 1: New user Record

Field	**Data type**	**Description**
*id	int(4)	User identification number
surname	varchar(30)	User surname
firstname	varchar(30)	User First name
middlename	varchar(30)	User Middle name
Sex	varchar(6)	User gender
Role	varchar(10)	User farmer or customer
phone	int(16)	User phone number
Email	varchar(25)	User email address
State	varchar(30)	User state
l.g.a	varchar(30)	User local government area
Username	varchar(15)	Unique username
Password	varchar(10)	User password

Table 2 shows a new livestock when added into the database.

Table 2: New Livestock Record

Field	Data type	Description
id	int(4)	Unique livestock identification number
Code	varchar(50)	Unique code for the livestock
name	varchar(5)	Name of seller
Category	varchar(255)	Category of animal
farmer	varchar(30)	Name of Farm
Email	varchar(30)	Email of the farm
Address	varchar(30)	Address of farm
Phone	varchar(20)	Phone of farm
livestock	varchar(20)	Type of livestock
image	varchar(20)	Picture of livestock
quantity	varchar(255)	Quantity of livestock uploaded
Age	varchar(20)	Age of animal
Breed	varchar(10)	Specie of livestock
weight	varchar(8)	Weight of livestock
added_date	date	Date added

Table 3 shows new order when added into the database and Table 4 shows payment details.

Table 3: New order Record.

Field	Data type	Description
Id	int(4)	Order identification number
Name	varchar(30)	User identification for order
Email	varchar(30)	Customer's email
Phone	varchar(20)	Customer's phone number
Address	varchar(15)	Specified address for delivery of livestock
date_time	varchar(15)	Date and time of making order
livestock	varchar(30)	Livestock to be delivered
Quantity	varchar(10)	Quantity of livestock

Table 4: Payment table

Field	Data type	Description
Id	int(4)	Payment identification number
User_id	int(4)	User identification for payment
Unit_cost	varchar(10)	Unit cost of livestock
Amount	varchar(10)	Amount paid for livestock

Table 5 shows customer/ farmer communication details while Table 6 shows the transaction details.

Table 5: Message table

Field	Data type	Description
Id	int(4)	Message identification number
Email	Varchar(20)	Sender's email address
message	Varchar(300)	feedback
Status	varchar(20)	Sender's status
Name	varchar(20)	name of sender

Table 6: Cart table

Field	Data type	Description
Id	int(20)	Livestock identification
p_id	Varchar(50)	Product identification
ip_add	Varchar(50)	Product add
user_id	Varchar(50)	User identification
Qnty	int(20)	quantity

3.4.Class Diagram and entity relationship of the Proposed system

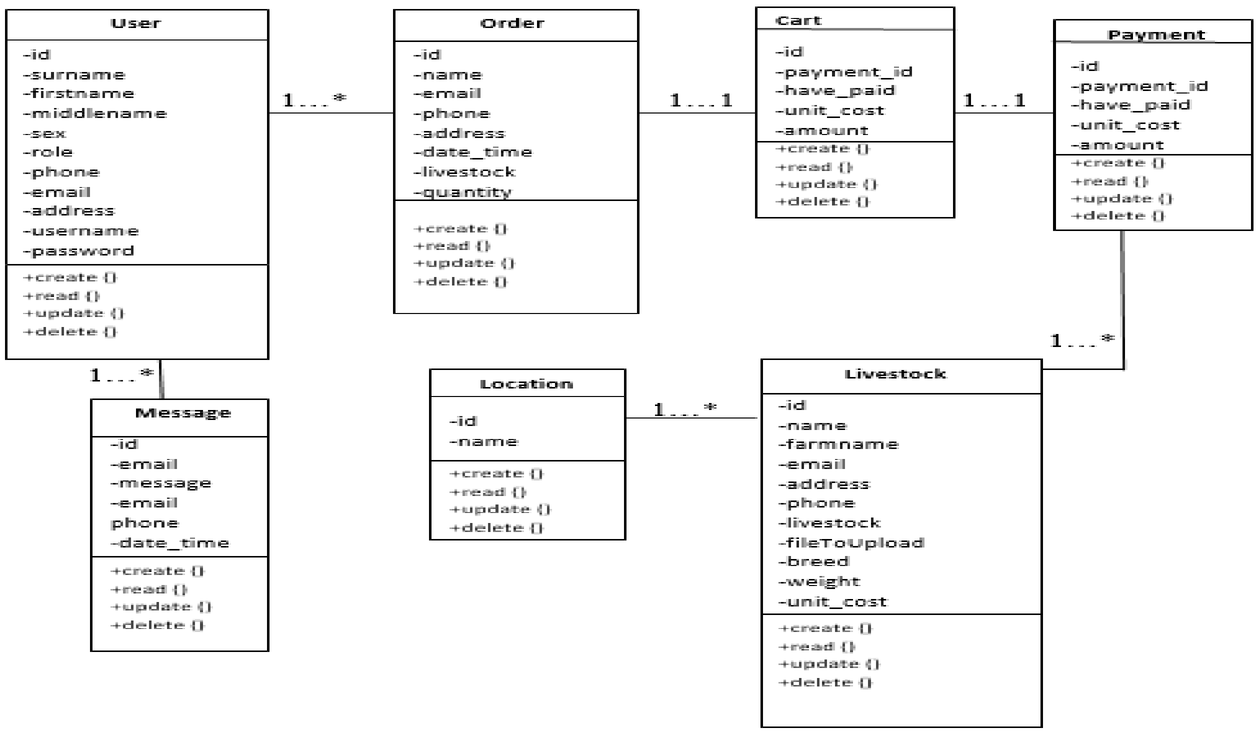

Fig. 2.0: Class Diagram with Entity relationship

Fig 2.0 shows the Class Diagram with Entity relationship of web based livestock ordering and delivery system

4. IMPLEMENTATION

The implementation architecture defines the key components of the proposed system together with the interactions between the components. The overall functional structure of the frame work is summarized as follows:

A farmer who wants to upload a new livestock into the system menu or who has already uploaded a livestock for sale can access the information about the livestock by running through the livestock information stored in the computer as follows:

When the system is open, and login to farmer's dashboard, click on Product, main menu form will appear comprising NEW, PRODUCT, and My Products/EDIT module.

i. New

When you click on new, it redirects you to an input page 'Add New', prompting you to input the breed, gender, age, size, picture and quantity of livestock you intend to sell. Then click 'Create' button, the price of the livestock is calculated and allocated by the system. Finally the livestock is added to your record of livestock you own. Assuming you do not want to open neither products nor Add new, select Exit, the user will logout.

ii. Product Module

When you want to view all the existing livestock, description and their codes, you use this menu. A form containing all the exiting livestock of that particular farmer will appear but in the administrator's dashboard a collection of all the livestock from all farmers will appear. You exit by clicking 'Logout'. Select Products and click on the breeds to view all the exiting breeds and exit by clicking on close button.

iii. My Products/EDIT

It is only the administrator and farmer that is authorized to make changes in the system either by adding a livestock or by editing an already existing livestock in the database. To make changes on existing livestock, click on an icon on the top right hand side of the livestock box and select 'edit', a form named 'edit' will appear where you fill in the livestock's details and click on 'update' command button, click on exit to close.

A customer who wants to buy livestock can do so as follows:

When the system is open, login to customer's dashboard, click on Home, the home page will appear comprising Livestock Categories and Search module.

4.1. Implementation Architecture

Figure 3 shows the system architecture which defines the key components of the proposed system together with the interactions between these components. The system was modeled in a way to have three major key players: an administrator who the main controller of the system, the farmer and the customer. A customer can access livestock information in the system by viewing available livestock or have option to enter descriptions of a particular livestock, from where livestock selected. Here customer can order and make payment. Farmers also upload description of the livestock available for sell and also receive information on any of their ordered product. The developed system allows the key users to use it simultaneously while ensuring high availability any time the systems services are needed. For security purposes, update module can only be accessed by an Administrator.

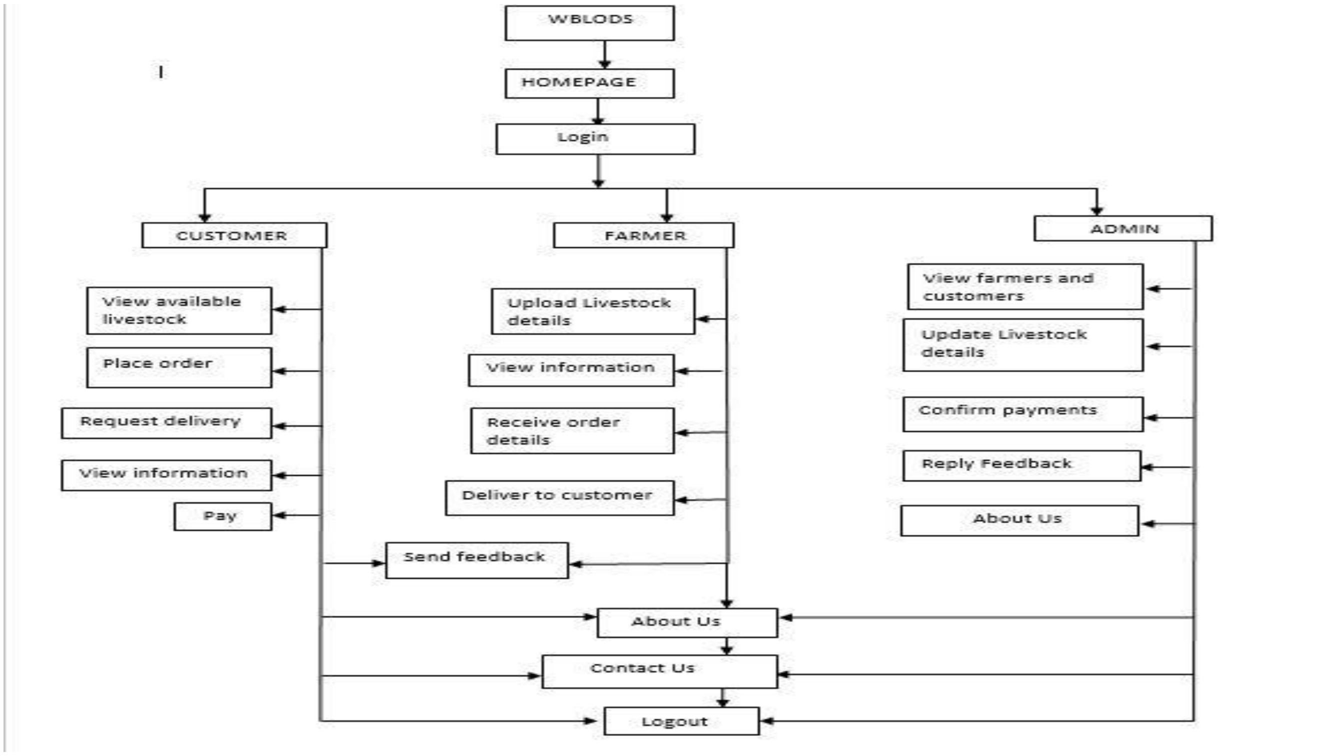

Figure. 3: The Implementation Architecture of the System

i. Livestock Categories

This category shows the type of livestock that are available in the system, here a customer can click on any type and it shows the available livestock under each type of livestock. To order a particular livestock click on the 'basket icon' add the product to your cart, this will redirect you to an input page 'paystack gateway' where you are prompted to input card details for payment.

ii. Search

This is an input column that serves as a help when searching for choice livestock to buy. Click on each of the input boxes and state the description 'age', 'size', 'breed' of choice livestock, the system searches from the available livestock in the database and displays the search result. Click exit upon completion.

4.2. Screenshots and Result Presentation

Figure 4 to 7 shows a few of the major screenshots of the developed proposed system. It shows the screenshots of the input and output (results) of the developed system.

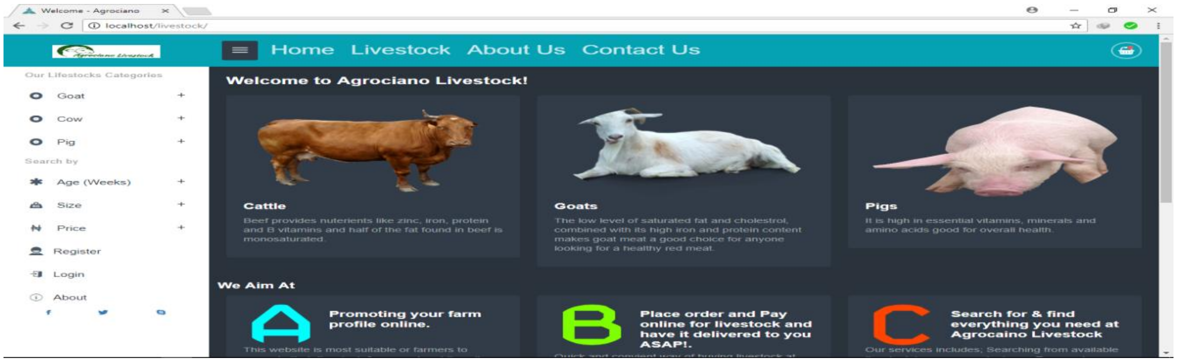

Figure 4: Homepage of the system

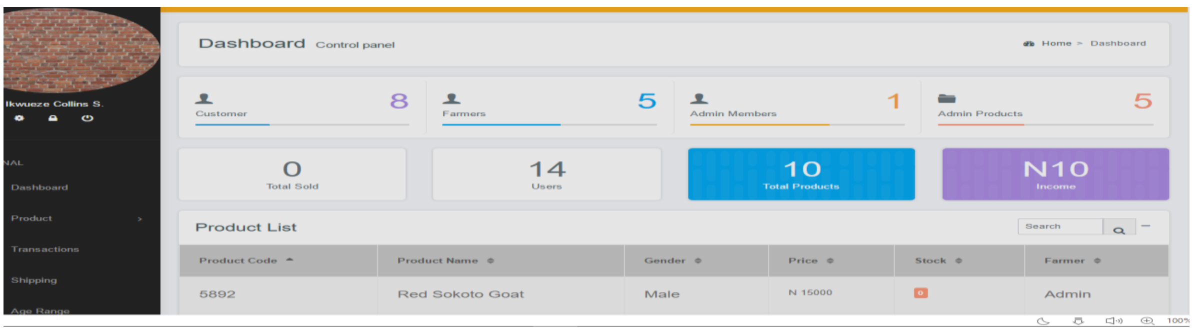

Figure 5: Administrator dashboard

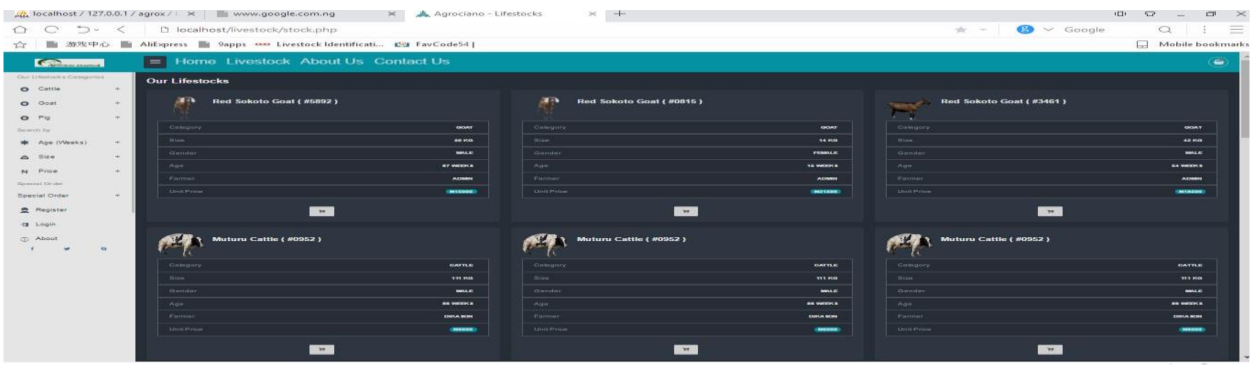

Figure 6: Available Livestock Page

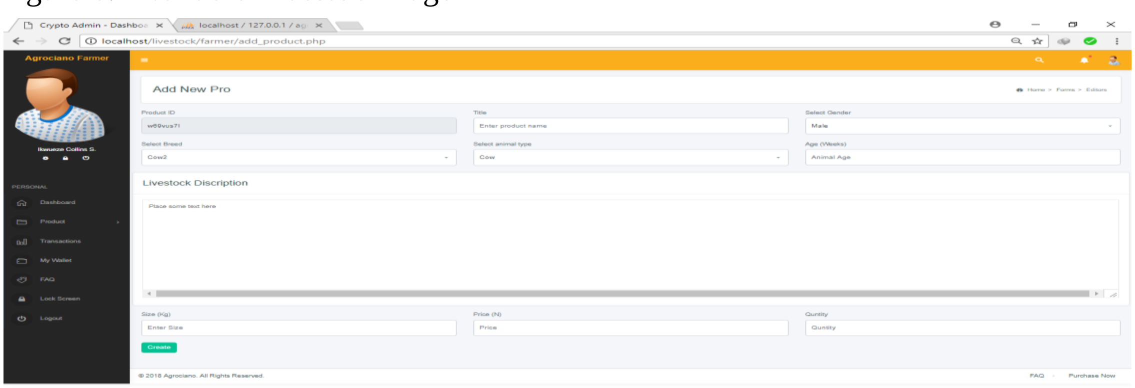

Figure 7: Livestock upload page

5. CONCLUSION AND RECOMMENDATION

People with busy schedules and crazy traffic obstructions often use various means to make sure they prevent stress and delays when buying a commodity. One of this means is the use of E-commerce, whereby a person can order a product online and get it delivered to them. These means have been practiced using many commodities that people find stressful to purchase in person. This time it has been brought to the agricultural sector whereby, people can now order for livestock online and have it delivered to them. This system helps farmers to promote their sells. A very interesting aspect of this system is its enablement to young entrepreneurs to be able to gain information on growing their own farm and also get the livestock to startup their farm.

Meat is a common meal with a lot of nutritional contents. Livestock vary in size depending on their growth and effort from the farmers and its significance exist in different areas of the world. The benefits of eating meat are quite numerous as it is one of the major source of protein needed for body growth and repair of tissues. Therefore, the use of this system encouraged for constant availability of meat.

The conventional manual process of ordering for livestock by customers has bottlenecks that have already been highlighted in the preceding sections of the work. This paper was able to provide solution to the main objective of the work which is to enable members of the public purchase livestock of choice at the comfort of their homes and to improve farmer sales and profitability. This application makes these enables activities without stress and much delay.

Future work will incorporate market information. This will be a big plus to the research because awareness of up-to-date market information on the prices of livestock, services and consumer trends can improve livestock farmers' livelihoods substantially. Such information is instrumental in making decisions about future livestock and commodities and about the best time and place to buy and sell goods. This information can be broadcast to the rural populace through electronic media such as radio, TV and mobile phones.

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PERFORMANCE ASSESSMENT OF SELECTED BIOMASS COOKSTOVES

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Abstract
In this study, the energy and exergy performance of four biomass cookstoves were investigated using wood chips as the fuel source. The performance of the cookstoves was carried out using the water boiling test both in the cold and hot start conditions. The cookstoves evaluated include the three-stone fire, charcoal stove, modified charcoal stove, and the top-lit updraft (TLUD) cookstove. The result of the study revealed that the energy efficiency of the cook stove was higher than the exergy efficiency both in the cold and hot start. The efficiencies increased steadily with time until the water was brought to 100^{o}C boiling temperature. The efficiencies in the cold and hot start for the cookstoves appeared similar with no obvious differences; that is, the performance of the cookstoves appear the same irrespective of whether the stove is being used in the cold or hot start condition. The TLUD cookstove offered better energy and exergy efficiencies compared to the other cookstoves.

Keywords: biomass fuel, cookstoves, energy analysis, exergy analysis, water boiling test

1. Introduction

One of the widely accepted renewable energy options is biomass energy which is the energy obtained from biomass. Majority of the communities in developing countries are predominantly rural and use biomass as fuel for cooking and heating purposes. Biomass, mainly agricultural and wood residues, is used by almost half of the world population and about 90 % of rural population in developing countries (Tyagi *et al.*, 2012a). The World Health Organization estimates that about 2.5 billion people globally rely on biomass, such as wood, agricultural waste and animal dung to meet their energy needs for cooking utilising traditional low-efficiency cookstoves (Abeliotis and Pakula, 2013). Traditional cookstoves have been reported to have low thermal efficiencies less than 10 % with the accompanying large amount of fuel being consumed and pollutants being emitted (Tyagi *et al.*, 2012a; Smith et al., 2000; Bruce et al., 2000). Such pollutants include carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), suspended particulate matters (SPM) and a host of organic compounds. Indoor air pollution has been attributed to cause acute respiratory infections and other diseases (Smith et al., 2000). As a result of this, improved cookstoves are being developed and disseminated for use to mitigate the aforementioned challenges faced with the use of traditional cookstoves, and also to improve quality of life in rural households (MacCarty *et al*., 2008).

Renewable energy systems generally have been reported to suffer from low energy conversion efficiency therefore requiring special consideration for real life applications in terms of its energy performance (Park et al., 2014). Performance of most renewable energy systems has been based on energetic analysis which basically accounts for energies entering and exiting (Dincer and Rosen, 2007). In terms of system efficiency, energy is based on the first law of thermodynamics and gives the quantity of energy only. However, recently, the exergetic performance based on the second law of thermodynamics has been found to be a useful method in the design, evaluation and optimization of energy systems (Kaushik et al., 2011). Exergy analysis identifies the causes, locations and magnitudes of system inefficiencies and provides the true measure of its individual component efficiency (Kaushika *et al*., 2011; Dincer and Rosen, 2007). Energetic and exergetic performance criteria provides information on the efficient and effective usage of fuel resources by taking into account the quantity and quality of the energy used (Kaushika *et al*., 2011). Energy is concerned only with the magnitude of energy while exergy is concerned with the quality as well as quantity of the energy; quality meaning the ability or work potential of a certain energy source having certain amount of energy to cause change (Hepbasli, 2008).

Several studies on energy and exergy analysis of renewable energy systems were reviewed by Park et al. (2014) and it showed that research on energy and exergy analysis of improved biomass cookstoves is scanty. Exergy efficiencies are usually lower than the energy efficiencies due to the irreversibility of the process which destroys some of the input exergy (Hepbasli, 2008). Performing energetic and exergetic analyses together can give a comprehensive analysis of energy system characteristics which is a more convenient approach for performance evaluation and improvement (Abeliotis and Pakula, 2013; Kaushika *et al*., 2011; Naterer *et al*., 2010; Ganapathy *et al*., 2009). Kaushik *et al*. (2013) added that it helps to identify ways of maximizing the efficiency of a renewable energy system. This is useful for performance comparisons, assessments and improvement of biomass cookstoves. The objective of this study therefore is to provide information on the energy and exergy performance of traditional and improved biomass cookstoves using wood chips as fuel source.

2. Materials and Method

2.1 Materials

In this experimental study, which is centred on the energetic and exergetic analysis of traditional and improved biomass cookstoves using wood chips as the fuel source, the following traditional and improved cookstoves were evaluated:

i. Three-stone fire
ii. Charcoal stove
iii. Modified charcoal stove
iv. Top-lit updraft (TLUD) cookstove

2.2 Description of the cookstoves

All the cookstoves selected for the study utilize one pot at a time and do not require specialized fuel type. The cookstoves are all improved cookstoves except the three-stone fire which is a traditional cookstove still used by some rural people.

2.2.1 Three-stone fire

The three-stone fire (TSF), also called “open fire”, is the traditional and primary stove type used throughout sub-Saharan Africa (Adkins et al., 2010). It consists of three similar sized stones (Fig. 1) on which a cooking pot is balanced over a fire. The arrangement of the stones is such that they act as support for the cooking pot. The height of the stones are usually about 15 – 30 cm high, depending on the size of the pot, which gives sufficient clearance above the ground for fuel wood to be placed beneath the pot. As open fire is lit beneath the pot, combustion in the TSF is incomplete and uncontrolled, generating a great quantity of particles and gases that are emitted directly into the kitchen (Berrueta *et al*., 2008). It has been reported that the thermal efficiency of the TSF typically falls between 5 to 17 % (Ayoub and Brunet, 1996; Ballard-Tremeer and Jawurek, 1996).

Fig. 1 Three-stone fire

2.2.2 The charcoal and the modified charcoal cookstove

The charcoal stove and its modified version is another very common cooking device originally designed to utilize charcoal as its fuel. However, other fuel sources such as wood chips and biomass briquettes are now been used in the stove. The key difference between the charcoal stove and its modified version is the perforations on the wall of the combustion chamber of the modified charcoal stove (Fig. 2). This allows for increased air flow into the combustion chamber in addition to the air inlet just below the fuel grate. The pot is usually positioned as close as possible to the fuel and it increases the full utilization of the heat generated from the fuel reducing heat loss to the environment.

Fig. 2 (a) Charcoal stove **(b)** Improved charcoal cookstove

2.2.3 Top-lit updraft cookstove

The top-lit updraft (TLUD) cookstove which is an improved biomass cookstove is shown in Fig. 3. To use the stove, the combustion chamber is loaded with the desired biomass fuel and the fire is started up using a small quantity of kerosene. The TLUD cookstove has been reported to reduce emissions resulting from the combustion of biomass in cookstoves (Birzer et al., 2014).

Fig. 3 Top-lit updraft cookstove

2.3 Stove performance test

The energy and exergy performance analyses of the cookstoves were evaluated following the standard testing protocol of water boiling test (WBT) as detailed in Bailis et al. (2007a). The water boiling test which is used in obtaining a relatively fast feedback on design and modifications gives an indication of the time and fuel needed to boil a certain quantity of water under controlled conditions (Berrueta *et al*., 2008). Water Boiling Test (WBT) can be carried out in two phases: (i) the high power phase that is conducted in cold and hot start conditions of the cookstoves; and (ii) the low power phase which simulates slow cooking tasks or tasks that require low heat.

In the high power cold start condition, the test begins with the stove at room temperature and uses a pre-weighed bundle of fuel to boil 5 l of water in an aluminium pot (Bailis *et al*., 2007b). The fire is usually ignited using kerosene. In the high power hot start, the fire is set immediately after the high power cold start condition and the test repeated to identify any difference in the performance of the stove when it is cold and when it is hot. This is important for cookstoves whose performance may vary significantly between cold and hot start conditions (Bailis *et al.*, 2007a). The low power simmering phase was designed to test the ability of stoves to shift into a low power phase following a high power phase in order to simmer water for 45 minutes using minimal amount of fuel (Bailis *et al.*, 2007a). It is important to note that in the simmering test, water is maintained at a boil rather than heated from room temperature. The energy and exergy analysis was carried out under the cold and hot start conditions of the high power phase only since theoretically, there is no temperature change in the simmering of water.

Temperature readings were taken after every 5 minutes using a data acquisition device equipped with temperature thermocouples (MCC TC) until the water in the aluminium pot used in the study reached boiling temperature of 100^{o}C. The performance analysis of the cookstoves was carried out in a simulated laboratory kitchen at the Department of Agricultural and Bioresources, University of Nigeria, Nsukka, Nigeria. The tests were carried out using wood chips as the fuel source. The wood chips were obtained from the processing of neem wood (*Azadiractha indica*) logs in Nsukka saw mill, south-eastern Nigeria.

2.4 Energy and exergy analysis

The energy and exergy equations used in the performance analysis of the cookstoves were as described in Park et al. (2014), Tyagi et al. (2012a, 2012b), Pandey et al. (2011) and Tyagi *et al.* (2007).

2.4.1 Energy analysis

An energy balance for the overall process can be written as:

Energy input - [Energy recovered + Energy loss] = Energy accumulation

Energy input is given by:

$$E_{in} = m_{bf}c_1 + x \times d \times c_2 \qquad (1)$$

Where m_{bf} is the mass of biomass fuel (kg), c_1 is calorific value of the fuel (kcal/kg), and c_2 is the calorific value of kerosene (kcal/kg), x is the volume of kerosene (ml), d is density of kerosene (g/cc).

Energy output is given by:

$$E_o = m_W C_p\left(T_{fw} - T_{iw}\right) + m_{pot}Cp_{Al}(T_{fp} - T_{ip}) \qquad (2)$$

Where, m_W is mass of water in pot (kg), C_p is specific heat of water (J/kg K), T_{fw} is final temperature of water (K), T_{iw} is initial temperature of water (K), Cp_{Al} is specific heat of Aluminium (J/kg K), m_{pot} is the mass of pot (kg), T_{fp} is final temperature of pot (K), and T_{ip} is initial temperature of pot (K).

Energy efficiency, η (%) defined as the ratio of output energy to input energy is given as:

$$\eta = \frac{E_o}{E_{in}} \times 100 \tag{3}$$

2.4.2 Exergy analysis

An overall exergy balance for the system can be written as:

Exergy input – [Exergy recovered + Exergy loss] - Exergy consumption = Exergy accumulation

Exergy input is given by:

$$Ex_{in} = m_{bf} C_1 \left(1 - T_a/T_{fuel}\right) \times \eta_c + x \times d \times C_2 \tag{4}$$

Where T_a is ambient temperature (K), T_{fuel} is temperature of burning fuel (K).

Exergy output is given by:

$$Ex_o = m_W C_p \left(T_{fw} - T_{iw}\right)\left(1 - T_a/T_{fw}\right) + m_{pot} Cp_{Al} (T_{fp} - T_{ip})\left(1 - T_a/T_{fp}\right) \tag{5}$$

Exergy efficiency, ψ (%) defined as the ratio of output exergy to the input exergy is given as:

$$\psi = \frac{Ex_o}{Ex_{in}} \times 100 \tag{6}$$

3. Results and Discussions

The performance of four biomass cookstoves which include the three-stone fire, charcoal stove, modified charcoal cookstove, and the top-lit updraft (TLUD) cookstove were evaluated on the basis of their energy and exergy efficiencies using wood chips as the fuel source. The result of the experimental tests is discussed below.

3.1 Three-stone fire

The result of the energy and exergy efficiencies of the three-stone fire, a traditional cookstove, in the cold and hot start conditions is plotted in Fig. 4. It was observed that the energy and exergy efficiencies both in the cold and hot start conditions increased steadily as the boiling time increased. The energy and the exergy efficiencies, both in the cold and hot start each appeared similar and followed the same trend. The energy efficiency in the cold start ranged from 15.61 to

50.71 % while in the hot start, it ranged from 16.30 to 50.62 % as the boiling time increased from 5 to 40 minutes. The exergy efficiency which was lower than the energy efficiency at all the measured times ranged from 1.11 to 9.68 % in the cold start while in the hot start, it ranged from 1.21 to 9.69 %. It took the stove a total of 40 minutes to bring 5 l of water to boiling temperature of 100^{o}C using 1 kg of wood chips in the cold and hot start conditions, respectively.

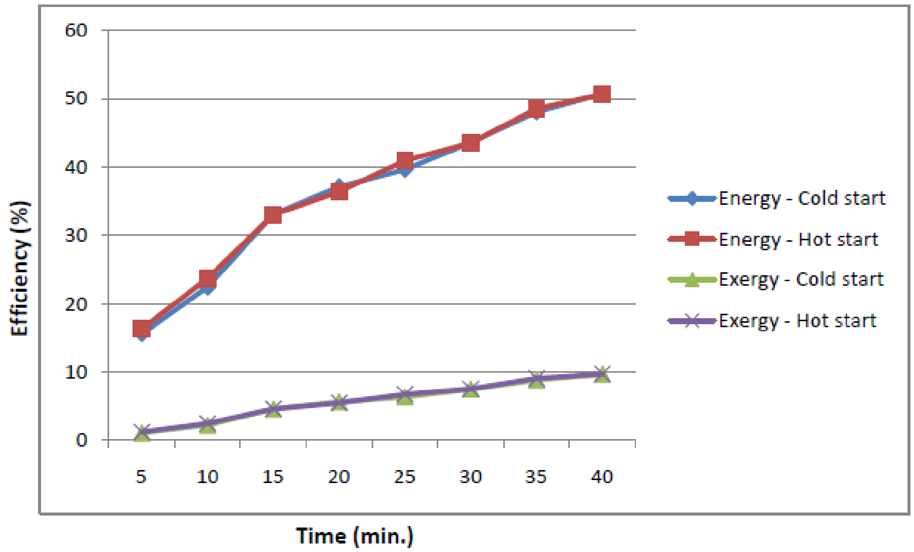

Fig. 4 Energy and exergy performance of the three-stone fire

3.2 Charcoal stove

The result of the energy and exergy efficiencies of the charcoal cookstove is presented in Fig. 5. The efficiencies increased steadily as the boiling time increased. The result of the energy efficiency in the cold and hot start appeared similar as was also observed for the exergy efficiency in the cold and hot start, and they followed the same increasing trend. However, the energy efficiency at both the cold and hot start was higher than the mean values observed for the corresponding exergy efficiency. The energy efficiency ranged 19.22 to 49.81 % in the cold start while it ranged from 17.26 to 49.54 % in the hot start. The exergy efficiency however ranged from 1.63 to 9.48 % in the cold start while it ranged from 1.33 to 9.48 % in the hot start. As is shown in Fig. 5, the time required to boil (100^{o}C) 5 l of water in the hot start condition was lower than that of the cold start and were recorded to be 20 and 23 minutes, respectively using 0.83 kg of wood chips in the hot start and 0.90 kg in the cold start condition.

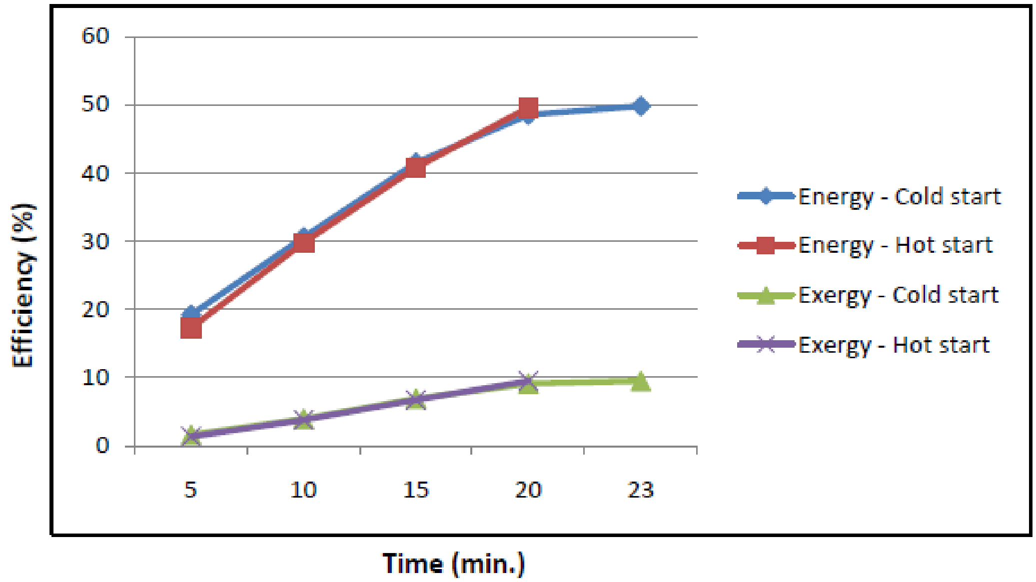

Fig. 5 Energy and exergy performance of the charcoal stove

3.3 Modified charcoal cookstove

The result of the energy and exergy efficiencies of the modified charcoal cookstove as presented in Fig. 6 followed the same trend as the charcoal stove. However, the numerical difference in the efficiencies determined in the cold and hot start were easily observed at the 10 and 15 minutes marks both for the energy and exergy efficiencies. The energy efficiency ranged from 19.20 to 56.79 % and 20.05 to 56.11 % in the cold and hot start conditions, respectively. While the exergy efficiency ranged from 1.46 to 10.72 and 1.61 to 10.71 % in the cold and hot start, respectively. The energy efficiency in the cold and hot start was higher than the exergy efficiency in the corresponding hot and cold start conditions. The modified charcoal cookstove took a total of 20 minutes to boil (100^{o}C) 5 l of water using 0.85 kg of wood chips in the cold start and 0.70 kg in the hot start.

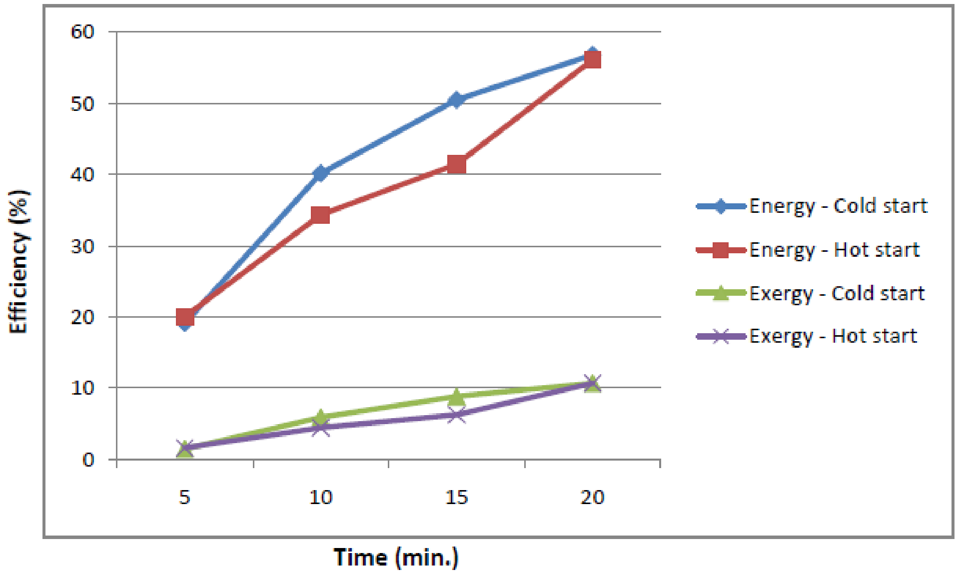

Fig. 6 Energy and exergy performance of the modified charcoal stove

3.4 Top-lit updraft (TLUD) cookstove

The top-lit updraft cookstove took a total of 10 minutes to bring 5 l of water to 100°C resulting in the energy and exergy efficiencies being determined at two boiling times of 5 and 10 minutes only as shown in Fig. 7. As was observed for other cookstoves investigated in this study, the energy and exergy efficiencies of the TLUD cookstove increased with time, and the efficiencies at the cold and hot start both appeared similar with no easily observable difference. The energy efficiency was generally higher than the exergy analysis. The energy efficiency in the cold and hot start at the 5 minutes mark was 53.27 and 52.45 % respectively while at the 10 minutes mark, the energy efficiency was 88.48 and 88.95 % in the cold and hot start, respectively. For the exergy analysis, the efficiency at the 5 minutes mark was 6.62 and 6.62 % in the cold and hot start while the corresponding exergy efficiency at the 10 minutes mark was 15.19 and 15.74, respectively. In the cold start, the stove consumed a total of 0.97 kg of wood chips while it consumed 0.80 kg in the hot start to bring 5 l of water in the aluminium pot to 100°C.

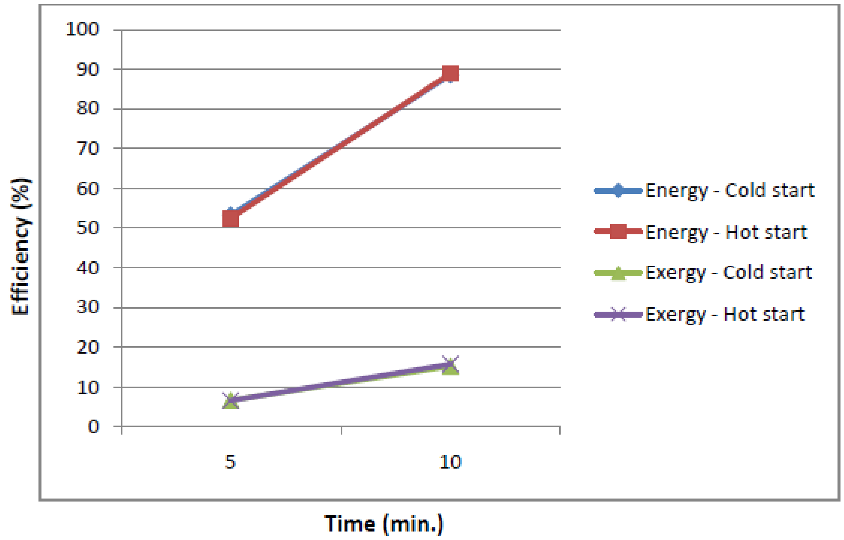

Fig. 7 Energy and exergy performance of the TLUD cookstove

3.5 Comparison of the performance of the cookstoves

The comparison of the energy and exergy efficiencies of the cookstoves in the hot and cold start conditions is presented in Figs. 8 and 9. It could be observed that in both the cold and hot start, the energy efficiency was much higher than the exergy efficiency for all the cookstoves. Similar result was reported by Tyagi *et al*. (2012a) for four different stove models and they stated that the difference in the efficiencies could be explained in terms of the quality of energy gained by the hot water in the pot during the water boiling test procedure. The two efficiencies both increased from the charcoal stove to the three-stone fire and then the modified charcoal stove followed by the TLUD cookstove. The TLUD cookstove had the highest energy and exergy efficiencies of 88.48 and 15.19 % in the cold start condition, and 88.96 and 15.74 % in the hot start condition, respectively. It took the TLUD cookstove a total of 10 min. to bring 5 l of water to 100^{o}C. However, it took the three-stone fire 40 minutes; charcoal stove 23 min. in the cold start and 20 min. in the hot start; and the modified charcoal stove 20 min. to bring 5 l of water in the aluminium pot to 100^{o}C. The TLUD cookstove offered better energy and exergy efficiencies in comparison to the other cookstoves reflecting higher amount of energy inflow and outflow, and better heat quality. The lower energy and exergy efficiencies determined for the charcoal stove both in the cold and hot start conditions could be attributed to poor air supply to the combustion chamber as the air inlet to the chamber appeared small compared to the other stoves. The higher energy efficiency and the slightly higher exergy efficiency of the modified charcoal stove over the charcoal stove could be attributed to the openings all around the combustion chamber of the modified charcoal stove giving rise to increased rate of fuel combustion. The funnel-shaped air-inlet flow into the combustion chamber of the TLUD could contribute to its higher energy and exergy efficiencies over the other cookstoves as the air flows into the combustion chamber in a concentrated manner and at a higher flow rate which could lead to faster paced combustion of the biomass fuel.

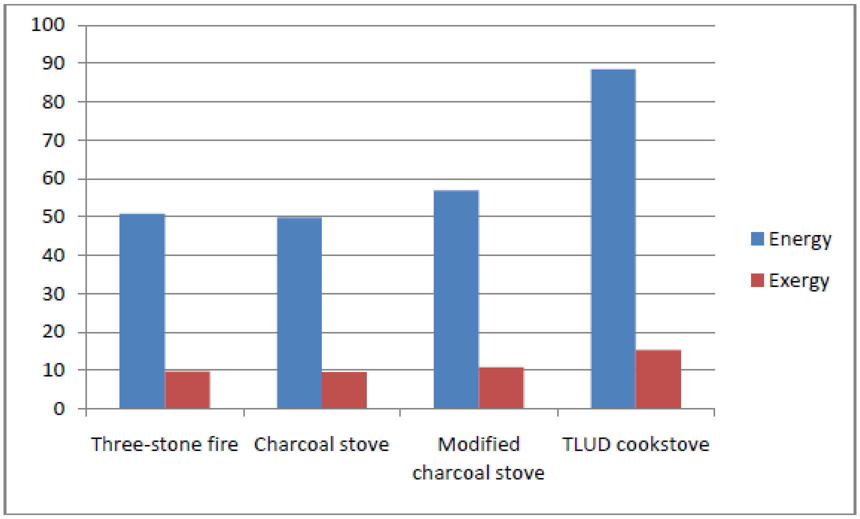

Fig. 8 Exergy and energy comparison of the cookstoves in cold start

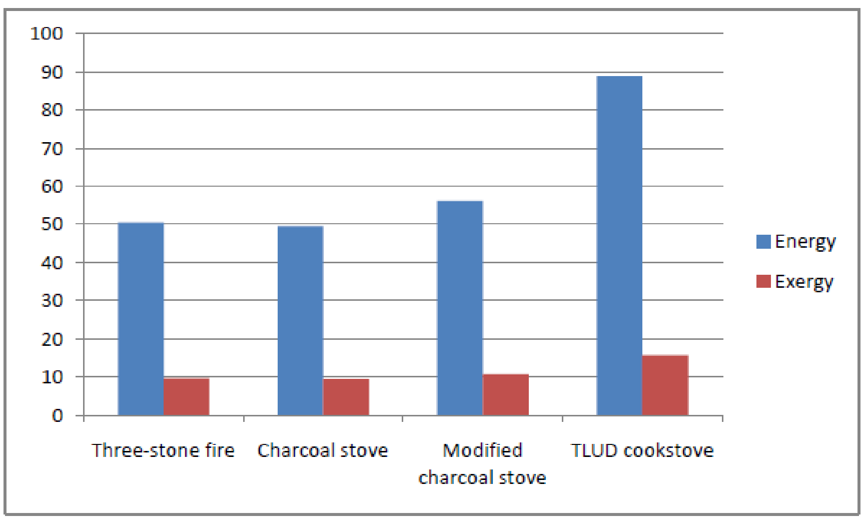

Fig. 9 Exergy and energy comparison of the cookstoves in hot start

4. Conclusions

The performance analysis of four different biomass cookstoves based on energy and exergy efficiencies was evaluated. It could be concluded that the energy efficiency which accounts for the quantity of energy flowing in and out of the cookstoves was higher than the exergy efficiency which accounts for the quality of the heat in all the cookstoves. The energy efficiency in the cold and hot start as well as the exergy efficiency in the cold and hot start of all the cookstoves investigated showed no significant numerical difference. The stoves were observed to generally consume more fuel in the cold start than in the hot start condition in boiling 5 l of water in an aluminium pot. The top-lit updraft cookstove offered better energy and exergy efficiency compared to the three-stone fire, charcoal stove and the modified charcoal stove.

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THE DIELECTRIC PROPERTIES OF SPRAY-DEPOSITED ZINC SULPHIDE THIN FILMS USING TRISODIUM CITRATE COMPLEXING AGENT

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Abstract

The purpose of this work is to the dielectric properties of spray-deposited zinc sulphide thin films using trisodium citrate complexing agent. Zinc sulphide thin films were deposited on soda-lime glass substrates at 300°C, 350°C and 400°C by chemical spray pyrolysis deposition technique. The thin films were characterized by X-ray diffraction study, which showed that the thin films are polycrystalline with hexagonal crystal structure. Surface morphology was obtained by scanning electron microscopy which showed flower-like and nanorod-like particles. The transmittance of the thin films were between 40.83 and 50.86 % at 550 nm, the energy band gap were between 3.52 and 3.72 eV while the real dielectric constant were between 9.37 and 15.95 at 550 nm wavelength. Photoluminescence exhibited emission at 380 nm. The thin films find application for the construction of poultry houses.

Key words: Zinc sulphide, trisodium citrate, dielectric constant, transmittance

1. Introduction

Energy is of great importance in human activities (Amuzuvi et al., 2014). The available fossil energy resources, particularly petroleum, are limited, and will certainly be depleted (Chen, 2011). The change to renewable energy is a sure option. One renewable energy source with a very large potential is solar energy. The total solar irradiance at sea level in one year is about 1.1 x 10^6 PWh and more energy is provided by the sun each hour than the worldwide energy consumption every year. The issues to be handled include maximally harnessing the inexhaustible solar energy which is abundantly available in the tropics. Solar cells convert solar energy directly into electricity and are an obvious way to utilize this great amount of renewable energy (Kusterle, 2014).

Zinc based chalcogenide thin films are one of the most important classes of semiconductors. However, of special interest are zinc sulphide (ZnS) thin films due to their variety of applications in optoelectronic, electroluminescence, photoluminescence devices and solar cells (Offor et al., 2017). Hence, zinc sulphide thin films have attracted attention of researchers in the past several years. The vital applications of zinc sulphide is attributed to its wide direct energy band gap of about 3.65 eV in the bulk, low optical absorption in the visible and infrared regions of the electromagnetic spectrum, high refractive index and non-toxicity (Kobayashi et al., 2013), Offor et al., 2015) and Offor et al., 2015a). Several thin film deposition methods have been adopted for the fabrication of ZnS thin films for example Physical vapour deposition (Amrollahi et al., 2011), thermal evaporation (Xiaochun et al., 2008), chemical bath deposition (Osuji, 2016) and Alkhayath et al., 2014), Continuous flow reaction (Lee et al., 2008), Co-precipitation (Patil et al., 2014), chemical spray pyrolysis (Offor et al., 2018) and Screen printing (Vipin, 2008). Currently, chemical spray pyrolysis which its advantages include scalability, simplicity and cost effectiveness is drawing great interest.

Though much work has been done on zinc sulphide thin films deposition by chemical spray pyrolysis few has been done using trisodium citrate complexing agent (Offor et al., 2018). However, to the best of our knowledge the dielectric properties of spray-deposited zinc sulphide thin films using trisodium citrate complexing agent for application in agriculture has not been reported. This will play a vital role for profitable harnessing the abundant solar energy in Nigeria.

2. Experimental procedure

Zinc sulphide (ZnS) thin films were spray deposited on soda-lime glass substrates at 300 ^oC, 350 ^oC and 400 ^oC. The films were not annealed. The substrates were washed with detergent and double distilled water (DDW), boiled in chromic acid for 1 hour and left in the acid for 5 hours. After which they were again washed with DDW, ultrasonically cleaned for 1 hour and left to dry. Then, the substrates were cleaned with acetone before the spray process.

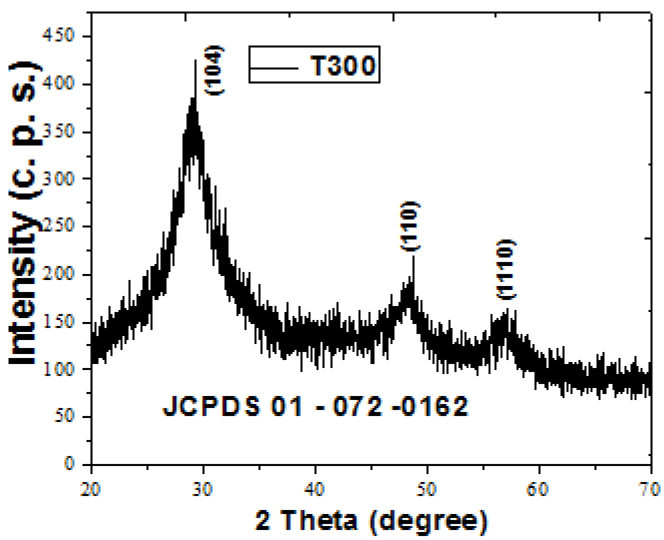
The chemicals used were zinc chloride ($ZnCl_2$) (dry) AR, Thiourea ($CS(NH_2)_2$) AR and trisodium citrate ($Na_3C_6H_5O_7.2H_2O$). $ZnCl_2$ provided Zn^{2+}, $CS(NH_2)_2$ provided S^{2-} while $Na_3C_6H_5O_7.2H_2O$ functioned as a complexing agent. 0.1 M solution of $ZnCl_2$ was prepared in double distilled water (DDW), 0.1 M of solution of ($CS(NH_2)_2$ in DDW and 0.01 solution of $Na_3C_6H_5O_7.2H_2O$ in DDW. The 30 ml final spray solution made of 10 ml of each of these three solutions was sprayed on the preheated soda-lime glass substrates at 300 ^oC, 350 ^oC and 400 ^oC. The spray rate and carrier gas flow rate were 4 ml/min and 6 ml/min respectively.

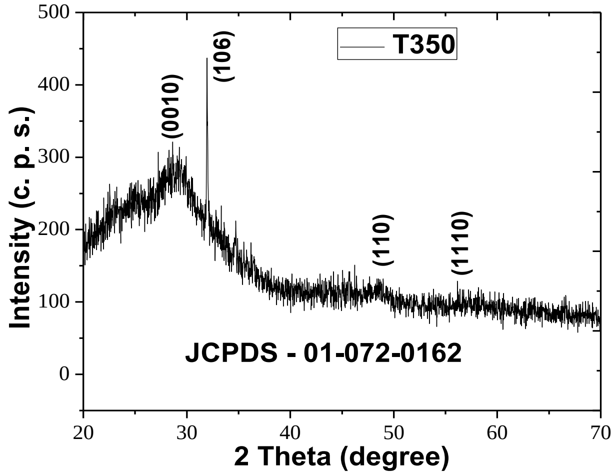
The structural properties of the thin films were analyzed by the X-ray diffraction (XRD) method employing a Bruker D2 phaser table-top model diffractometer. The surface morphology was studied with JEOL JSM-6360 scanning electron microscope (SEM) while the optical properties were determined by UV-1800 Shimadzu, UV–vis spectrophotometer. The photoluminescence study was studied with Flouromax-4 spectrofluorimeter.

3. Results and discussions

3.1 Structural analysis

The XRD patterns the zinc sulphide thin films are shown in Figure 1 as reported earlier in literature (Offor et al., 2017) and Offor et al., 2018). The presence of multiple and broad peaks shows that the ZnS thin films are both polycrystalline and nanocrystalline in nature in accordance with the literature (Offor et al., 2018).





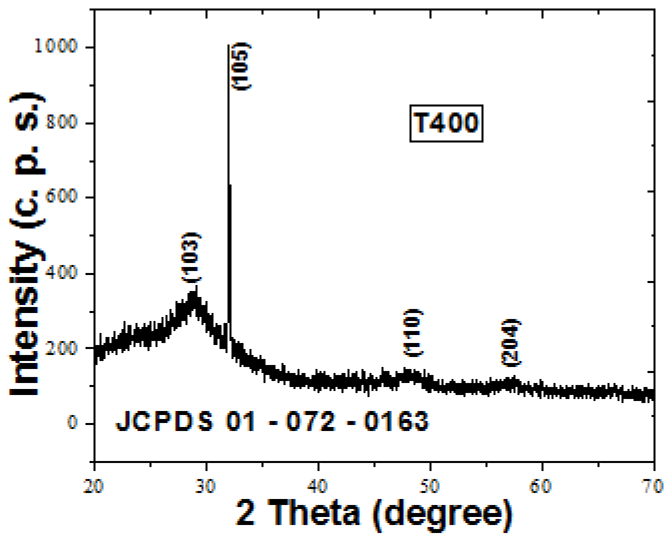
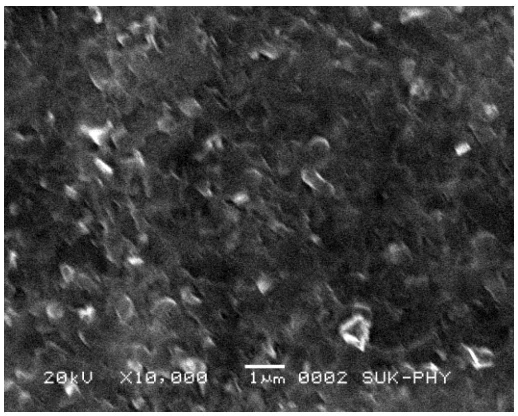


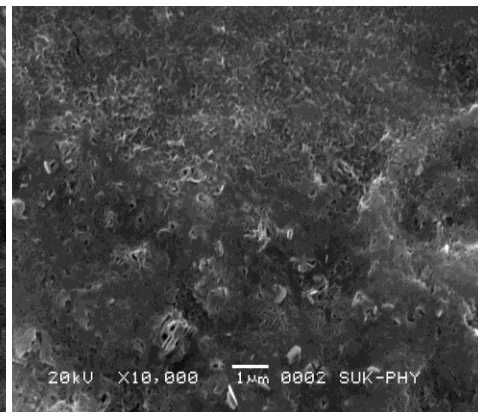
Figure 1. XRD patterns of ZnS thin films deposited at (a) 300°C, (b) 350°C and (c) 400°C Offor (2018).

The observed Bragg angle (2θ) angle and *d*-spacing values exhibited by the peaks of zinc sulphide thin film synthesized at 300°C are 29.235° (d = 3.052 Å), 47.504° (d = 1.912 Å), and 56.338° (d = 1.632 Å) which corresponds to (104), (110) and (1110) peaks of Joint Committee on Powder Diffraction Standards (JCPDS) Card No. 01 – 072 – 0162 wurtzite ZnS structure. The ones at 350°C are 28.640° (d = 3.120 Å), 32.016° (d = 2.793 Å), 47.544° (d = 1.911 Å), 56.399° and (d = 1.630 Å) which corresponds to (0010), (106), (110) and (1110) peaks of JCPDS Card No. 01 – 072 – 0162 wurtzite ZnS structure while the ones at 400°C are 28.959° (d = 3.081 Å), 32.010° (d = 2.794 Å), 47.538° (d = 1.911 Å), 57.574° and (d = 1.600 Å) which corresponds to (103), (105), (110) and (204) peaks of JCPDS Card No. 01 – 072 – 0163 wurtzite ZnS structure. These have been reported in the literature Offor et al. (2018). Increased peak intensity indicates increased crystallinity with temperature.

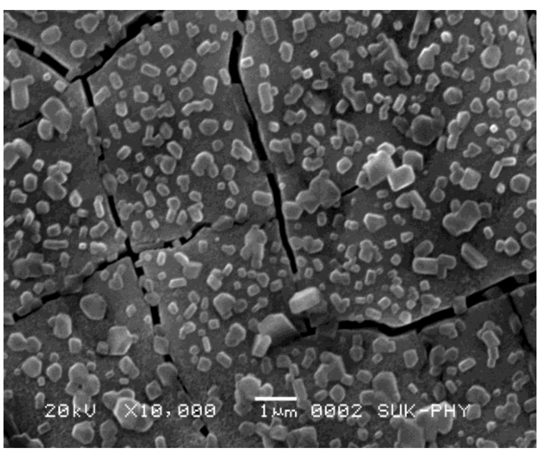
3.2 Surface morphology

Figure 2 shows SEM micrographs of the thin films being studied. It is observed that the films deposited at 300 ^oC and 350 ^oC appear flower-like. The one deposited at 350^oC is compact and more uniform. The film deposited at 400^oC is dense and uniform at the background but contains cracks and randomly distributed rectangular shaped nanorod-like particles of different sizes.





(a) (b)



(c)

Figure 2: SEM image of ZnS thin films deposited at (a) 300^oC, (b) 350^oC and (c) 400^oC.

3.3 Optical properties

Figure 3 shows that transmittance changes with the substrate temperature. It can be readily seen that that an increase in temperature enhances transmittance. This observation has been reported in literature by Nithyaprakash (2009). Moreover, shows low transmittance in the ultraviolet region. Thin films that transmit poorly in the ultraviolet region of electromagnetic radiation might be successfully used for coating of poultry houses. The reason for this is that the thin films will prevent the loss of trapped heat as reported by Osuji (2016). According to Ilenikhena (2008) and Agbogu et al. (2015) the thin films would be helpful for the erection of poultry houses (walls and roofs) to promote the utilization of under used inexhaustible infrared radiation to provide warmth for chicks and at the same time shield the chicks from ultraviolet radiations burns. Moreover, the thin films could be economically used for drying of grains, chicken manure and for egg incubation (Ilenikhena, 2008). This is good news for agriculturists. Moreover, the thin films could find application for the manufacture of anti-dazzling wind screens and mirrors (Agbogu et al., 2015a). Such wind screens and driving mirrors greatly minimized the dazzling effect of light. This will enable smooth driving of vehicles at night (Agbogu et al., 2015a).

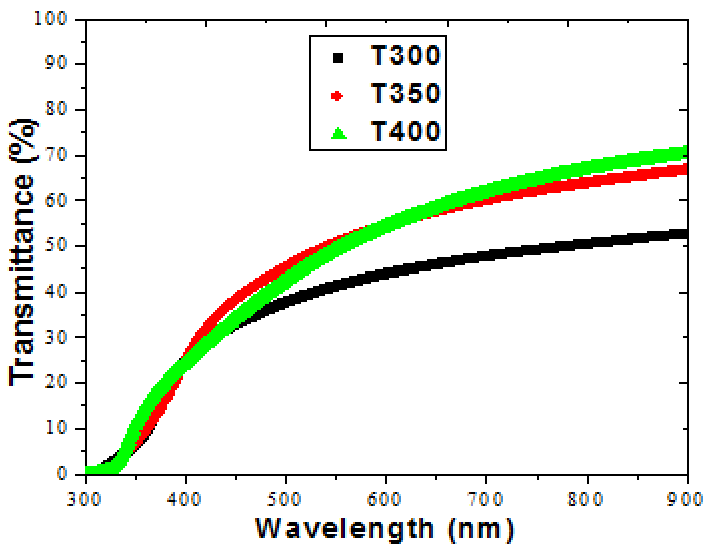


Figure 3: The transmittance spectra of ZnS thin films as a function of wavelength Offor et al. (2018).

Figure 4 shows the process of estimation of the energy band gap of the ZnS thin films deposited at 300°C, 350°C and 400°C Offor et al. (2018). The energy band gaps obtained for the films deposited at 300°C, 350°C and 400°C are 3.52 eV, 3.72 eV and 3.66 eV respectively. These are in good agreement with values reported by Nithyaprakash et al. (2009). The films will conveniently be used as window layer in solar cells (Osuji, 2016).

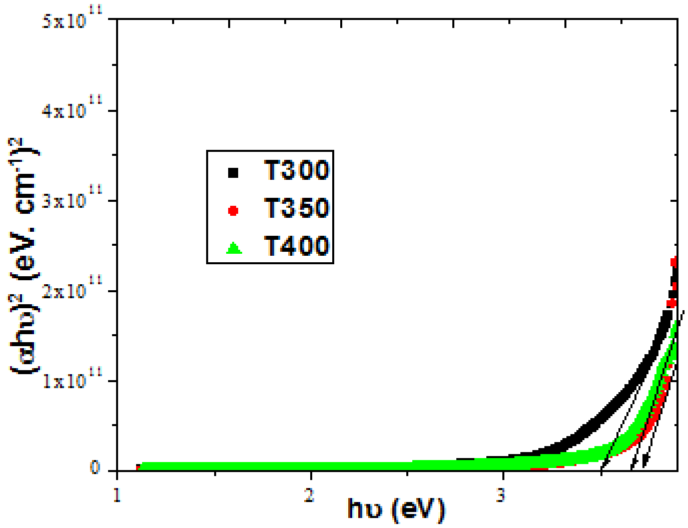


Fig. 4: The optical energy gap for ZnS thin films
Source: Offor et al. (2018).

Figure 5 shows the plot of real dielectric constant of the thin films with wavelength (Offor et al., 2018). The thin films have values of real dielectric constant which are between 9.37 and 15.95. The real dielectric constant is a measure of retardation of the speed of light through a given material (Bakr et al., 2014). The higher the value the more the speed of propagation of light is retarded in the material of interest. A material with high real dielectric constant would readily find application as effective coating of poultry houses because it would reduce entry of light into the houses. This would shield the chicks from ultraviolet radiation or heat burns.

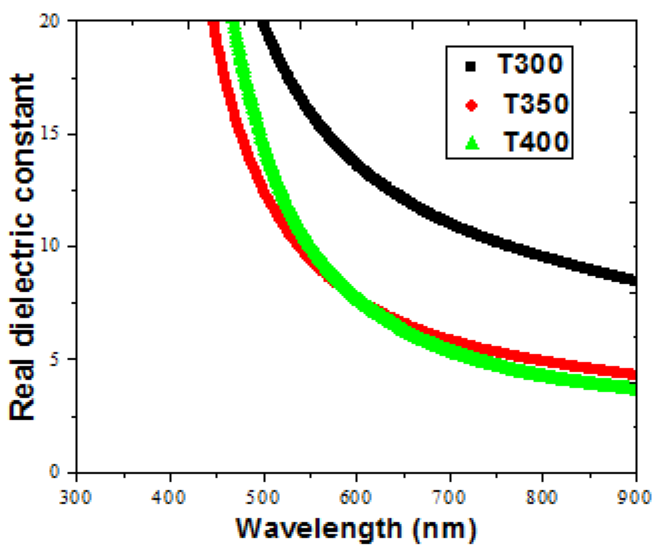


Figure 5. The Real dielectric constant of ZnS thin films as a function of photon energy.

Figure 6 shows the plot of imaginary dielectric constant of the thin films with wavelength. The imaginary dielectric constant is a measure of how much a dielectric material absorbs energy from an electric field due to dipole motion (Bakr et al., 2014). Actually, this is a measure of charge absorption and storage by a given dielectric material. A material with high value of imaginary dielectric constant will readily find application as a capacitor used for charge storage. Thin films with high dielectric constants find applications as capacitors for charge storage. This was observed earlier in the literature by Dhanam et al. (2009) for tin selenide thin films.

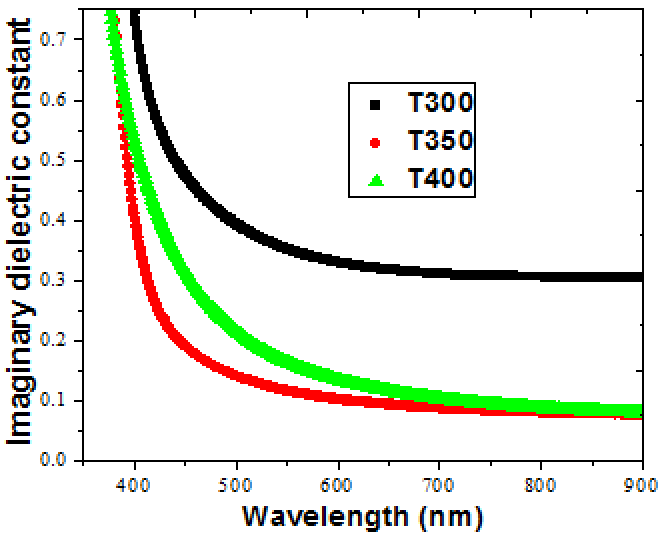


Figure 6. The imaginary dielectric as a function of wavelength

3.6 Photoluminescence

Photoluminescence (PL) spectrum of zinc sulphide thin films deposited with trisodium citrate complexing agent 300^{o}C by spray pyrolysis technique is shown in Figure 7 by Offor et al. (2018).

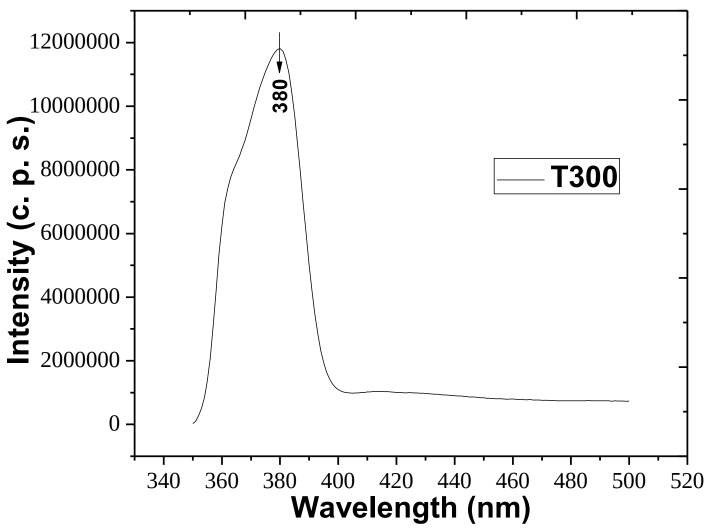


Figure 7: Photoluminescence Spectra of ZnS thin film with trisodium citrate complexing agent

Source: Offor et al. (2018).

Figure 7 shows a peak at emission wavelength of 380 nm for the deposited ZnS thin film (Offor et al., 2018). The position of the emission maxima the emission wavelength of 380 nm indicated excitonic near band edge emission. The principle is that on excitation electrons transfer from the valence band to the conduction band. The electrons jump to apparent equilibrium states otherwise interstitial states are formed by sulphur or oxygen leading to the formation of excitonic band emission at 380 nm (Lohar et al., 2014). This observation is in line with report in the literature by Onwudiwe et al. (2014).

Conclusion

Zinc sulphide thin films were deposited on soda-lime glass substrates at 300°C, 350°C and 400°C by chemical spray pyrolysis deposition technique. The thin films were characterized by X-ray diffraction study which showed that the thin films are polycrystalline with hexagonal crystal structure. Surface morphology was obtained by scanning electron microscopy which showed flower-like and nanorod-like particles. The thin films have low transmittance in the ultraviolet region. The transmittance of the thin films were between 40.83 and 50.86 % at 550 nm, the optical energy band gap were between 3.52 and 3.72 eV while the real dielectric constant were between 9.37 and 15.95 at 550 nm wavelength. Photoluminescence exhibited emission at 380 nm. The thin films find application for the construction of poultry houses.

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FORMULATION AND PROCESS OPTIMIZATION OF COMPOSITE GARRI FROM THE BLENDS OF CASSAVA, SWEET POTATO AND BENISEED MEAL

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ABSTRACT
Garri is one of the staple foods in Nigeria made from cassava which have been gelatinized and dried. Research has shown that over 70% of the cassavas produced in Nigeria are processed into garri. This study investigated the formulation of garri made from blends of cassava, sweet potato and beniseed meal. The impact of beniseed roasting temperature, beniseed roasting time, cassava/sweet potato fermentation time, garification temperature and garification time on garri quality were also investigated. Investigations were conducted employing a three-component, five processing parameters, constrained D-optimal mixture-process experimental design with 33 randomized experimental runs. The formulation design constraints were cassava $20\% \leq x_1 \leq 70\%$, sweet potato $20\% \leq x_2 \leq 40\%$ and beniseed meal $10\% \leq x_3 \leq 30\%$. The processing parameters investigated were beniseed roasting temperature $80°C \leq z_1 \leq 150°C$, beniseed roasting time $10min \leq z_2 \leq 20min$, cassava/sweet potatofermentation time$24hr \leq z_3 \leq 72hr$, garification temperature $80°C \leq z_4 150°C$ andtimemin$\leq z_5 \leq 25min$. The formulated samples were evaluated for the proximate properties, physical properties and sensory properties. From the numerical optimization through the desirability function, the formulation that produce composite garri of highest desirability index was 50% of cassava, 25.068% of sweet potato, 24.932% of beniseed meal with beniseed roasting temperature of 80°C, beniseed roasting time of 11.26min, cassava/sweet potato fermentation time of 72hr, garification temperature of 80.17°C and garification time of 5min. The proximate properties, physical properties and sensory properties of optimal formulation are as follows; - 9.01% moisture content, 7.88% protein content, 1.41% ash content, 0.90% fibre content, 4.40% fat content, 75.95% carbohydrate content, 147.94% water absorption capacity, 4.01 pH, 200.56% swelling capacity, 0.73g/ml bulk density, 5.77 colour, 6.38 aroma, 6.31 taste, and 5.87 texture and 6.48 overall acceptability.

Keywords: Garri, Optimization, Formulation, Beniseed meal, Sweet potato, Cassava.

1.0 INTRODUCTION

Garri is a free-flowing product, made mainly from cassava which have been gelatinized and dried. In Nigeria, over 70% of the cassava yield is processed into garri (Sanni and Olubamiwa,2004). Composite flour is a mixture of flours, starches, and other ingredients intended to replace wheat flour totally or partially in bakery and pastry products (Noorfarahzilah *et al.*,2014). Composite Garri is the mixture of grated cassava, leguminous crops or rich protein cereals and other ingredients intended to replace grated cassava totally or partially in the production of garri in order to increase the nutritional content of the product.

Cassava belongs to the class Dicotyledoneae, family *Euphorbiaceae*, species *Manihot esculenta Crantz* (Alves, 2002). Cassava (*Manihot esculenta crantz*) is a major food crop in Nigeria, supplying about 70% of the daily calorie of over 50 Million people (Oluwole *et al.*,2004). It has also been estimated that cassava provides food for over 500 Million people in the world, (Abu *et al.*,2006). It is essentially a carbohydrate food with low protein and fat (Ajala *et al.*,2012). Edible part of fresh cassava root contains 32-35% carbohydrate, 2-3% protein, 75-80% moisture,0.1% fat, 1% fibre and 0.75 -2.50% ash (Ajala *et al.*,2012; Oluwole *et al.*,2004). Cassava roots are highly perishable and a lot of post-harvest losses occur to this commodity during storage due to high physiological activities and activities of micro-organisms that entered bruises received during harvesting as well as the inherent high moisture content of fresh roots which promote both microbial deterioration and unfavourable biochemical changes in the commodity (Ajala *et al.*, 2012). The Sweet potato (*Ipomoea batatas (L.) Lam*.) is a dicotyledonous root and tuber crop belonging to the family *convulaceae* (Zhang *et al.*, 2000). Sweet potato particularly provides energy in the human diet in the form of carbohydrates. According to USDA (2009), besides carbohydrates, they are also rich in dietary fibre and have high water content and also provide 359 kJ energy with low total lipid content, which is only about 0.05 g per 100 g. In addition, sweet potatoes also are high in minerals such as potassium, calcium, magnesium, sodium, phosphorus, and iron (USDA, 2009). Because of the various roles that sweet potatoes play around the world, the concept of nutritional quality and its contribution must transform to meet specific roles in human diet. Beniseed (*Sesamum indicum L.*), a member of the *Pedaliaceae* family, is an erect annual herb commonly known as sesamum, benniseed, or simsim. In Nigeria, beniseed occurrence is fairly widespread, borne out by the fact that there are over twenty different names in different languages for the crop (Dia and Gwandi, 2015). It is called Ridi (Hausa), Isasa (Igbo), Ocha (Idoma), Ekuku (Yoruba) etc. Main areas of cultivation in Nigeria are around guinea and sudan savannah zones including large portions of present day Jigawa, Pleateau, Kano, Kastina, Yobe, Gombe, Benue, Kwara, Kogi, Nasarawa, and Niger States, (Faisal *et al.*, 2016 ; Ojiako *et al.*, 2010). Beniseed seeds have both nutritional and medicinal value because they are rich in fat, protein, carbohydrates, fibre, and essential minerals. They are chemically composed of 44–57% oil, 18–25% protein, 13–14% carbohydrates (Borchani *et al.*, 2010). Beniseed oil is famous for its stability as a result of its resistance to oxidative rancidity after long exposure to air (Global Agri Systems, 2010). Garri is nutritionally inferior with low protein content; there is need therefore to improve the nutritional quality by substituting other nutritionally rich quality crops like the legumes. The major objective of this study is to formulate, via mixture process design, composite garri from blends of cassava, sweet potato and beniseed meal. However, processing parameters play vital role in the final quality of the product. The variable processing parameters considered in this study are beniseed roasting temperature, beniseed roasting time, cassava/sweet potato fermentation time, garification temperature, and garification time.

2.0 MATERIALS AND METHODS

2.1 Collection and Preparation of SamplesThe major ingredients for this study include cassava, sweet potato, beniseeds. They are obtained from Kure Market, Minna Niger State.

2.2 Equipment and Apparatus

The equipment and apparatus used in the study include stainless steel knife, trays, gas cooker, weighing balance, jute sacks, hydraulic press, plastic containers, thermometer, frying pan, spatula, grating machine, chopping board, oven, petri dishes, crucibles, desiccator, Kjedehl apparatus, muffle furnace, beaker, filter paper, soxhlet apparatus, magnetic stirrer, centrifuge, measuring cylinder, pH meter, conical flask, and thimble.

2.3 Preparation of Beniseed Meal

Beniseeds meal was prepared according to the methods of Ayo *et al.*, (2012). The Beniseeds were thoroughly cleaned to remove stones and other extraneous materials. The cleaned beniseeds were toasted (roasted) at different temperatures and duration as specified in the design matrix (Table 1)

2.4 Preparation of Cassava/ Sweet Potatoes

Cassava and sweet potato tubers were prepared according to the methods of Ojo and Akande, (2013). The cassava and sweet potato were differently sorted, washed and peeled. The different peeled tubers were cut into smaller sizes, grated, dewatered and fermented at different fermentation durations as specified in the design matrix (Table 1).

2.5 Processing of Composite Garri

The milled beniseed meal were incorporated into the fermented cassava and sweet potato mashes at different proportion as specified in the design constraints (Table 2) and sieved together using hand sieve. After sieving, the composite blends were toasted (garified) in a shallow iron pan at different garification temperatures and time as specified in the design matrix (Table 1) with intermittent stirring until thoroughly gelatinized. The products were removed from the iron pan and spread out on a tray to be cooled before packaging. (See Fig.1)

Table 1; Matrix design

	X1	**X2**	**X3**	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**
Run	**(%)**	**(%)**	**(%)**	**(°C)**	**(min)**	**(hrs)**	**(°C)**	**(min)**
1	50	20	30	150	10	72	150	5
2	56.667	26.667	16.667	150	20	24	**80**	25
3	60	30	10	150	10	24	150	25
4	50	20	30	80	10	24	150	5
5	70	20	10	80	20	72	80	25
6	50	20	30	150	10	24	80	25
7	70	20	10	80	10	72	150	5
8	50	40	10	150	10	24	150	25
9	50	20	30	150	20	24	150	25
10	70	20	10	150	10	72	80	25
11	53.333	23.333	23.333	115	15	48	115	15
12	70	20	10	150	20	24	150	25
13	70	20	10	80	20	24	150	5
14	50	40	10	80	20	24	80	5
15	70	20	10	150	20	24	80	5
16	50	20	30	80	10	24	150	5
17	56.667	26.667	16.667	150	20	24	150	5
18	50	40	10	80	20	72	150	25
19	50	40	10	150	20	72	150	5
20	70	20	10	80	10	24	80	25
21	50	30	20	80	20	24	150	25
22	56.667	26.667	16.667	150	10	24	80	5
23	56.667	26.667	16.667	80	20	72	150	5
24	50	20	30	80	10	72	150	25
25	50	40	10	80	10	72	80	5
26	60	20	20	80	20	72	80	25
27	50	20	30	80	20	72	80	5

28	60	30	10	150	10	72	80	5
29	50	20	30	80	10	72	150	25
30	50	40	10	150	20	72	80	25
31	50	40	10	150	10	24	150	25
32	50	40	10	80	20	24	80	5
33	50	20	30	80	20	72	80	5

X_1 = Cassava (%) Z_1 = Beniseed Roasting Temperature (°C)

X_2 = Sweetpotato (%) Z_2 = Beniseed Roasting Time (Min)

X_3 = Beniseed Meal (%) Z_3 = Cassava/ Sweetpotato Fermentaion Duration (Hrs)

Z_4 = Garification Temperature (°C)

Z_5 = Garrification Time (Min)

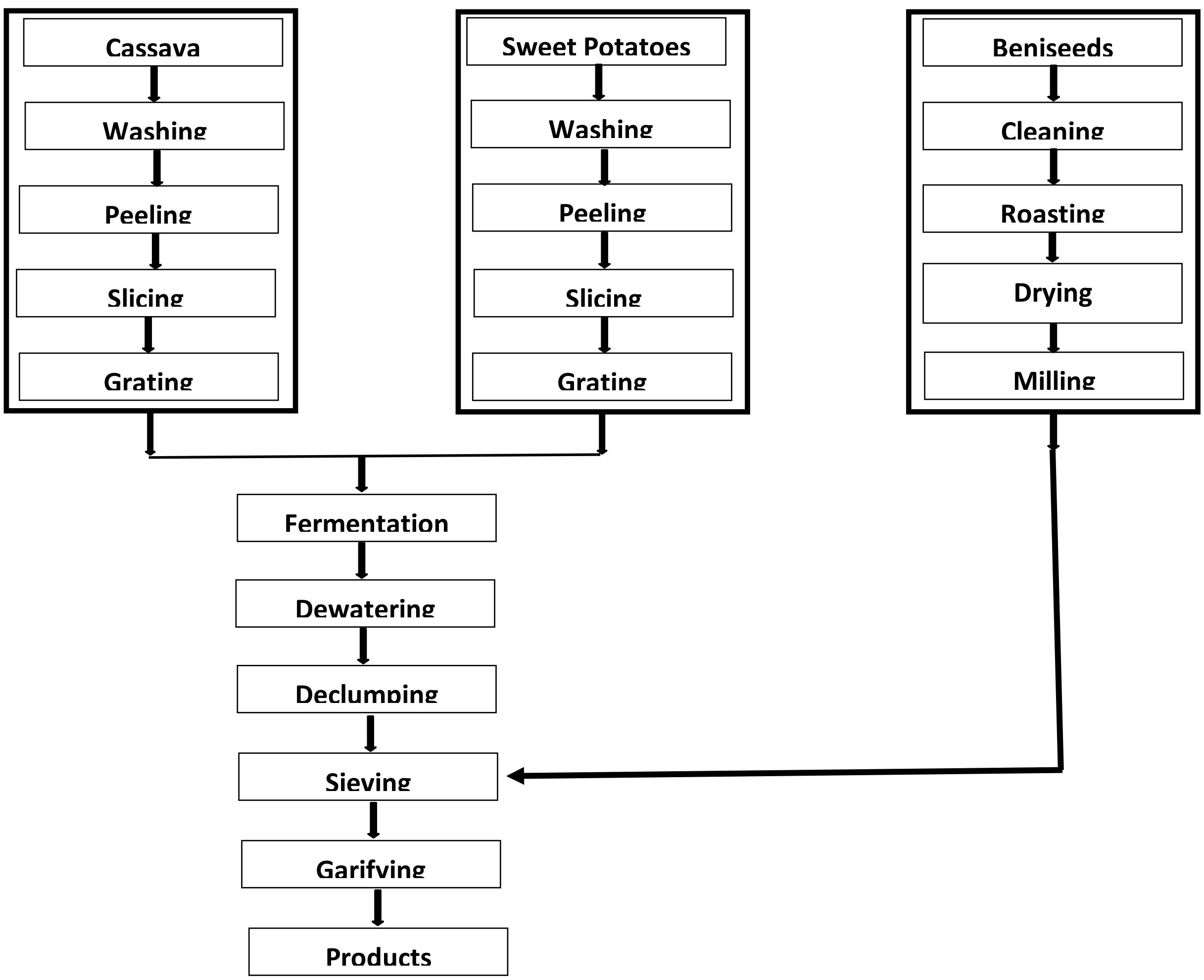

Figure 1: Flowchart of Composite Garri Production

Low	Constraints	High
20	x_1: Cassava (%)	70
20	x_2: Sweet Potato (%)	40
10	x_3: Beniseed meal (%)	30
	x_1+x_2+x_3	100

2.6 DESIGN SUMMARY

Table 2; Design constraints for matrix components

Table 3; Design constraints for process variables

Low	Constraint	High
80	z_1: Beniseed RoastingTemperature (°C)	150
10	z_2: Beniseed Roasting Time (min)	20
24	z_3: Cassava/Sweet Potato Fermentation Time (hr)	72
80	z_4: Garification Temperature (°C)	150
5	z_5: Garification Time (min)	25

2.7 Proximate analysis

The moisture content, protein, ash, fat, fibre, and carbohydrate were determined using methods of Association of Official Analytical chemist (AOAC, 2002).

2.8 Physical Properties

Water absorption capacity was determined using the method of Ajala *et al.,* (2012), pH using the method of Nwafor *et al.*, (2015), swelling index with the method of Nwosu *et al.*, (2011), and bulk density was determined using the method described by Nwanekezi *et al.,* (2001).

2.9 Sensory Properties

Sensory evaluation of the samples was conducted using Twenty panelists. A 9-point hedonic scale ranging from 9= like extremely and 1= dislike extremely was used to evaluate the samples for colour, aroma, taste, texture and overall acceptability. Table water was used for mouth rinsing intermittently to minimize the carry over effects (Akinjayeju, 2010)

2.10 Statistical Analysis

Design expert 11.0 software was employed for both the design and the analysis of the obtained data.

3.0 RESULT AND DISCUSSION

3.1 Results

The overlay contour and the overlay contour – mixture process plots showing the optimized formulation with the respective processing parameters are presented in figures 2 and 3.

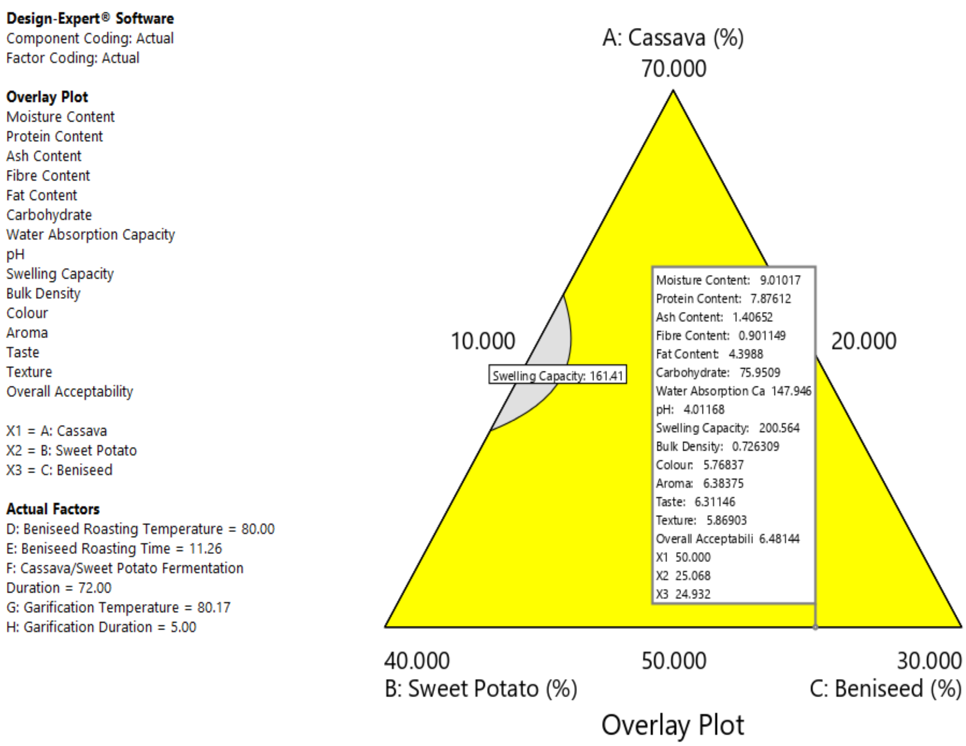

Figure 2: Overlay Contour Plot for the Effect of Formulation of Cassava, Sweet-potato and Beniseed on Desirability.

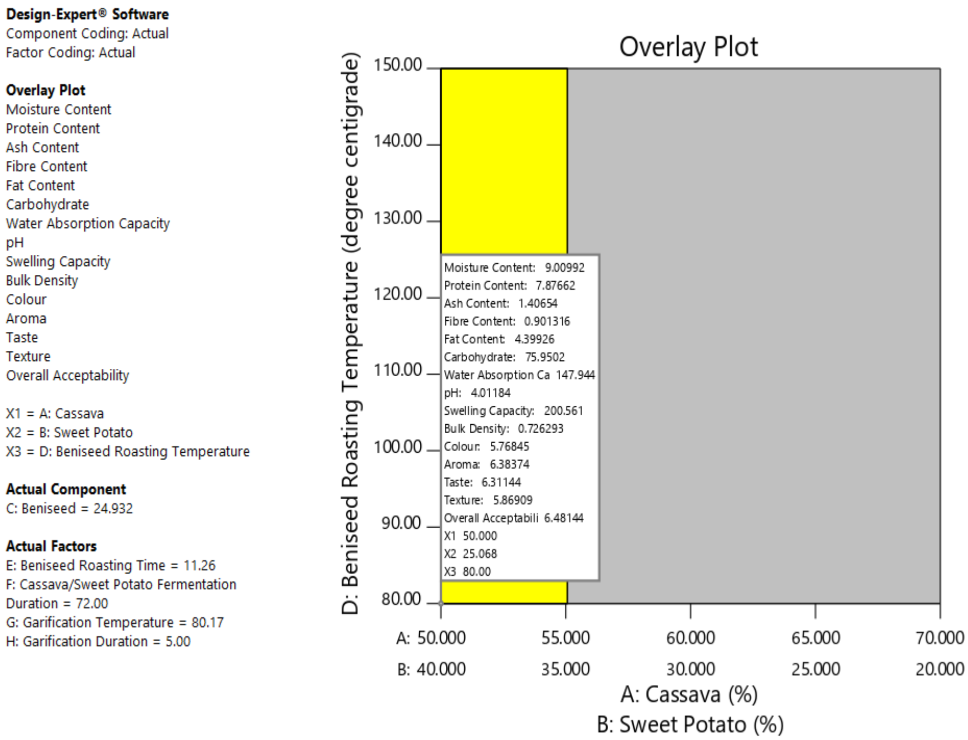

Figure 3: Overlay Contour Mix-Process Plot Showing the Effect of Beniseed RoastingTemperature of the grated Cassava, Sweet-potato on Desirability.

3.2 Discussion

A Numerical optimization method exploiting the desirability technique was utilized to generate the optimal formulation with the anticipated responses. The optimal formulation was obtained based on the criteria of achieving minimum usage of cassava, maximum usage of sweet potato, maximum usage of beniseed, minimum beniseed roasting temperature, minimum beniseed roasting time, targeted cassava/sweet potato fermentation duration of 24hr to 72hr, minimum garification temperature, minimum garification duration, minimum moisture, maximum protein, maximum ash, maximum fibre, minimum fat, minimum carbohydrates, maximum water absorption capacity, minimum pH, maximum swelling capacity, maximum bulk density, maximum sensory properties.

Optimal garri with desirability index of 0.552, based on the individual processing parameters and response desirability indices was obtained. Desirability is an objective function which varies between 0 and 1. The numerical optimization locates a point that maximizes the desirability. The box in the overlay contour indicates the best mixture that gave rise to the best responses. The box on the overlay contour mix-process plot shows the optimal conditions for the composite garri product.

4.0 Conclusion

From the numerical optimization through desirable function, the formulation that produced composite garri of highest desirability index of 0.552 are 50.000% cassava, 25.068% sweet potato 24.932% beniseed meal. The proximate composition of the optimal formulated composite garri obtained are 9.01% moisture content, 7.88% protein content, 1.41% ash content, 0.90% fibre content, 4.40% fat content, 75.95% carbohydrate content. The optimal physical properties obtained are 147.94% water absorption capacity, 4.01 pH, 200.56% swelling capacity, 0.73g/ml bulk density. The Optimal sensory properties rated by the panelists are 5.77 colour, 6.38 aroma, 6.31 taste, 5.87 texture and 6.48 overall acceptability. The optimized garri shows the processing conditions of 80◦C beniseed roasting temperature, 11.26min beniseed roasting Time, 72hours cassava /sweet potato fermentation duration, 80.17C garification temperature and 5.00min garification time.

Acknowledgement

My sincere gratitude goes to my Supervisor Dr. S.T. Olorunsogo who despite his schedule took time to supervise this work from the beginning to the end and his fatherly advice. May the Good LORD continue to bless you abundantly. I remain indebted to Miss Esther Odinaka Orjigwe for her kind gestures throughout this work and beyond may the Lord continue to bless her for me.

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COMPARATIVE ANALYSIS OF OIL EXTRACTION FROM *MORINGA OLEIFERA* SEED USING MECHANICAL AND SOLVENT METHODS

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ABSTRACT

This study evaluated the comparative analysis of oil extraction from *Moringa oleifera* seed using mechanical and solvent methods. Moringa is regarded as nutritive and medicinal source available in the tropics whose seeds possess inherently rich vegetable oil. The seeds for the investigations were obtained locally from market in Enugu state. 120g of the Moringa seeds were used. The seeds were also subjected to proximate analysis to ascertain the physicochemical properties. Thereafter, the seeds were separated from the membrane and broken to remove the kernel from the hard shell. At stepwise increment of moisture content starting from 5-15% and time interval of 10-50 min with varying temperature of 60-75^{o}C, the milled granules were subjected to mechanical screw press; the substrates were also subjected to solvent extraction using N-HEXANE for the oils. The proximate analysis carried out showed that the Moringa seeds were composed of 5.0% crude fibre, 0.60% moisture content, 1.50% Ash, 2.19% Crude protein, 39.50% crude fat, 56.42% carbohydrate. The oils extracted from mechanical screw press were 90.5% for 30min while solvent extraction methods were 181% for 30min. Therefore, the oil gotten from solvent extraction methods was double compare to the mechanical method. The oil obtained can be used for both industrial and domestic needs.

Keywords: *Moringa oleifera* seed, comparative analysis, Mechanical screw press, and solvent extraction method.

1.0 INTRODUCTION

Moringa oleifera, known as “Moringa” or “Malungay” is an Indian tree that also grows in Asia, Africa, South America, the Caribbean and Oceania. *Moringa oleifera* plant which is the most widely cultivable species of the genus Moringa belongs to the family Moringaceace (Ahmad et al., 2016). It is described as a wonder plant thus essential for food security (Egboka et.al, 2010). Moringa is one of the important plant species in Nigeria that can provide the natural capital for health, livelihood as well as industrial raw material. But due to limited knowledge of the value of the plant, they are depleted, destroyed through bush burning, deforestation and so on

(Ogwo and Ogbonnaya, 2010). It is considered very useful, as every part of it is used for food or other beneficial applications (Mani et al, 2007)~~.~~ The oil extracted from Moringa is known as Ben oil and reportedly contains 70% of oleic acid, an 18-carbon long monounsaturated fatty acid (MUFA). Since the oleic acid has good oxidative stability when compared with polyunsaturated fatty acids (PUFAs), it has found use in the food industry, as it allows for longer storage and high-temperature frying processing. It also has usefulness in medicine and water treatment. According to Abdulkarim et al. (2016) Ben oil is more stable than canola oil, soybean oil, and palm oil when used in frying. Blending Ben oil with sunflower oil and soybean oil enhances the oxidative stability of the mixture. Mani et al. (2007) discussed that comparing chemical properties of vegetable oil, Moringa seed oil is considered equivalent to olive oil, and may be used for human consumption. Moringa seeds has shown the strongest anti-fungal activity against a zoophilic dematophyte, that can cause marked inflammatory reactions in humans (Chuang et al, 2007). Moringa oil is a potential biodiesel feedstock. Currently, there is a nascent biodiesel industry in the Yucatan Peninsula, Mexico, that has been active for the last 2 - 3 years. Several groups are trying to obtain biodiesel from vegetable oils, especially *Jatropha curcas*, and from waste cooking-oil. As an alternative source of oil, Moringa seeds have been proposed as a potential source to complement the mentioned feedstock. With all these potentials of Moringa, there is no doubt that it has both domestic and commercial usage. Therefore, the objectives of this study were to ascertain the oil content of Moringa seeds and compare the efficiency of the two oil extraction method.

2.0 MATERIALS AND METHODS

Fresh Moringa seeds (pod) were sourced locally from Ogbete main market Enugu ~~S~~tate. The pods were pre-treated to get the seeds. The weight of the seed sample was 120g (which is equivalent to 12 cups of the seed). The seeds were cleaned and samples taken for proximate analysis to ascertain the physicochemical properties of the seeds. The seeds were separated from the membranes and broken to remove the kernel from the hard shell. The moisture content of the seeds were determined by stepwise increment of moisture content starting from 5-15% and time interval of 10-50 min with varying temperature of 60^{o}-$75^{o}C$ were adopted for this study. The seed kernels were crushed into fine particles with grinder. These particles were sieved using sieve shaker of 500µm to facilitate oil extraction. The samples were stored in a safe place for oil extraction purposes. The mechanical oil extraction process was carried out with the use of instrument such as: Mechanical Screw press, Stop watch, Rotary Evaporator, Centrifuge, Sieving cloth, digital weighing machine, aluminum weighing boat, hot plate(burner), and heating mantle,

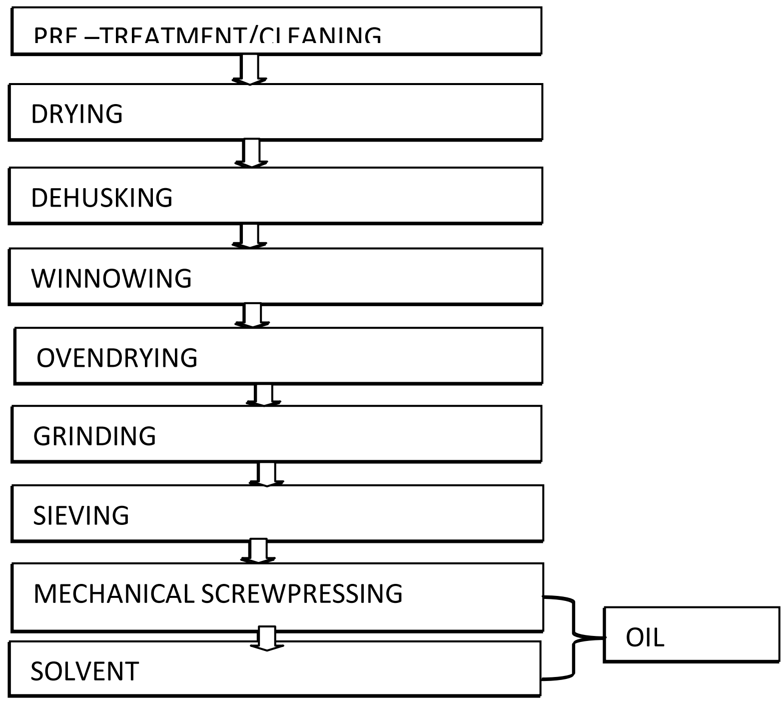

Fig. 1: Flow chart of the oil extraction process of Moringa seeds.

while that of solvent extraction process includes: condenser, thimble, filter paper, reagent bottle (100ml, 250ml, 500ml & 1 litre), beakers (500ml), rotary flask (500ml), round bottom flask (1 litre), soxhlet apparatus, and N-hexane solution. The unit operations undertaken to prepare the seed for oil extraction are given in figure 1 above.

2.1 Moringa seed sample preparations

Preparation started with collection of riped *Moringa oleifera* pods containing the seeds thus with continued cleaning. Cleaning process was crucial since cleaned seeds yield clean oil devoid of impurities. Thereafter, the seeds were subjected to oven drying for 24 hours at 105ºC in order to further reduce the seeds moisture content then undergo size reduction process as stated above. The grinded seeds were sieved using 200mm, 100mm, 500µm sieve and weighed using electronic weighing balance to get 0.001µm fine particles that will be subjected to mechanical screw press.

Seed collection/preparation

The locally sourced Moringa oleifera seed pods were collected and sundried. The drying process stimulated the opening of the pods to release seeds embedded inside. The seeds were separated from the chaffs and other impurities and were made whole.

Drying, Milling and weighing process

After cleaning process, the seeds were subjected to electric oven drying at range of 60^{o}C-75^{o}C to reduce the moisture content of the seeds from 5-15% dry basis. Moringa oleifera seeds were milled into pastes using hammer Willey mill. This operation ruptured the cell walls and released the endogenous substances that prepared the seed for oil extraction. Before the operation above, the weight of the moringa seed after cleaning or before oil extraction were 220.5g and the weight of the fine granules of the seeds after milling were 120g using electronic weighing balance.

2.2 Oil extraction process

The conventional processes involved in oil extraction from seeds had been to subject the seed to mechanical screw press. The residual oil on the substrates were recovered through solvent extraction to completely expel the oil out of the seed.

Fig. 2: Showed the Mechanical Screw press Experimental setup.

The grinded Moringa seed were poured into the hopper of the mechanical screw press, and then covered with rounded iron plate thereafter; the oil expeller was tightened continuously in clockwise direction to expel oil from the moringa seed for 60min. Fig 2 above shows the experimental setup of the mechanical screw press used in the oil extraction process. After that, the substrates (with residual oil) were used for solvent extraction process.

Soxhlet apparatus with n-hexane as solvent was used in this operation. 20g of the substrates(grinded sample) were emptied into the thimble. Two third volume of the round bottom flask was filled with the solvent. The heating mantle was adjusted to (60-75ºC) at the interval of 10-50min, then heating commenced. When the solvent got heated up, it evaporated, and the solvent condensed back into the sample in the thimble to continue the cycle. The oil got extracted in the process due to change in the densities of the solvent and the oil via the rotary evaporator at the temperature of 65^{0}C.

Fig.3: Experimental set up of the solvent extraction method of moringa seed

Some portion containing the solvent then recycled back to the round bottom flask as it refluxed and the total process of reflux continues until all oil was extracted. This process was repeated for 5 more runs of the sample to expel all the oil. Proximate analysis was carried out according to the procedure of Association of Official Analytical Chemist (AOAC, 1990) to determine the moisture content, crude fiber, protein, crude fat, and carbohydrate components of the seed oil.

3.0 RESULTS AND DISCUSSIONS

The Moringa seeds sample was taken for laboratory test to determine the proximate composition of the seed. Table 1.0: shows the proximate composition of the *Moringa oleifera* seed sample.

Table 1.0: Proximate Composition of *Moringa oleifera* seed

Nutrient	Composition%
Moisture content	10.60 ± 0.07
Ash	6.50 ± 0.01
Crude fiber	5.00 ± 0.00
Crude protein	40.19 ± 0.21
Crude fat	33.50 ± 1.00
Carbohydrate	7.42 ± 0.72

Each data is mean of three replicates ± standard deviation (S.D)

The result above was in close agreement with Aja et al, 2013. Slightly low moisture content in *Moringa oleifera* seed indicated moderate activities of the deteriorating micro-organisms thereby increased the shelf life of *Moringa oleifera* sample. The moisture content value of 10.50% was higher than the value 9.40% and the ash content was 5.00% and was higher than the value 3.87% reported by (Peter *et al*, 2014) but in agreement with the value 5.00% ash content reported by (Aja et al, 2013). The crude fiber content was 5.00% and this was higher than 2.87% reported by (Peter and Philip 2014) but lower than 2.0% reported by (Aja et al, 2013), Crude protein and fat content were 39.57% and 32.50% respectively. The crude protein content was higher than 35.97% and 29.98% reported by (Peter and Philip 2014 and Aja et al, 2013).The oil extracted was subjected to laboratory test to characterize the oil extracted for further studies. Table 2.0: showed the chemical properties of the extracted *moringa oleifera* seed oil.

Table 2.0: Showed chemical properties of *Moringa oleifera* seed oil.

Characteristics	Values
pH	5.96 ± 0.03
Saponification value	164.09 ± 1.58mg/g
Iodine value	68.23 ± 0.60g/mol
Free fatty acid	8.27 ± 0.19mgkoH/g
Specific gravity	0.86 ± 0.01

From the table 2.0 above, the specific gravity of *Moringa oleifera* seed oil was 0.86 with higher iodine value which indicated higher unsaturation fats and oils. The iodine value of the oil was 68.23, the Saponification value of the oil was 164.09, the free fatty acid of oil was 8.27 mgKOHg-1 and these values were in agreement with the (FAO/WHO, 2009) reported on the 21st session of the Codex Alimentarius Committee on fats and oils, Kola Kinabalu, Malaysia, International standard for edible oil. From the study, the extraction methods adopted yielded percentage oil as shown in table 3.0 below.

Table 3.0: Oil yield from *Moringa oleifera* seeds extraction methods

Methods	vegetable oil obtained (%)
Mechanical screw press	90.5
Solvent Extraction	181

From the table, solvent extraction method yielded 181% while mechanical screw press produced 90.5%. Therefore, the yield by percentage was at the ratio 2:1. The oil seed subjected to mechanical screw press yielded low oil by to percentage when compared to solvent extraction method.

4.0 CONCLUSIONS

Moringa oleifera seed has proven the characteristics and potentials of an oil seeds and its full values should be explored. It contained high unsaturated to saturated fatty acids ratio with its high iodine and saponification values and might be an acceptable substitute for high saturated oil such as olive oil in diets. The study showed that mechanical screw press yielded 90.5%, while the solvent extraction method yielded 181% of vegetable oil respectively. Therefore, the amount of oil produced in solvent extraction method was much more than the oil produced from mechanical screw press method. While the former were devoid of impurities the latter were recovered from chemical process but possessed the same quality. The oil extracted from seeds could be of economic importance in the areas where the trees are cultivated in abundance. There should be further studies to compare oil yield from these two extraction methods for Moringa seeds with other non-edible vegetable oil seeds. Finally, to investigate the effects of temperature in oil yield based on the two extractions adopted.

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OVER VIEW OF POST-HARVEST FOOD LOSSES HANDLING TECHNOLOGIES

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ABSTRACT

Post-harvest food losses have been and still a major problem globally, especially among the developing countries due to inadequate availability of handling, processing and storage facilities. Studies showed that the total food production in sub-Sahara Africa as at 2014 was estimated to range between 31.95-34.22 million tons while postharvest losses ranged between 30-80% based on crop types. Globally, postharvest losses were estimated between 30-50% based on crop types. This paper examined the existing traditional methods of postharvest handling of agricultural products. It also went on to outline the present modern postharvest handling technologies practiced by farmers in handling food losses after crop harvest. It concluded that improved application of modern postharvest food technologies in handling postharvest losses of agricultural produce could guarantee food security among nations. Suggestions on the role of government, institution, private organization and individual were also outlined.

INTRODUCTION

Post-harvest handling of crops is a sub-sector in agriculture covering all activities from immediately after harvest to further processing; this includes threshing, cleaning, sorting, grading, drying, pest control and management, quality control, standardization, transportation, milling, packaging and storage. Quantitative and qualitative losses could occur from the time of harvest till it reaches to consumers. This food losses have been and is still a major problem globally especially in the developing countries, that lack modern storage and processing facilities (Odemero & Ngozi, 2014; Salunkhe *et al.*, 1974). The total food production in sub-Sahara Africa as at 2014 was ranged at approximately 31.95 to 34.22 million tons with total postharvest losses ranging from 30 to 80% depending on nature of the crop, while globally postharvest losses is estimated at 30 to 50% according to FAOSTAT, 2017(Ghosh *et al.*, 2016; James & Zikankuba, 2017; Karungi *et al.*, 2011; Niewiara, 2016; Singh *et al.*, 2014). One fourth of all produce harvested is not consumed because of spoilage between the time of harvest and the time of purchase by the consumer. There is also reduction in the nutritive value and general quality of freshest produce and processed foods that are sold to consumers. The instant a crop is removed from the ground, or separated from its parent plant, deterioration commences, if not controlled or handled properly will lead to postharvest losses. Postharvest handling of food crops determines the final quality of the crops at the selling point or during consumption (Bachmann & Earles, 2000). Most African countries that depend solely on agriculture as the main stay of their economy find postharvest losses of food crops and vegetables a serious problem that needs urgent attention of which if not attended to will crumble her economy. Therefore, reducing postharvest losses is one of the best strategies of reducing importation of food and a positive step toward self-sufficiency in food production. A supply chain approach to postharvest loss reduction has become essential to improving marketing efficiency and profitability and creating significant market advantage (Buntong *et al.*, 2013).

Modern technology has greatly increased the production of fruits and vegetables. But high production is useless if the harvested crops are not consumed by people. Major influences on the ripening and deterioration of fruits and vegetables are endogenous factors such as plant hormones produced by the plant body and exogenous factors which consist of environmental factors such as microbial growth, temperature, relative humidity, air velocity, and atmospheric composition. Postharvest losses of fruit and vegetable crops can be achieved by careful manipulation of these factors. Therefore, a series of sophisticated technologies have been developed and applied in post-harvest handling of horticultural crops in the last few decades. Unfortunately, many African countries have not been able to use this advanced equipment, owing to cost or adaptability problems. Post-harvest losses, therefore, remain high.

STATUS POSTHARVEST LOSSES OF HORTICULTURAL CROPS IN THE WORLD

Today, one of the main global challenges is how to ensure food security for a world growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70% to feed world population which will reach 9 billion by 2050 (Kiaya, 2014). Further trends like increasing urban population, shift of lifestyle and diet patterns of the rising middle class in emerging economies along with climate change put considerable pressure strain on the planet’s resources: declining freshwater resources and biodiversity, loss of fertile land, etc. Consequently, there is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption (Bank *et al.*, 2011; Hodges *et al.*, 2011; Nellemann *et al.*, 2009). Ensuring sustainable food supply cannot only be achieved by increasing world’s food production but also by ensuring that virtually all the foods produced are consumed by people. It is a waste of labor and resources when foods are produced to spoil at the postharvest handling stage of the food.

Postharvest loss is the degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. These qualitative losses are generally more common in developed countries (Kader, 2002). Quantity losses refer to losses as a result of the amount of a product lost. Loss of quantity is more common in developing countries (Kitinoja and Gorny, 2010). A recent FAO report indicates that at global level, volumes of lost and wasted food in high income regions are higher in downstream phases of the food chain, but just the opposite in low income regions where more food is lost and wasted in upstream phases (FAO, 2013).

In many African countries, the postharvest losses of food cereals are estimated at 25% of the total crop harvested. For some crops such as fruits, vegetables and root crops, being less hardy than cereals, postharvest losses can reach 50% (FAO, 2013). In Europe, food waste is estimated at 6.7 million tones every year, around one third of the 21.7million tones purchased. This means that approximately 32% of all food purchased per year is not eaten. Most of this (5.9 million tones or 88%) is currently collected by local authorities. In Australia, food losses is estimated to about AUD8 billion annually, of which 33% this losses are horticultural product (McKenzie *et al.*, 2017). Most of the food waste (4.1 million tones or 61%) is avoidable and could have been eaten had it been better managed (Kiaya, 2014).

In 2010, it was estimated on weight basis that about 133 billion pounds of food (31% of the total available food) was wasted at retail and consumer level in the United States. Among different agricultural commodities, cereal crops, roots crops, and fruit and vegetables account for about 19%, 20%, and 44% losses respectively (Lipinski *et al.*, 2013). According to Kumar & Kalita (2017), on a calorific content basis, losses in cereal grains, such as wheat, rice, and maize which are the most popular food crops in the world and the consumed food especially in most African countries, holds the largest share of the postharvest losses (53%). It was further stated that approximately one-third of the food produced (about 1.3 billion ton), worth about US $1 trillion, is lost globally during postharvest operations every year. The above literatures show how serious post-harvest losses is and the huge economic losses it has resulted to, this would have been prevented or reduced if adequate and appropriate handling techniques were used.

Reduction in postharvest losses will not only help in ensuring food security, but also help in reducing other adverse effects of postharvest impact on the environment such as land and air pollutions. According to Kumar & Kalita (2017), utilized food also results in extra CO_2 emissions. A report from the FAO (2013) using the life cycle perspective, estimated about 3.3 Gtonnes of CO_2 equivalent emissions due to food loss which eventually is affecting the environment. Water use during production of lost foods globally was estimated to be about 250

km^3 (FAO, 2013; Fox & Fimeche, 2013). The spent energy by the farmers and handlers of these foods are also regarded as waste of energy.

TRADITIONAL METHODS OF POSTHARVEST HANDLING OF AGRICULTURAL CROPS

Different traditional methods have been used over the years for postharvest handling of agricultural crops. These methods are unique to the culture of every society, so they vary according to agro climate, available material, societal culture and values etc. Traditionally, postharvest handling of agricultural crops are done manually and the handling practices include picking, cleaning, cooling, packaging, storage, transportation and processing (Bridgemohan & Isaac, 2017). Harvesting of agricultural crops is also done manually by hand picking (usually for fruits and vegetables) or use of manual tools like cutlass, sickles and hoes etc. (usually for grains and root crops). This manual practices by farmers actually affects the quality and shelf life of the crops as the practices can lead to mechanical damages on the crops (Arah *et al.*, 2016). Most rural farmers harvest fruits and vegetables early (Isaac *et al.*, 2017), fruits are harvested at unripe and half ripe stages to reduce rodent attacks, enable handling when the fruit is still firm and hence avoid mechanical damages as some fruits lose their firmness as they ripens hence are susceptible to mechanical damages when harvested at the ripping stage (Bridgemohan & Isaac, 2017). This practice of harvesting under-ripped fruits when the fruits have not fully developed their flavor also affects the quality of the fruit, as a result might not certify consumers wants.

Fig. 1 harvesting of grain using sickle. (Source: http://www.onescytherevolution.com/index.html)

After harvest and threshing, most agricultural crops are left with different kinds of dirty, crops which are uprooted from the ground are mixed with sands and other forms of dirt's, tree fruits are harvested using long sticks which usually falls on the ground when hit with such sticks and as result got mixed with sands. Therefore, most agricultural produces require cleaning after harvest. Traditionally, agricultural crops are cleaned by winnowing and washing inside a bowl of water for most fruits. Winnowing which is the most common practice especially in the developing countries is performed using a container made of bamboo sticks or trays made of tins or plastics. The grains are placed in the trays and slow winnowing generated using mouth blow leads to separation of dirt and husk from the grains (see Fig. 2). For bulk cleaning, the grains are allowed to fall from a height of about 4-5 ft in a thin vertical flow crossing the direction of the wind as shown in Fig. 3. Almost all types of dry grain like wheat, maize, paddy, pulses etc. can be cleaned in this manner.

Fig. 2 Winnowing of grains (Source: FAO, 1998)   Fig. 3 Bulk cleaning by winnowing (Source: FAO, 1998).

Traditional Methods of Packaging Agricultural Produce

Traditionally, agricultural crops are packaged with different types of containers all over the world, the packaging container used majorly depend on the availability of the material and the culture of the people. In Nigeria, containers made from palm fronts called baskets are commonly used while in lower areas of Himachal, containers made of bamboo sticks called Ddalh are used in the fields for packing grain, maize cobs, potato, ginger, turmeric etc. and also for carrying the material from the field to the house (FAO, 1998). For packaging threshed and cleaned grains, in Nigeria, South Africa, China, Bangladesh, and other developing countries, it is done using jute bags and some other countries use containers made of bamboo sticks lined with cow dung called Tokroo or Kiltas. The Tokroo is carried on the head while Kilta is carried on the back and is also provided with two large ropes used for carrying it on the shoulders. Packaging of fruits and vegetables like apples, tomatoes, peas, beans, capsicum, potatoes, ginger etc. Kiltas lined with gunny bags to provide a cushion so as to prevent mechanical injuries are use in some Asian countries while some counties like Nigeria use baskets from palm front and countries like Ghana, South Africa and some parts of Shimla district and Bharmour area of Chamba district, wooden boxes made up of very thick wood were used to pack and transport apples. The weight of the empty wooden boxes ranges from 20 to 25 kg i.e. the empty weight was invariably more than that of apples, it carried in it (FAO, 1998; Idah *et al.*, 2007; Jayathunge *et al.*, 2011). In lower parts of Himachal pickled mangoes, galgal, lime etc. are packed in earthen pots. The earthen pots are sterilized using fumes generated from burning red chillies along with Asafoetida (Heeng) and a little mustard oil. The top of the container is covered with a lid made of wood. The antimicrobial properties of fumes of red chillies, mustard oil and Asafoetida not only sterilize the containers and result in increasing shelf life of its contents but also has potential for preservation which serves as a replacement to inorganic chemicals. An excess use of inorganic chemicals may pose health problems (FAO, 1998).

Traditional Methods of Storage

Traditional storage is a major method used for preserving fruits in many parts of the world. It has the advantage of low cost over modern methods (Bhat & Khan, 2017). The two main methods of preserving foods traditionally are by drying and storing under room temperature. For instance, in northern China two main ways of traditional storage are trench storage and kiln storage. Trench storage is suitable for preserving late-maturing fruit varieties. Before use, trenches are filled with wet sand at a thickness of 3-7 cm. Then apples are placed in the trenches at a thickness of 33-67cm and the trenches covered with a reed mat or maize straw in order to maintain and control the temperature. Although trench storage is simple, it is very effective. The storage period of apples preserved in trenches can be 5 months. In some countries, they use pit storage; apples are packed into wooden boxes which are then placed in underground pits and the mouth of pits is covered with thatch and soil. In this way, the apples can be stored up to summer time without any appreciable loss in quality (FAO, 1998). Grains like maize, paddy etc. they are dried under the sun and stored in special structures made of bamboos plastered with clay and in some countries with cow dungs while some farmers store in a wooden houses (FAO, 1998). In Nigeria, they are stored in jute bags after drying in a clay house. The use of bamboo containers allows the free exchange of gases inside the grain and keeping containers on the ground floor ensures cool temperature for storage. Loading from top and unloading from bottom offers easy material handling. Keeping storage structures away from main living room protects grain from fire etc. (FAO, 1998). For tuber crops like yam, potato, ginger, turmeric, colocasia (arbi) etc., they are stored in underground pits and the top is covered with thatch and soil in some countries but in Nigeria they are stored in bans and thatch houses.

Traditional Drying Methods

Drying is one of the oldest techniques used to preserve food products from decomposing or deterioration. As early as 12,000 B.C., Middle Eastern and Oriental cultures were drying foods using the power of the sun. Vegetables and fruits are naturally dried by the sun and wind. Drying has been the predominant method for traditional vegetable preservation because of no affordability of freezing and chemical processing technologies for preservation. Another traditional method of storing or preserving food is by salting or curing. This method draws moisture from a substance by osmosis which is cured with salt, sugar or a combination of the two. It was a main method of preservation in medieval times and around the 1700s. The earliest cultures have used sugar as a preservative, but presently, the common practice is storing fruits in honey. This process deactivates the microbial cells by dehydrating them, thus killing them. This method keeps food safe from microbial spoilage (Msagati, 2012).

Transportation Methods of Postharvest Handling of Agricultural Produce

Transportation is another important factor to consider in postharvest handling of agricultural crops. Traditionally, after packaging small scale farmers transport their produce by carrying it on their heads. Some countries still practice the use of animals like horses and donkey for transporting agricultural produce from the farms to their homes and markets places. According to Idah *et al.* (2007), there are two main modes of transportation available to domestic transporters and handlers of fresh produce in Nigeria, the rail and the road systems. However, farmers and fresh produce handlers complained of the non-availability and unusual delays in the rail system, so they all use the road system for their regular and long distance haulage. The major types of vehicles used in transporting their produce are shown in Table 1. Some farmers who cannot afford the cost of haulage vehicles or those that consider the quantity of their produce to be small transport their farm produce with motor cycles and tricycles as shown in Fig 4.

Table 1: Major types of vehicles used for transporting agricultural produce in Nigeria

Vehicle types	Number of axles	Dimension			Capacity rating (kg)	Percentage involved (%)
		Length (m)	Width (m)	Height (m)		
Mercedes 911 lorry 2	2	5-6	2-3	3-4	7500	50
Canter	2	5-6	2-3	3-4	4500	15

Fuel tanker	3	8-15	2-3	3-4	3000	10
Pick-up van	1	4-5	2-3	2-3	1000	8
Buses	1	4-5	2-3	2-3	400	2
Articulated truck	4	8-15	2-3	2-4	7500	15

Fig 4.: A man transporting tomatoes on a motor bike in Nigeria (Source: Arah *et al.*, 2015)

The bad nature of roads in most African countries coupled with the inappropriateness of the transportation options therefore provides these unfavorable factors during transportation resulting in great losses.

The problem of postharvest losses is further compounded by the lack of processing facilities in most developing countries which can be used to process and preserve the fruits for later consumption. Producers from developed countries always have supply contract with multinational supermarkets to supply cash crops. An example is the Blush tomatoes in Australia which supplies Coles and Woolworth with tomatoes making access to market already predetermined. In the case of producers in Africa, there is no information on reliable market availability. There is lack of communication between producers and consumers and also lack of market information (Kader, 2005). This has been the main reason for the mismatch between production and available markets. Producers therefore have to sell their harvest at very low cost to prevent total loss. Marketing cooperatives are needed by producers in African countries in major tomatoes producing areas to create market for producers.

APPLICATION OF MODERN TECHNOLOGY IN HANDLING POST-HARVEST LOSSES

Practicing modern postharvest handling technologies can reduce postharvest losses of horticultural produce and also maintain food quality up to final consumption level. Many postharvest technologies have been developed according to Kitinoja et al. (2011) and Singh et al.(2014), but adoption of these technologies in some countries especially developing countries are difficult due to the financial involvement in acquiring and installation of the technologies, the technical know-how, societal culture and value etc. according to Elemasho et al. (2017) the factors that affect the adoption of postharvest technologies are socio-economic characteristics and source of information.

Some of the techniques and technologies for postharvest handling of crops are as follows; Crops harvested where the produce is in contact with soil or manure should be considered for a postharvest washing step. However, washing can cause qualitative loss due to abrasions from brushes and enhanced decay resulting from the water (Shewfelt and Prussia, 2009). When harvesting, care should be taken that fresh items do not come in contact with soil. The containers used to hold harvest items should be free of debris and sanitized after each use. Plastic crates are easier to sanitize and better containers for harvesting than wooden containers or woven baskets (Kitinoja & Kader, 2002).

When fruits or vegetables are harvested at temperatures around ambient temperature, the high temperatures result in an extremely high respiration rate leading to high deterioration rate. Therefore, harvesting should be done at the cooler times during the morning hours or evening. It is essential to harvest at the ideal maturity stage so that consumers can have the best quality of the farm produce. Maturity standards have been established for commodities to enable producers to harvest at the proper maturity. Each individual participating in harvesting should be trained to identify the proper maturity. In fresh fruits and vegetables size and external color are common indicators of maturity. Qualitative postharvest loss can result from improper harvesting techniques (wrong tools, too early, or too late) (LaGra, 1990). Sorting (removal of damaged, infected or diseased fruits) and grading (based on color, size, stage of maturity etc.) can prevent the production of ethylene, contamination of adjacent fruits and spread of microorganisms (Bridgemohan & Isaac, 2017). Care should be taken when grading since untrained labor can be rough, hence leading to skin damage and allow for microbiological contamination (Saeed et al., 2010). A simple reduction in rough handling can decrease the incident of mechanical damage in fruits (Kitinoja *et al*., 2011).

Packaging is done to protect products from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources to improve handling, storage, and transportation. As described earlier, in most developing countries packaging is done using the local available containers (container made from bamboo, palm woven baskets etc.) for all agricultural produce without putting into consideration firmness and hardness of the produce packed in the packages. Some agricultural produce like fruits and vegetables are fragile and easily damaged or punctured due to their high moisture content, therefore lead to fast deterioration of the produce. Modern materials used vary from wooden and plastic crates, cardboard and Styrofoam boxes, woven palm baskets to nylon, jute sacks, and polythene bags depending on the farm produce to be packaged (Idah *et al.*, 2007). Some researchers have worked on the best packaging materials and methods for different agricultural produce. For instance, Onu (2018) suggested that the best packaging material for handling and transportation of tomato in Nigeria is with the use of carton crate. Jayathunge et al. (2011) stated that the nestable plastic crate is the most suitable package for handling and transportation of vegetables such as beans, cabbage, brinjals and curry chilies. Improper or inadequate aeration within the packaged commodity can result in a buildup of heat as a result of respiration. Similarly, crates or baskets with rough surfaces and edges can induce mechanical injuries which will increase ethylene production, thus reducing postharvest quality of the fruits (Arah, *et al.*, 2015).

The storage conditions play important role in influencing the quality and shelf life of fresh fruits and vegetables. The practice of cooling immediately after harvest is important to remove the field heat, minimizes the effect of microbial activity, metabolic activity, respiration rate, and ethylene production (Akbudak *et al.*, 2012). The traditional methods of storage and cooling of farm produce as described earlier has the problem of temperature and relative humidity control, they work according to the weather condition of a place. Most fruits can be stored for short terms at ambient temperature (10–15°C) and relative humidity (85–95%) (Žnidarčič *et al.*, 2003), provided that ventilation is adequate to prevent heat built from respiration and reduce poor ripening and chilling injuries. However, these conditions are difficult to achieve in some countries with high temperature and low relative humidity (Parker & Maalekuu, 2013). Also, very low storage temperature affects the shelf life and quality of many tropical fruits and will reduce its flavor, total soluble solids (TSS), and pH of the fruit (Moreti *et al.*, 1998). Modern storage and pre-cooling practices include the use of refrigeration storage, Postharvest heat treatments using hot air and heated water, Modified atmosphere packaging (MAP), Treatments of 1-methylcyclopropene (1-MCP) and pre- and postharvest treatment of calcium chloride ($CaCl_2$) (Bridgemohan & Isaac, 2017).

Agricultural products are usually transported from the farm to the marketing centers, processing plants, and inaccessible roads. After harvest, biological processes continue, leading to deterioration of agricultural produce, hence quality losses commence immediately. These processes can also be rapid enough to spoil the product within few hours of harvest for some fruits and vegetables. Produce like that needs to be pre-cooled or stored in a controlled environment to retard or reduce the rate of the biological processes and field heat build-up immediately after harvest. Therefore, there is need for proper transportation system like refrigerated vehicles, which for now is a big challenge for both producers and distributors in developing countries. During transportation, the produce should be immobilized by proper packaging and stacking to avoid excessive movement or vibration or heat build-up, if transport is not refrigerated. Refrigerated trucks are not only convenient but also effective in preserving the quality of fruits. But it has a high initial investment which is usually unaffordable for small scale farmers and handlers of agricultural products.

THE ROLE OF GOVERNMENT AND ORGANIZATIONS IN POSTHARVEST HANDLING

Post-harvest handling of agricultural produce is a serious issue and a big problem that cannot be left for farmers alone to handle. Government, institutions and other organizations have their own roles to play in handling the problem.

The government has a major role to play in handling postharvest losses in the world. Countries where traditional techniques are the prevailing technique in postharvest handling of agricultural produce, their government can start by organizing committees to look into the postharvest technologies used and how they can be modernized, create awareness of the available modern technologies, train farmers/individuals who are involved in postharvest handling of agricultural produce on available modern technologies, invest in modern equipment for postharvest handling of agricultural produce, subsidize the cost of the equipment for her citizens when necessary and ensure good transportation/ logistics facilities by constructing good roads and railways that connects the rural and urban areas. This will ensure good flow of commodities and agricultural produce from the farms to the markets. Furthermore, government intervention such as movement of agricultural produce, storage and sales either to influence their pricing and movement or to supplement existing market channels and increase competition, support researches that will better and further modernize the technologies of post-harvest handling of agricultural produce will go a long way to help.

Organizations such as institutions, NGOs, industries, etc. also have their own roles to play in this context, they should get involved in researches and innovation of modern technologies of post-harvest handling of agricultural produce, disseminating information to local farmer/processors about developed post-harvest technologies, they could also help farmers/processors subsidize the cost of acquiring post-harvest technologies and they can give out loans to farmers at low interest rate for the purchase of post-harvest technologies (Bolarin & Bosa, 2015).

CONCLUSIONS

The paper reviewed the current techniques of postharvest handling losses of horticultural crops. Application of modern postharvest technologies in handling postharvest losses of agricultural produce will improve postharvest handling of agricultural losses and enhance food security and availability. Traditional methods of postharvest handling of agricultural produce are complex and require more energy unlike the modern technologies that aim at maintaining quality, ensure food safety, and decrease the food loss after harvest and before consumption and reducing drudgery attached to postharvest handling of agricultural produce. Daily, more postharvest technologies are being developed all over the world, yet the adoption of these postharvest technologies is still a big challenge in most developing countries due to lack of information, farmer sticking to the old methods of postharvest handling as a result of societal culture, cost of implementation, source of information etc. all hands needs to be on deck in ensuring the adoption and application of these modern technologies in the developing countries. The government can help in creation of awareness, establish and modernize postharvest, transport/logistics facilities to ensure efficient flow of commodities, maintain quality and reduce losses. Institutions can research on developing the existing postharvest technologies and in cooperate the teaching of postharvest courses. Private organizations and individuals who are educated and exposed can invest on innovation and adoption of these modern technologies.

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DEVELOPMENT AND OPTIMIZATION OF BISCUITS PRODUCED FROM COMPOSITE FLOURS OF CORN, PEANUT, SWEET POTATO AND SOYA BEAN.

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ABSTRACT

Biscuits are one of the staple baked products consumed in Nigeria by all age grades particularly children. They are produced basically from wheat flour. However, wheat production in Nigeria has been a roller coaster. This study investigated the formulation of biscuit made from blends of roasted corn, peanut, soybean and sweet potatoes. The impact of baking temperature and baking time on biscuit quality were also investigated. Investigations were conducted employing a four-component, two processing parameters, constrained D-optimal mixture-process experimental design with 20 randomized experimental runs. The formulation design constraints were roasted corn flour, peanut, blanched soybean and sweet potato flour. The processing parameters investigated were baking temperature and baking time. The formulated samples were evaluated for the proximate properties, mineral content, sensory qualities, digestibility, bulk density and spread ratio. From the numerical optimization through the desirability function, the formulation that produced biscuit of highest desirability index was 5% of sweet potatoes, 17% of soybeans, 39% of roasted corn, 34% of peanut with baking temperature of 180°C and baking time of 11 min. The proximate properties, mineral content, digestibility, bulk density and spread ratio of this optimal formulation are ; moisture content (11%); crude protein (22); crude fiber (4.5); fat content (12.6); carbohydrate (44); ash content (7.4); energy value (373); potassium (314); calcium (80); iron (3.6); zinc (0.5); digestibility (73); spread ratio (18.7); bulk density (0.6); breaking strength (2) ; colour (5.8); taste (5.3); flavor (4.2); texture (5.2); overall acceptability (4.7). It was deduced the interactions of the mixture component and process variable have significant effect on the sensory quality and the proximate analysis of biscuit from the blends with the level of probability ($p<0.005$).

Keywords: Biscuit, Optimization, Proximate properties, Formulation, D-Optimal Design

1.1 INTRODUCTION

Food deficit is increasing, which affect millions of people especially in developing counties. Food production and processing are encouraged as part of the solution to the mounting problem of food shortage and food wastage due to inadequate storage system. Biscuit are recommended as one of the snack food that can be processed. It is cheap and can be eaten by all age grades, have long shelf live, easy accessible anytime and anywhere. It can be fortified to be highly nutritious. The necessity to optimize local food products help to meets daily supplement needs of the malnourished people in Africa. This need to be propelled in different research activities, to bring about a different high-energy-protein food (Sanni, 1997; Gilbert, et al., 2000; Jideani et al., 2001). Deliberate effort is required to attain high quality, wholesome and safe product in the snacks food business. New product development is one of the most difficult activities in the food industry. Product development strategy has a very important impact on final product quality.It translates the functional needs and expectation of the consumers into specific engineering and quality characteristics. It is responsible for designing new product which meet customer’s requirement and expectation and which can be consistently and economically produced by manufacturing. Product quality has been defined as a product ability not merely to meet consumer’s expectation but also to exceed them. In product development studies, a simple, but effective strategy of experimentation involves optimizing the formulation via mixture design and optimizing the process with factional design and response surface methodology. Biscuits are amongst the most famous generally expended prepared food item in Nigeria and a standout amongst the most consumed baked food on the earth. It is one of the processed convenience food ever created and widely accepted staple food which requires no extra preparation. Its wide popularity is sequel to it convenience, moderate cost, great nourishing quality, accessibility in various taste and longer shelf life (Kakalibandyopadhyay et al. 2014). Biscuit preparation is a demonstration of transforming a basic ingredient into brilliant delightful nourishment with various aromas and crunchy taste. The basic ingredients are varying proportion of refined wheat flour, vegetable shortening margarine, and sugar, baking powder and seasoning agent (Meena 2013). Biscuits are one of the minimal cost prepared food. They are less expensive than most other snacks, can be eaten anyplace, easy to be access, have variety of tastes, packs and are eaten by all age group consumers, specifically health disorder individuals on account of its moment vitality discharge (Meena, 2013). The nourishing estimation of biscuit can be upgraded by fortification and supplementation with a wide assortment of protein, vitamin and minerals (Sivakamin and Sarojini, 2013). Due to competition in the market and increased interest for healthy characteristic and functional food, efforts are being made to enhance the nutritive estimation of biscuit and usefulness by adjusting their nutritive arrangement.

Biscuits are produced basically from wheat flour. However, wheat production in Nigeria has been a roller coaster. The locally produced wheat is not enough to meet the demand, since wheat are used for other product. Reports indicated that up to 1985, domestic wheat production in Nigeria was about 66,000 metric tonnes. In 1988/89 crop production season about 600,000 tons of wheat was produced from a total of 214,000 hectares with an average yield of 2 tons per hectare. In 2011 the production was 165,000 metric tonnes which drastically dropped to 60,000 metric tonnes in 2016 (Olugbemi, 1991). Since wheat cannot perform well under tropical climate, the country had over the years been dependent on wheat imports mostly from the United States. This wheat importation had detrimental effects on the Nigerian economy involving huge expenditure of foreign exchange (Olaoye et al., 2006). In order to reduce the impact of wheat importation on the economy, the Federal Government released a policy mandating the flour mills to partially or wholly substitute wheat flour. This resulted in the adoption of alternative solutions by the baking industries to stay in business. One of the solutions developed was the mixing of flour from other sources with wheat flour (Shittu et al., 2007; Sanni et al., 2007; Orunkoyi, 2009; Abdelghafor et al., 2011).

Studies on the mixing of flour from other sources with wheat flour has been conducted by many researchers, among which are; wheat/colocasia/sweet potato/water chestnut flours (Baljeet et al 2014), wheat/ taro flour (Amman et al., 2009) wheat/sweet potato flour (Taneya et al 2014), wheat/soy/cassava flour and wheat/cassava/carrot flour (Adegunwa et al., 2012), yellow peas/lentils/chickpeas (Zhao et al., 2005) and 15% banana flour (Ovando-Martinez et al., 2009). Several other studies on substitution of wheat partially with other composite flour and the analysis on their different characteristics have been conducted.

This study was conducted to develop and optimize the formulation and some production processes of biscuit from blends of corn, peanut, sweet potatoes and soya bean. The nutritive, physiochemical, and sensory properties of the formulated biscuits were also estimated.

2.0 Material and Method

2.1 Materials: The materials used were roasted corn flour, defatted peanut meal, blanched soybean, sweet potato extract/gel. The reagents used were distilled water, petroleum ether, boric acid, hydrogen tetraoxosulpatevi, sodium hydroxide, hydrochloric acid, bromescresol green and methyl red indicator, N-hexane, Selenium tablet, anhydrous copper sulphate mixture. The equipment and apparatus used in the study include dryer, deep fryer, manual kneader, chopping board, steaming machine, grater, milling machine, mixer bowl, petri-dishes, electronic weighing balance, desiccators, crucibles, bunsen-burner, fume cupboard, thimbles, soxhlet apparatus, filter paper, beaker, kjeidal apparatus, pipette, condenser, oven, weighing balance, spatula, petri dish, soxhlet apparatus, thimble, complete digestion block set, burette, pipette, pipette filler, cornical flask, makahmps apparatus.

2.2 Methods

The formulation was designed based on the mixture design experimental concept. The constraints for the mixture component of the design are: 20%≤x1 (Roasted corn flour) ≤70%, 10% ≤x2(Defatted peanut meal) ≤30%, 10% ≤x3(Blanched soybean)≤30%, 5% ≤x4(Sweet potatoes)≤20%,Other minor component (constants) used in the formulation are: Sugar 1%, Baking powder 0.8%, Baking fat 0.2%, Water 5%, Total 7%**.**

Table 2.1 Process Parameter and their Levels are:

Factors	Process variables	Low (-1).	High (+1)
Z1.	Baking Temperature.	120.	180
Z2.	Baking Time.	10.	25

2.3 Mixture-Process Variable Design

Investigations were conducted employing a four-component, two processing parameters, constrained D-optimal mixture-process experimental design with 20 randomized experimental runs. The formulation design constraints were roasted corn flour defatted peanut meal blanched soybean , and sweet potato flour. The processing parameters investigated were baking temperature and baking time. The formulated samples were evaluated for the proximate properties, mineral content, sensory qualities, digestibility, bulk density and spread ratio
The table below shows the variation of between the process component and the materials component.

Table 2.2 Mixture-Process Variable Design

S/N	Roasted Corn Flour %	Defatted Peanut Meal, %	Blanched Soybean Flour %	Sweet Potato Extract/Gel, %	Baking Temperature, Degree Centigrade	Baking Time, minutes
1	35	10	30	20	135	13.75
2	50	30	10	5	180	10
3	35	10	30	20	120	25
4	20	25	30	20	180	25
5	39	33	10	13	180	25
6	70	10	10	5	165	21.25
7	50	10	30	5	180	25
8	37.5	27.5	10	20	120	10
9	45	10	20	20	180	25

10	55	10	10	20	180	25
11	50	30	10	5	120	25
12	20	40	30	5	180	10
13	20	40	30	5	120	25
14	55	10	10	20	120	10
15	20	50	10	15	150	17.5
16	50	10	30	5	120	10
17	50	30	10	5	180	10
18	20	32.5	30	12.5	120	10
19	20	40	30	5	120	25
20	20	25	30	20	180	25
21	20	45	10	20	180	10
22	20	50	15	10	180	25
23	20	32.5	30	12.5	120	10
24	20	45	10	20	180	10
25	35	10	30	20	180	10
26	30	50	10	5	120	10
27	30	50	10	5	180	25
28	35	25	30	5	180	10
29	20	45	10	20	120	25
30	47	20	19.5	8.5	150	17.5
31	70	10	10	5	135	13.75
32	70	10	10	5	180	10
33	70	10	10	5	120	25
34	20	50	20	5	120	10

2.4 Proximate Composition

Determination of proximate composition of the biscuit was carried out using standard method. Moisture Content, Crude Protein, Fat Content, Carbohydrate, Crude Fiber, Ash Content, was estimated using approved method (AOAC, 2005).

2.5 Mineral Analysis

The mineral analyses for Iron, calcium, copper, and zinc was determined by atomic-absorption spectrophotometer. Potassium was determined by flame photometry was performed in according to AOAC 2005.

2.6 Physical Properties

Breaking strength and spread ratio as describe by Agu and Ndidiamaka,(2014) was carried out. Bulk density as described by Onwuka, (2005) was carried out.

2.7 Sensory Evaluation

Sensory evaluation as describe by Iwe (2002) was used. Coded sample biscuit was presented to a 10 man semi trained panelists to evaluate the biscuit. The following attributes were estimated: appearance, flavor, texture, taste and overall acceptability of the product using a 9-point hedonic scale ranging from 1(like extremely) to 9(dislike extremely). The means were calculated and the data was subjected to analysis.

3.0 Result and Discussion

3.1 Presentation of Result

Experimental results obtained during the experimental procedures are shown in table 1.

3.2 Discussion of Result

Factor model equations used to optimize all response were all significant except for: crude fiber; ash content; potassium; calcium; bulk density which were not significant. Model significant indicate that the probabilities that the factors are not modeling noise (error) is low, while not significant means that the probability that the factors are modeling noise is high at confident level of 95% ($P< 0.05$). These non significant occurrences may be due to the errors (noises) that occur during measurements of these responses. For the mixture components model equation used for optimizing the responses, all of them were significant except for: crude fiber; ash content; potassium; calcium; zinc; bulk density, which was not significant. The reasons for these non significant results are the same as that explained for factor model. Two responses, moisture content and spread ratio did not display mixture model equation on its analysis of variance. This was because the mixture components have no effect on these two responses. Rather only the factors affect these two responses. The lack of fit for all responses during the analysis of variance were not significant except for: spread ratio; breaking strength; colour; taste; flavor; texture, which were significant. Non significant lack of fit shows that the probability that the chosen model equation fit the response is high. While significant lack of fit shows that the probability that the chosen model equation fit the response is low. So we always want the lack of fit to be not significant. The significant fit occurs due to physical errors by both measuring equipments and man during measuring of these responses. Before optimization, parameters to be optimized were constrained to achieve the set goals of optimization. For the mixture components, the roasted corn flour was set at maximize because of its availability and low cost. The same goes for defatted peanut meal and blanched soybean flour. The sweet potato extract/ Gel was set at minimize because it is expensive to prepare. For the factors components temperature was set at maximize because high temperature produces high texture quality in the biscuit, while time is set at minimize to save time of production which in turn save cost of production. For responses, moisture content was minimized to give the biscuit a crunchy texture. Crude protein and fiber were set in range to see which protein and fiber values give a better biscuit within the experimental range.

Table 3.1 Experimental result table

Run	C1 A %	C2 B %	C3 C %	C4 D %	F5 E deg	F6 F min	R1 moisture %	R2 protein	R3 fiber	R4 fat	R5 carbohydrate	R6 ash	R7 energy	R8 potasium	R9 calcium	R10 iron	R11 zinc	R12 digestibility	R13 spread ratio	R14 bulk density	R15 breaking strengh	R16 colour	R17 taste	R18 flavour	R19 texture	R20 overall acceptability
1	35	10	30	20	135	13.8	13.3	25.3	5.32	20.5	29.6	6	404	340	79.2	3.24	0.38	76.2	24.5	0.78	0.815	2.5	1.5	1.5	3.8	4
2	50	30	10	5	180	10	10.3	21.3	4.76	10.1	47.5	6.04	366	333	76.3	2.81	0.22	71.9	20	0.77	3.746	6.8	5.8	4.3	4.5	5
3	35	10	30	20	120	25	17.6	26	6	15	30.9	4.5	363	349	75.3	2.72	0.36	76.3	19.6	0.65	0.795	4.5	3	3	3.5	5.5
4	20	25	30	20	180	25	11.3	30.3	3	18.6	30.3	6.5	410	350	80.3	3.33	0.42	76	20	0.67	3.246	6.8	4.5	5.5	4	6
5	39	33	10	13	180	25	10.2	21	4	12	48.3	4.5	385	358	81.6	4.81	0.51	71.3	20	0.65	3.246	2.3	3	2.5	3.8	4
6	70	10	10	5	165	21.3	13.1	16.5	6.31	8.5	52.1	3.5	351	355	82.2	4.32	0.43	71	19	0.61	2.246	6.8	6.3	5.5	6.3	5.5
7	50	10	30	5	180	25	11.1	22.2	4.11	14.3	43.4	5	391	342	80.7	3.92	0.36	76.5	16.5	0.65	3.5	3.8	3.3	2	2.3	3
8	37.5	27.5	10	20	120	10	14.7	14.3	4.5	8	53.1	3.5	341	350	77.3	3.96	0.44	71.5	24.8	0.69	0.5	3	2.8	2	3.8	4.5
9	45	10	20	20	180	25	9.38	16.5	5.5	7.72	54.4	5.5	353	402	74.2	4.61	0.3	74	16.3	0.71	2.74	4.8	3.3	2.3	2.5	5
10	55	10	10	20	180	25	8.7	12.5	5.5	8.5	61.4	3.5	372	393	76.4	4.72	0.3	71.3	16.7	0.69	2.398	2.5	3	2	1.8	4.5
11	50	30	10	5	120	25	12.1	24.1	4.91	14.3	37.2	7.5	373	349	86.3	4	0.33	70.9	24.5	0.68	0.5	8	6	5	5.5	5
12	20	40	30	5	180	10	10.1	28.1	4.32	16.8	33.7	7	398	379	86.3	3.33	0.32	76.5	19.8	0.65	0.746	4.5	6.3	5.3	5.3	4
13	20	40	30	5	120	25	16.2	26.5	3.5	17	31.1	5.5	383	370	84.2	3	0.44	76	24.8	0.67	2.246	4.5	5.3	4.3	4.5	4.5
14	55	10	10	20	120	10	15.2	11.5	2.5	9	59.4	2.5	364	381	79	2.83	0.38	71	20	0.61	0.5	6.5	6.3	5.5	4.8	5
15	20	50	10	15	150	17.5	12.5	17.5	5.5	11	50.5	3	371	382	72.2	2.94	0.32	71.5	16.3	0.68	3.246	4.3	4.3	3.3	4.5	4.5
16	50	10	30	5	120	10	16.6	14.2	6	12.5	46.3	4.38	354	374	70.3	2.63	0.41	75.9	20.4	0.63	0.746	6.8	3.3	2.8	4.8	4
17	50	30	10	5	180	10	11.3	17.1	3.98	10.5	51.3	5.8	368	403	74.7	3.98	0.46	71.3	20	0.68	3.746	6.8	5.8	4.3	4.5	5
18	20	32.5	30	12.5	120	10	16.8	22.8	4	18.1	35.2	3.14	395	400	79.9	3.9	0.52	76.6	20	0.65	0.5	4.8	4.8	4	3	5.5
19	20	40	30	5	120	25	15.4	25.8	5	17.2	33.1	3.61	390	378	83.1	4.11	0.55	76.4	24.8	0.64	2.246	4.5	5.3	4.3	4.5	4.5
20	20	25	30	20	180	25	12.1	20.9	4.22	15	40.3	7.5	380	379	83	3.22	0.57	76.1	20	0.61	3.246	6.8	4.5	5.5	4	6
21	20	45	10	20	180	10	15.2	19.3	4.11	18.6	36.1	6.11	389	360	80.2	2.62	0.48	71.2	19.6	0.62	1.246	4.8	5.5	4.3	4.8	4.5
22	20	50	15	10	180	25	11.7	22.8	3.5	10	47.5	4.5	371	364	84.3	2.99	0.41	72.3	20	0.58	3.246	6.8	6.3	6	7.5	5.5
23	20	32.5	30	12.5	120	10	16.1	24	4.32	16.2	34.7	4.7	380	370	84.1	3	0.36	75.9	19.6	0.75	0.5	5	4.5	4.3	4.3	6.5
24	20	45	10	20	180	10	12.9	25.4	5	14	36.2	6.5	372	363	84.3	3.33	0.4	71	19.6	0.7	1.246	4.8	5.5	4.3	4.8	4.5
25	35	10	30	20	180	10	10.9	23.8	6.11	17.5	34.2	7.5	389	340	79.3	4.16	0.42	76.1	19	0.66	3.246	3.5	4.3	4.5	3.8	6
26	30	50	10	5	120	10	17.5	24.7	5.31	10.1	37.6	4.8	340	360	76.2	4.43	0.39	71.8	24.5	0.61	0.5	5.3	4.5	5	4	5
27	30	50	10	5	180	25	11.6	23.8	6	11	42.1	5.5	363	358	80.4	5.11	0.4	72.1	16.7	0.58	1.246	7.3	5.8	5.3	6	5
28	35	25	30	5	180	10	14.5	25	6.5	12.5	40.1	2	373	354	79.2	5.18	0.52	76.5	19.4	0.61	1.246	4.3	4	4.8	4.3	4
29	20	45	10	20	120	25	16.5	26.2	4.81	16.5	33.5	2.5	387	368	83.3	5	0.57	71.3	20	0.63	0.5	2.3	3	3.5	2.8	5
30	47	20	19.5	8.5	150	17.5	15.1	18.8	4.33	16.1	37.2	8.5	369	261	77.8	4.32	0.48	73.7	16.7	0.66	1.246	2.8	2.8	3.3	3.5	3.5
31	70	10	10	5	135	13.8	13.5	18.2	5.21	13	47.1	3	378	300	78.6	2.91	0.52	71.5	19.6	0.7	1.246	4.5	4	4.5	5.5	4.5
32	70	10	10	5	180	10	12.1	18.6	5.5	14.3	43	6.5	375	320	80.1	4.28	0.57	71.9	16.3	0.64	3.246	6	5.5	5	5.3	4
33	70	10	10	5	120	25	16.7	19	3.61	13	42.3	5.4	362	340	80.1	3.12	0.53	71.1	19.6	0.68	0.746	5.8	4.5	4.5	4.8	4.5
34	20	50	20	5	120	10	16.3	28.9	4	17.6	28.3	4.9	387	342	82.6	3.63	0.55	74.4	20	0.64	0.746	5.3	5	3.8	4.3	5.5

C = Conponent, F = Factor, R = Response, A = Roasted Corn flour, B = Defatted Peanut meal, C = Blanched Soybean flour, D = Sweet Potato extract/ Gel, E = temperature, F = time

The fat content, carbohydrate and energy values were set to maximize because of its high energy content for children. Ash content, potassium, iron, zinc, digestibility, spread ratio and bulk density, were all set to experimental range, to see which value produce a better biscuit. Calcium was set to maximize to give the children a healthy teeth and bones. Breaking strength was set at maximum to increase the strength of the biscuit for handling purpose. Colour was set at maximize to make the product attractive. Taste, flavor and texture were all set to maximize to give the biscuit an acceptable quality. Overall acceptability was set to maximize to see the best judgment. Then the product was optimized.

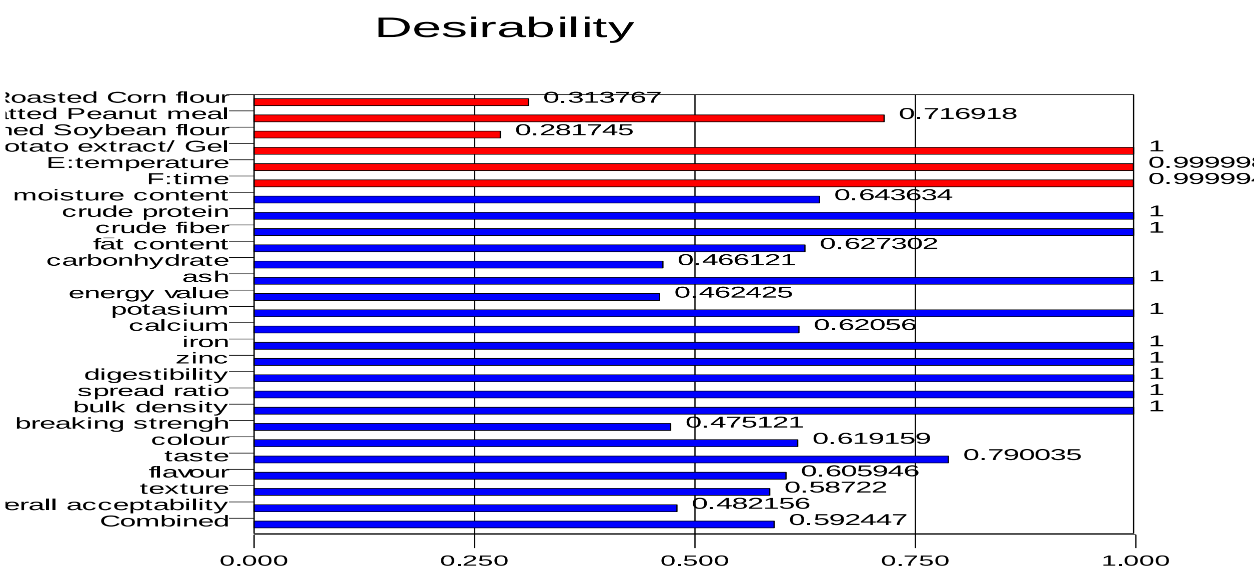
3.2 ANOVA for model equations used for optimization.

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Moisture Model	148.34777	2	74.173883	32.810876	2.226E-08	significant
Lack of Fit	66.071327	26	2.5412049	3.1695332	0.1008824	not significant
Protein Model	563.10454	15	37.540303	3.5567331	0.0060299	significant
Linear Mixture	404.36582	3	134.78861	12.770464	0.0001036	significant
Lack of Fit	116.79986	13	8.9846047	0.6138283	0.7789966	not significant
Fiber Model	17.084901	13	1.3142232	1.7832657	0.1186016	not significant
Linear Mixture	1.7109162	3	0.5703054	0.7738458	0.522228	not significant
Lack of Fit	12.118861	15	0.807924	1.5414573	0.3331207	not significant
Fat Model	284.63448	15	18.975632	2.5938345	0.02831	significant
Linear Mixture	170.90735	3	56.969116	7.7872747	0.0015379	significant
Lack of Fit	112.49147	13	8.6531903	2.2545446	0.1895272	not significant
Carbohydrate Model	2100.439	15	140.0293	5.073018	0.000774	significant

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
	6		1	9	1	
Linear Mixture	1258.5923	3	419.53076	15.198872	3.545E-05	significant
Lack of Fit	436.72992	13	33.594609	2.7939768	0.1318708	not significant
Ash Model	34.430599	9	3.8256221	1.6670459	0.1525411	not significant
Linear Mixture	1.8628783	3	0.6209594	0.2705881	0.845962	not significant
Lack of Fit	51.468725	19	2.7088803	3.7543037	0.0740911	not significant
Energy Model	2734.661	3	911.55365	4.334487	0.0118635	significant
Linear Mixture	2734.661	3	911.55365	4.334487	0.0118635	significant
Lack of Fit	5593.0654	25	223.72262	1.5622849	0.3287331	not significant
Potassium Model	15353.89	13	1181.0684	2.0986544	0.0659434	not significant
Linear Mixture	3894.8892	3	1298.2964	2.3069582	0.1075336	not significant
Lack of Fit	7892.6495	15	526.17663	0.7823413	0.6760406	not significant
Calcium Model	196.31839	9	21.813154	1.7676125	0.1277634	not significant
Linear Mixture	75.710536	3	25.236845	2.0450488	0.1343342	not significant
Lack of Fit	273.46792	19	14.393049	3.1698352	0.1024916	not significant
Iron Model	12.28803	11	1.1170936	3.18716	0.0099435	significant
Linear Mixture	0.779658	3	0.259886	0.741476	0.538695	significant

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Lack of Fit	55.7473587	17	20.3380799	60.8608676	50.6323628	not significant
Zinc Model	0.1275817	13	0.009814	1.3724095	0.2545254	not significant
Linear Mixture	0.005488	3	0.0018293	0.2558178	0.8562756	not significant
Lack of Fit	0.0809183	15	0.0053946	0.4343438	0.9032791	not significant
Digestibility Model	175.28577	3	58.428589	618.45957	4.717E-27	significant
Linear Mixture	175.28577	3	58.428589	618.45957	4.717E-27	significant
Lack of Fit	2.3042316	25	0.0921693	0.8695214	0.6391872	not significant
Spread ratio Model	69.300708	2	34.650354	7.16004	0.0027772	significant
Lack of Fit	149.94164	26	5.7669863	360.43665	1.375E-06	significant
Bulk density Model	0.0300345	13	0.0023103	1.0439288	0.4522117	not significant
Linear Mixture	0.0063754	3	0.0021251	0.96024	0.4307263	not significant
Lack of Fit	0.0297625	15	0.0019842	0.6841964	0.7401192	not significant
Breaking strength Model	35.731445	11	3.2483132	6.3229665	0.0001256	significant
Linear Mixture	0.4836185	3	0.1612062	0.313794	0.8152128	significant
Lack of Fit	11.302114	17	0.6648302			significant
Colour Model	51.75073	13	3.980826	2.544627	0.029414	significant

	Sum of		Mean	F	p-value	
		D				
Source	Squares	f	Square	Value	Prob > F	
	9		1	5	6	
	12.73681		4.245603	2.713878	0.072127	
Linear Mixture	1	3	7	9	5	significant
	31.26808			521.1347		
Lack of Fit	5	15	2.084539	5	6.01E-07	significant
	15.89313		5.297710		0.013298	
Taste Model	2	3	7	4.218339	4	significant
	15.89313		5.297710		0.013298	
Linear Mixture	2	3	7	4.218339	4	significant
			1.505251	167.2501	9.359E-	
Lack of Fit	37.63128	25	2	3	06	significant
	23.64915		2.627684	2.549788	0.032456	
Flavor Model	7	9	1	5	8	significant
	7.785127		2.595042	2.518114	0.082130	not
Linear Mixture	4	3	5	5	3	significant
	24.68819		1.299378	144.3754	1.406E-	
Lack of Fit	6	19	7	2	05	significant
	28.96515		2.633195	4.013881	0.002691	
Texture Model	5	11	9	5	1	significant
	12.48980		4.163267	6.346227	0.002896	
Linear Mixture	1	3	1	6	6	significant
	13.58749		0.799264	4.729374	0.047038	
Lack of Fit	2	17	2	1	7	significant
Overall acceptability	11.29737		1.255263	3.646614	0.005388	
Model	3	9	6	5	1	significant
	2.784201		0.928067	2.696089	0.052481	
Linear Mixture	7	3	2	8	6	significant
			0.408497	4.084974	0.062686	not
Lack of Fit	7.761451	19	4	2	9	significant



It can be deduced from the optimization process that biscuit of 0.5925 desirability index can be obtained from the optimal conditions selected on the basis of the chosen criteria. Desirability is an objective function that ranges from zero (0) outside of the limits to one (1) at the goal of optimization. For any exact solution within the optimized ranges see table 5.Figure 1 shows a typical 3D surface graph to study the desirability of optimization to achieve the set goals of optimizing among the mixture components. Figure 3 shows a typical 3D mix - process graph for determining the desirability of the product by combining both the mixture components and the factors. This graph is used to fine tune the best mixture components and factors that will produce the desired optimization goals.

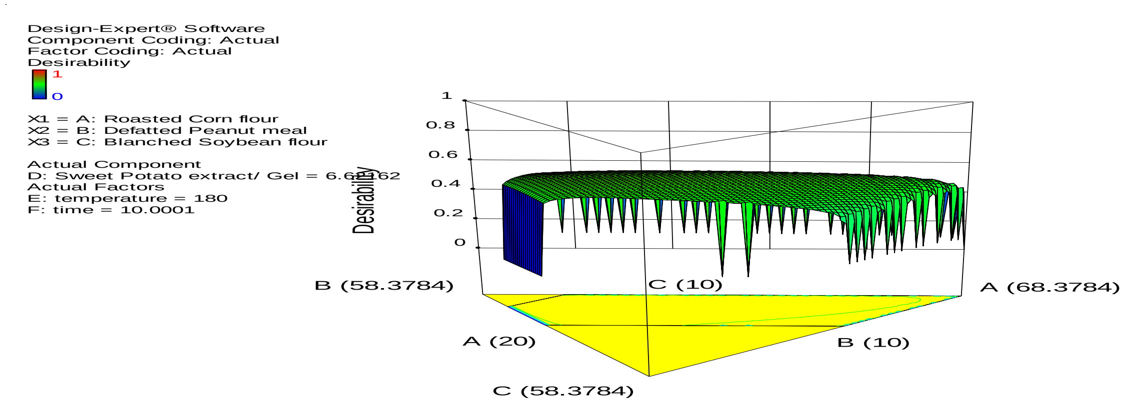


Figure 3.1: Typical 3D surface graph of the desirability of optimization

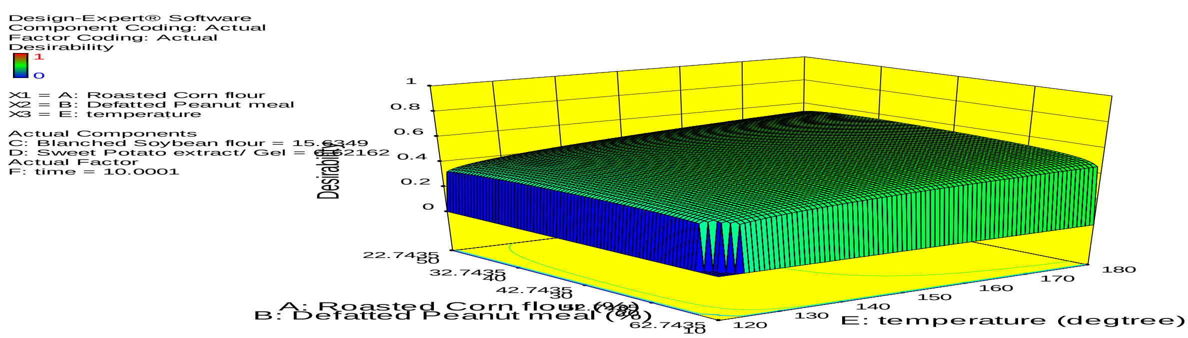


Figure 3.2: Typical 3D mix - process graph for desirability of the optimization

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

From the numerical optimization through the desirability function, the formulation that produced biscuit of highest desirability index was 5% of sweet potatoes, 17% of soybeans, 39% of roasted corn, 34% of peanut with baking temperature of 180°C and baking time of 11 min. The proximate properties, mineral content, digestibility, bulk density and spread ratio of this optimal formulation are moisture content (11%); crude protein (22); crude fiber (4.5); fat content (12.6); carbohydrate (44); ash content (7.4); energy value (373); potassium (314); calcium (80); iron(3.6); zinc (0.5); digestibility (73); spread ratio (18.7); bulk density (0.6); breaking strength (2) ; colour (5.8); taste (5.3); flavor (4.2); texture (5.2); overall acceptability (4.7); The fitted models provide the basis for selecting process parameters for optimal condition in the production of biscuit.

4.2Recommendation

The effect of more process variables using other methods of design of experiment should be explored**.** Further research should be carried out to determine the shelf life of the biscuit using suitable packaging material.

REFERENCE

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OPTIMIZATION OF SELECTED PROCESSING PARAMETERS OF PLANTAIN FLOUR

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ABSTRACT

Plantain fruit (pulp) when in contact with air triggers the activities of polyphenol oxidase (the enzyme responsible for enzymatic browning) which leads to loss in the quality of this fruit. Drying temperature if not controlled, destroys the quality indices of plantain flour. The effectiveness of blanching temperature to destroy the enzyme polyphenol oxidase and drying temperature for adequate heat supply is dependent on the right slice thickness of the plantain pulp in flour production. These parameters if not properly controlled as is the case with the local system of production cause changes within the plantain structure that affects its quality indices. The work investigated the influence of these processing variables on the moisture content and colour of the produced plantain flour. Box-behnken's approach was adopted as the experimental strategy. Multiple response optimization was done using desirability function. The results show that, all three processing variables have significant effect ($p < 0.05$) on the quality attributes considered. The models developed were all significant and have values of R^2 (coefficient of determination) > 0.9. The optimum conditions obtained are 68.5℃, 2mm, and 93.6℃ and the respective optimum yields are, 6.56% and 8.50. Based on the findings, it can be concluded that, increase in drying temperature reduced the values of MC and increased colour difference. Increase in thickness increased the values of moisture content and reduced colour difference. Increase in blanching temperature increased moisture content and reduced colour difference. Significant regression models to predict quality yield in terms of new observations of processing variables were developed.

Keywords: Food quality; Plantain flour; Box-Benkhen; Drying temperature; slice thickness and Blanching temperature.

1. INTRODUCTION

1.1 Background of the Study

In Nigeria, plantain fruits are best preserved by processing them into flour (Ukhum and Ukpebor, 1991). In this way, they can stay for several months without losing quality (Tchango *et al.*, 1999). Plantain fruit just like other fruits and vegetables suffer the effect of enzymatic browning when bruised or when the pulp is sliced. This increases the activities of polyphenol oxidase (Golan *et al.,* 1977). This browning effect has negative impact on the organoleptic properties, functional properties and nutritional value of the plantain (Martins and Whitaker 1995; Felton *et al.,* 1992b). The effectiveness of blanching temperature and drying temperature to keep quality is related to the thickness of plantain slices; as such the right settings of these variables for quality production are important. These are measures that are lacking in the traditional ways of producing plantain flour in Nigeria.

A lot of studies have been carried out on plantain processing to convert it into forms that offer a longer shelf life and maintain quality. Charles Tortoe *et al.* (2008), examined the viscoelastic properties, water activity and colorimetry properties of plantain flour made by hot dehydration of three cultivars; French Horn, False Horn and True Horn local plantain with the pre-treatment of osmo-dehydration, hot water blanching, semi-ripening and fresh unripe. Oluwalana *et al.* (2011) conducted a study on the effect of temperature and period of blanching on the pasting and functional properties of plantain flour. In another research by Arisa *et al.* (2013), the effect of pretreatment on quality and acceptability of the resulting product (plantain biscuit) was evaluated. The plantain flour was produced using the treatment of sodium metabisulphite, blanching at 80^{o}C for 10 minutes, and un-blanched plantain flour. However, more studies need to be carried out to investigate and determine the effect of different processing conditions on the various qualities attributes of plantain flour. Hence, in this research work, the focus is to optimize these selected processing parameters (drying temperature, slice thickness and blanching temperature) for optimum quality attributes of the plantain flour. The work considered the effects of varying drying temperature, slice thickness and blanching water temperature on moisture content and colorimetry properties of plantain flour. Optimization of processing parameters of plantain flour was carried out to determine optimum conditions of drying temperature, slice thickness and blanching water temperature for quality plantain flour production.

2. MATERIALS AND METHODS

2.1 Materials

The materials that were used for the project work include; Mature green plantain, Weighing balance, Thermometer, Measuring cylinder, Milling machine, Plantain slicer, Oven, Sieve, Thermostat water bath, Plastic bowl, Kitchen knives.

2.2 Sample and sample preparation

Freshly harvested, matured plantain bunch without bruise or any visual defect were obtained from a plantation in Ugbokolo, Benue state. The bunch was then de-fingered, washed, and peeled with the help of a kitchen knife. The pulps were cut into cylindrical slices and given a pre-treatment of blanching for four (4) minutes (Ngalani, 1989).

2.3 Experimental procedure

The study was conducted using response surface methodology (Box-behnken's design of experiment) through design expert (version 11.0). Three different drying temperatures (60℃ , 65 ℃ , 70℃), slice thicknesses (2mm, 4mm and 6mm), and blanching water temperatures (80℃ , 90℃ and 100℃) were considered to form the design. Box-behnken's design was employed to generate data for the responses concerning the experimental factors for the estimation of statistical model. Independent variables and their ranges were chosen based on observations and results obtained from preliminary experiments. Table 1 shows the independent variables, their coded and actual values.

Table 1: Independent variables

Independent Variable	+1	0	-1
Temperature (℃)	60	65	70
Thickness (mm)	2	4	6
Blanching Temperature (℃)	80	90	100

2.2.1 Preparation of plantain flour

The mature green plantain fruits were carefully selected, washed, peeled, and cut into cylindrical slices of 2mm, 4mm, and 6mm with the aid of a plantain slicer. The respective slices were then blanched, oven dried, milled and packaged in sterilized polyethylene bags (Ngalani, 1989).

2.2.2 Procedure for blanching

Using the measuring cylinder, a volume of 1000cm^3 of water was measured and poured into a container. The water in the container with the help of a water bath was heated to a temperature of 80℃ . Based on the experimental design, the plantain slices of 2mm, 4mm, and 6mm to be blanched at 80℃ were in turn poured into the container of hot water and allowed for 4 minutes. The respective samples of plantain slices were then drained with the help of a plastic sieve in preparation for drying. The procedure was repeated for 90℃ and 100℃ .

2.2.3 Procedure for the drying

The dryer was pre-heated to the desired temperature of 60℃ with the help of temperature regulator. The respective groups of the plantain slices according to their blanching temperature were then loaded into the dryer set at 60℃ on five (5) different dryer trays, each bearing a particular thickness, for 25hours 30minutes. The samples were then removed and kept aside for milling into flour. The procedure was repeated for the drying temperature of 65℃ and 70℃ one at a time.

2.4 Measurement of quality parameters

2.4.1 Proximate analysis

Moisture content determination: Two grams (2g) of each sample was measured and poured into a crucible of known weight. The crucible plus sample was then kept in an oven set at 105℃ to dry for 20 hours. The crucible plus sample was removed and placed in a desiccator for one hour to cool and then weighed (AOAC, 2005). The moisture content was calculated as

100 x (A-B)/A (A = initial weight of sample, B = weight of oven dry sample).

2.4.2 Measurement of color

The color characteristics of samples were measured using the L* a* b* color space with Konica Minolta colour reader CR-10 (Minolta Co. Ltd, Tokyo, Japan). The L* value is the luminance of lightness component, which ranges from 0 to 100, L* = 0 is completely black and L* = 100 is completely white. The a* value is from green to red i.e -a* to + a* respectively and b* value is from blue to yellow i.e - b* to + b* respectively. The meter was calibrated using raw plantain fruit; the plantain pulp was cut symmetrically and the colour meter was then immediately placed over it to capture the target characteristics so as not to allow browning effect of PPO interfere. The total colour difference (ΔE) values for the experimental samples were calculated to indicate the extent of deviation of color of sample from the standard or target values of the raw plantain used. Total colour difference (ΔE) is calculated as the square root of the sum of the squared deviations of L* a* b* values i.e. $\Delta E = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^2)}$ (Buckman *et al.*, 2015).

2.5 Statistical analysis.

The statistical technique that was used in assessing the significance of these models and the various model terms is called ANOVA (analysis of variance)**.** The significance of any factor was determined or judged based on its P-value. P-value less than 0.05 implies factor is significant (null hypothesis in this case is rejected and alternative hypothesis accepted), for value greater than 0.05, factor influence is non-significant else factor effect is significant.

2.6 Modeling and optimization

Appropriate statistical models were established using response surface methodology (Regression analysis) as approximation to the true response surface function to fit the experimental data generated. The models give the magnitude of the contribution of each factor in the linear, quadratic, and interaction forms (Myers *et al.*, 2008). They express the relationship between the independent variables and the response. In general form, according to Myers *et al.* (2008) the model can be written as;

$$Y = B_o + B_1x_1 + B_2x_2 + B_3x_3 + B_{12}x_1x_2 + B_{13}x_1x_3 + B_{23}x_2x_3 + B_{123}x_1x_2x_3 \quad (1)$$

Where $x_1, x_2, and\ x_3$ = independent variables (in this case, drying temperature, slice thickness and blanching temperature).

Y = Response parameter (dependable variable), and B's = Regression Coefficient

The model fitting was judged using the results from:

R^2 and $R^2_{adjusted}$, Prediction R^2 (it tells how well a model can predict responses) and Standard deviation (It tells how far the data values fall from the fitted values).

The optimum conditions for the production of quality plantain flour were established using the desirability function (response surface methodology) in the design expert software.

3. RESULTS AND DISCUSSION

Several factor combinations provided by box-benkhen's design were investigated and the findings of the analysis done on the plantain flour samples are presented and discussed below.

Table 3: Raw results of the experimental analysis.

Runs	Sample code	Drying temperature (℃)	Thickness (mm)	Blanching temperature (℃)	Moisture Content (%)	Colorimetric properties			
						Δ*L**	**Δ*a****	**Δ*b****	**Δ*E****
1	A	60	4	80	7.35	0.3	-4.2	-6.2	7.50
2	B	70	6	90	6.66	2.3	-5.6	-6.7	9.00
3	C	65	2	80	7.10	2.1	-4.1	-6.2	7.70
4	D	65	4	90	7.30	3.6	-5.4	-4.7	8.00
5	E	60	4	100	7.80	-1.1	-4.7	-4.7	6.70
6	F	65	4	90	7.25	3.6	-5.4	-4.7	8.00

7	G	65	4	90	7.28	3.5 7.80	-5.3	-4.6
8	H	65	6	80	7.26	2.7 8.50	-5.3	-6.0
9	I	70	4	80	6.35	3.7 9.50	-4.3	-7.6
10	J	60	6	90	7.65	3.6 6.80	-3.4	-4.7
11	K	65	4	90	7.25	3.6 8.00	-5.4	-4.7
12	L	60	2	90	7.24	3.4 6.30	-4.4	-2.9
13	M	65	2	100	7.15	4.9 7.40	-4.0	-3.8
14	N	65	4	90	7.26	3.5 7.80	-5.3	-4.6
15	O	70	4	100	6.62	2.7 8.80	-5.9	-5.9
16	P	65	6	100	8.00	1.3 8.03	-6.0	-5.1
17	Q	70	2	90	6.24	3.6 8.06	-4.1	-6.6

The standard or the target values, that is, the colorimetric properties of the plantain pulp are L* = 71.0, a* = -7.6 and b* = 35.2

3.1 Effects of drying temperature, thickness and blanching temperature on moisture content (MC).

The results of the ANOVA (Table 4) shows that the three processing variables had significant influence on the moisture content of plantain flour ($p < 0.05$). The moisture content (MC) of the experimental samples ranged from 6.24% to 8.00%. Sample Q (70°C, 90°C, 2mm) had the lowest value while sample P (65°C, 100°C, 6mm) had the highest. The safe recommended moisture content of flour is about 15% (FAO, 1997). These low values of moisture content will ensure shelf life stability of the plantain flour.

A quadratic model was obtained to fit the experimental data. It has a final equation in terms of coded factors as:

$$\boldsymbol{Moisture} = 7.26 - 0.52X_1 + 0.21X_2 + 0.16X_3 - 0.05X_1X_3 + 0.12X_2X_3 - 0.31X_1^2 + 0.07X_3^2$$

2

The model has a value of R^2 (coefficient of determination) of 0.9972, Adj R-square of 0.9950, Pred R^2 of 0.9821 and Standard deviation of 0.03. The value of R^2 (0.9972) indicate a good model as it can explain 99.66% of the variability of the response data around its mean.

From the fitted model (eq. 3.1), drying temperature showed a negative impact, that is, moisture content decreases with increase in drying temperature: this is because drying rate increases with temperature. Slice thickness indicate positive coefficient, that is, increase in moisture content with increase thickness. The increased thickness reduces the rate of drying. Blanching temperature showed positive influence on moisture content of plantain flour: this is in line with the report of Fagbemi (1999) and Harijono *et al.* (2013). The increased blanching temperature increases the kinetic molecular energy of the water molecules as such more water is taken up and since drying time is the same, moisture content appear to be comparatively more with increased blanching temperature.

Table 4: ANOVA results for moisture content.

3.1.3

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	3.21	7	0.4585	451.58	0.0001	significant
X_1-Drying temperature	2.17	1	2.17	2141.06	0.0001	
X_2-Thickness	0.3362	1	0.3362	331.16	0.0001	
X_3-Blanching Temperature	0.2145	1	0.2145	211.30	0.0001	
X_1X_3	0.0081	1	0.0081	7.98	0.0199	
X_2X_3	0.0600	1	0.0600	59.13	0.0001	
X_1^2	0.4047	1	0.4047	398.66	0.0001	
X_3^2	0.0209	1	0.0209	20.61	0.0014	
Residual	0.0091	9	0.0010			
Lack of Fit	0.0073	5	0.0015	3.09	0.1486	not significant
Pure Error	0.0019	4	0.0005			
Cor Total	3.22	16				

Effect of drying temperature, slice thickness and blanching temperature on colour of plantain flour

The ANOVA Table for color difference is shown in Table 6. It shows that the three processing parameters (drying temperature, slice thickness and blanching temperature) had a significant effect on the colour of the flour produced ($p < 0.05$). The total colour difference (ΔE^*) ranged from 6.30 to 9.50 with sample L (60°C, 90°C, 2mm) having the least and sample I (70°C, 80°C, 4mm) the highest. Δa^* and Δb^* read negative values which implies that samples are greener than standard and less yellow than standard respectively. Sample E (60°C, 100°C, 4mm) had a negative value for ΔL^* which implies that it is darker than standard. This may be as a result of some burning effects in the course of oven drying.

A quadratic model was obtained to fit the experimental data. It has a final equation in terms of coded factors as:

$$\textit{Colour difference } (\Delta E *) = 7.91 + 1.07X_1 + 0.29X_2 - 0.28X_3 - 0.23X_2^2 + 0.22X_3^2 \qquad 3$$

From eq. 3.3, the positive coefficient estimate of drying temperature indicates an increase in colour difference with increase in drying temperature. This may be as a result of increased burning effects in the course of oven drying. This trend is observed by Ihns *et al.* (2011) who worked on two varieties of apricot. Thickness also showed positive coefficient value, this may be as a result of reduced impact of heat treatment on polyphenol oxidase with increase in thickness. Blanching here is found to have a negative influence, that is, colour difference decrease with increase in blanching temperature. This effect of blanching is similar to that of Harijono *et al.* (2013) who worked on water yam flour, Buckman *et al.* (2015) (yam bean flour), Tortoe *et al.* (2009) who worked on flour from different cultivars of plantain.

Table 6: ANOVA results for colour difference (ΔE^*).

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	10.97	5	2.19	132.10	0.0001	significant
X_1-D/Temperature	9.25	1	9.25	556.48	0.0001	
X_2-Thickness	0.6786	1	0.6786	40.85	0.0001	
X_3-B/Temperature	0.6441	1	0.6441	38.77	0.0001	
X_2^2	0.2272	1	0.2272	13.68	0.0035	
X_3^2	0.2007	1	0.2007	12.08	0.0052	
Residual	0.1827	11	0.0166			
Lack of Fit	0.1347	7	0.0192	1.60	0.3393	not significant

Pure Error	0.0480	4	0.0120
Cor Total	11.16	16	

The modified model for colour difference on regression analysis gave a coefficient of determination of 0.9836, Adj R-square of 0.9762, Pred R^2 of 0.986 and Standard deviation of 0.13. This standard deviation is high; the smaller the better.

3.2 Optimization of quality parameters of plantain flour

Figure one (1) represent the charts showing the optimized conditions for quality plantain flour at best levels of drying temperature, slice thickness and blanching temperature. As presented in the chart, the Optimum conditions (of drying temperature, slice thickness and blanching temperature) obtained using desirability function in the design expert software are 68.5°C, 2mm, and 93.6°C. The respective optimum yields are, 6.56% and 8.1.

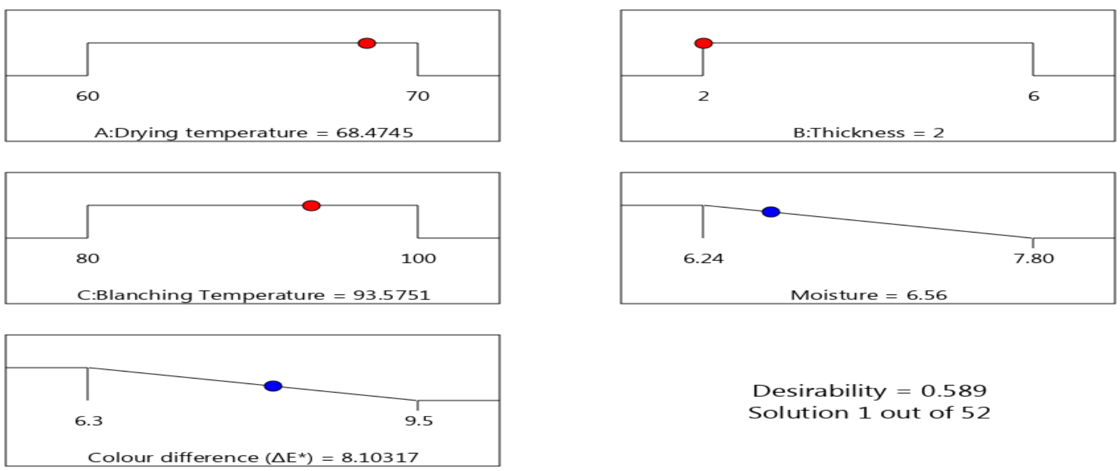

Fig. 1: Optimum conditions for optimum responses.

4. CONCLUTIONS

On the basis of the analysis carried out, the following observations were made; all three processing variables were found to significantly influence the quality parameters of plantain flour ($p < 0.05$). Increase in drying temperature was found to have a negative influence on moisture content and colour of produced flour. Slice thickness was found to increase (have positive influence) the values moisture content, it was also found to increase colour difference. Blanching temperature had a positive influence on moisture content but negative on the colour difference of plantain flour. The models developed were all significant and have values of R^2 (coefficient of determination) > 0.9 which implies that more than 90% of the experimental data can be explained or analyzed by these models. The optimum conditions obtained are 68.5°C, 2mm, and 93.6°C and the respective optimum yields are, 6.56% and 8.1.

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EFFECT OF SOAKING TIME AND TEMPERATURE ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF COWPEA (*VIGNA UNGUICULATA*)

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ABSTRACT

The physical and mechanical properties of cowpea are useful for design of grain processing equipment and machines. These properties were determined for three cowpea varieties (Iron beans, Oloyun beans, and Potiskum beans). The effect of soaking time (10, 15 and 20 mins) and soaking water temperature (30, 50 and 70^{o}C) on these properties were also investigated. The average weight, major diameter, intermediate diameter, minor diameter, arithmetic mean diameter (AMD), geometric mean diameter (GMD), and volume of a grain of cowpea were 0.35g, 9.04mm, 5.73mm, 4.20mm, 6.32mm, 6.01mm, and 15.94mm respectively for Iron beans. The values were 0.31g, 9.06mm, 5.46mm, 3.33mm, 5.95mm, 5.48mm, and 13.23mm^3 respectively for Oloyun beans. And for Potiskum beans variety, the values were 0.30g, 8.83mm, 5.32mm 3.77mm, 5.97mm, 5.61mm and 13.87mm^3 respectively. The average moisture content of the three varieties ranged from 9.53% (db) (for Iron beans) to 10.70% (db) (for Potiskum beans). Experimental results also show that the moisture content of the three beans varieties increased as the soaking time and soaking water temperature increased. Potiskum beans absorbed more water as both the soaking time and soaking water temperature increased followed by Iron beans. All the size indices also increased as the soaking time and soaking water temperature increased.

The mechanical properties measured generally decreased with increased soaking time and increased soaking water temperature. The results of the investigation show that increasing soaking time and soaking water temperature could reduce processing time and energy of cowpea.

Keywords: Soaking time; Soaking temperature; processing time; Physical properties; Mechanical properties.

1.0 INTRODUCTION

Cowpea is also known as the black eyed beans or southern peas. It is an important source of protein in Nigeria. It is also a fact that Nigeria is the largest producer and consumer of cowpea in all West Africa (Uzogara and Ofuya, 1992). More than 8 million hectares of cowpea are grown in the West and Central Africa and they serve as a good source of protein, energy and other nutrients. Nigeria is the largest producer with 4 million hectares, followed by Niger with 3 million hectares. Other producers include: Mali, Senegal, Burkina Faso, etc. (Uzogara and Ofuya, 1992). The cowpea grain contains about 25% protein and 64% carbohydrate. It is considered a dual- purpose crop that provides grains for human consumption and fodder for livestock (Uzogara and Ofuya, 1992). Cowpea seed has a coat called testa or hull. This hull contains tannin and trypsin inhibitor which are anti-nutritional factors (Odedeji and Oyeleke, 2011). The testa, however, is rich in mineral elements (Akpapunam and Daribe, 1994 cited in Odedeji and Oyeleke, 2011). Cowpea can be processed into various finished and semi-finished products. The advantages of cowpea processing include improving digestibility, reducing or eliminating anti-nutritional factors, improving consumer appeal and acceptability, extending shelf-life, income generation, etc. The flour is less prone to insect pest attack and can be stored for relatively longer period of time. Cowpea flour is usually rehydrated and utilized in formulations as desired. Cooked cowpea seeds can be consumed in form of cooked whole cowpea or cooked de-hulled cowpea. Whole cowpea (with intact testa) takes longer period of time to cook than de-hulled cowpea. Cooked whole cowpea is eaten whole or de-hulled, either alone or in combination with other food products like bread, garri, boiled yam with vegetable soup. Cowpea flour is used to prepare akara (bean cake), dawanke (cowpea dumplings), and moi-moi (steamed cowpea paste). Cowpea seeds are utilized whole or processed into flour and further into paste.

Cowpea seed is a nutritious component in the human diet as well as a nutritious livestock feed. Cowpea is used at all stages of growth as a vegetable crop. It is cultivated mainly for its seeds which can be processed into flour which is used to make cake, akara balls, etc., into paste to make moi-moi (pudding), or even cooked and eaten alone or mixed. Various parts of cowpea are used medically. Cowpea is a good fertilizer because of its ability to fix nitrogen from the air. Cowpea is of considerable importance in Nigeria and in many African countries as a nutritious leguminous crop providing an alternative source to animal protein (Dolvo et al., 1976) the consumption of bean is however curtailed because of the long cooking time needed to achieve the desired palatability and digestibility (Sefa-Debeh et al., 1978; Tian and Philips, 1991). Cowpea is used as a feed ingredient in diet for poultry and pigs (Murillo-Amador et al., 2000). It is also used as a digestible ingredient in diets for aquatic organisms such as penaeusmonodon (Eusebio, 1991) and tilapia (Keembiyehetty and De Silver, 1993, Olvera et al., 1997). Therefore, cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins. Cowpea can be used at all stages of growth as a vegetable crop. The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature snapped pods are used in the same way as snap beans, often being mixed with other foods. Green cowpea seeds are boiled as a fresh vegetable, or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning. In many areas of the world, the cowpea is the only available high quality legume hay for livestock feed. Digestibility and yield of certain cultivars have been shown to be comparable to alfalfa. Both physical and mechanical properties are important factors in solving problems associated with the design of specific machines or analysis of the behaviour of the product during agricultural processes such as planting, harvesting, handling, threshing, sorting, and drying. Solution to these problems involves having the knowledge of the physical and the mechanical properties of products (Irtwange and Ugbeka, 2002). The aim of this study is to investigate the influence of soaking time and soaking water temperature on some physical and mechanical properties of cowpea seeds relevant for de-hulling and milling.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials that were used in the course of this study include: Cowpea seeds, universal hounsfield tensometer, an oven, a vernier calliper, a stop clock, a weighing balance, a thermometer, a sieve, plastic bucket, and a boiling ring.

2.1.1 Cowpea seeds

The varieties of the cowpea seeds to be used include:

Iron beans (Sample A)

Oloyun beans (Sample B)

Potiskum beans (Sample C)

2.1.2 Universal Hounsfield tensometer

The photograph of the universal hounsfield tensometer (UTH) used in this work is shown in figure 3. It is also known as the universal tester. It was used to find compressive strength, rupture, bio-yield force, deformation at rupture, hardness, etc of the beans. The components of the UTH includes: load frame, load cell, cross head, means of measuring extension or deformation, output device, conditioning and the test fixtures.

Fig.1: Universal hounsfield tensometer (UHT).

2.1.3 Oven

The photograph of the oven used in this work is shown in Fig. 3.2. The oven was used to determine the moisture content in the cowpea seeds immediately it was procured from the market and immediately after soaking.

Fig.2: Thermostat Oven (DHG-9053A).

2.1.4 A digital vernier calliper

The photograph of the vernier calliper was used to measure the major (length), minor (thickness) and intermediate (width) diameter of the cowpea seeds, with the digital venire calliper having an accuracy of 0.01mm.

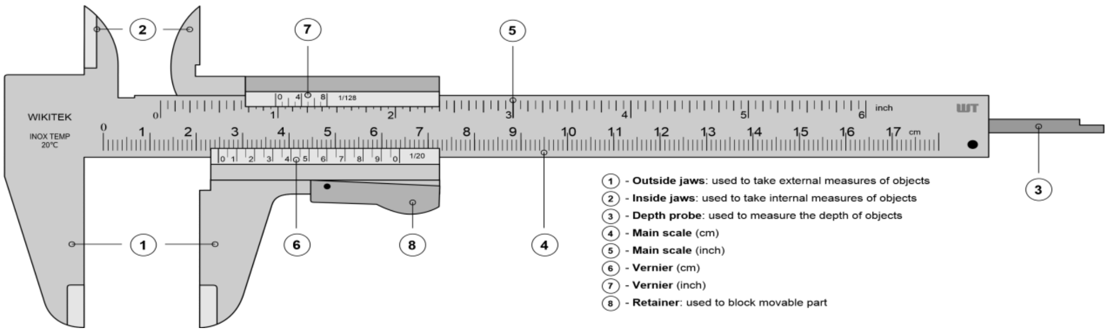

Fig.3: A digital vernier caliper.

2.1.5 A stop clock

The stop clock used in this study is shown in Fig. 3.4. It was actually used for measuring the soaking time of the cowpea seeds.

Fig.4: A diagram of a stop clock.

2.1.6 A digital weighing balance

The picture of the digital weighing balance that was used for this work is shown in Fig. 3.5. It was used to measure the weight of the beans before soaking and after soaking.

Fig.5: UWE (ADM Series) digital weighing balance.

2.1.7 A thermometer

The thermometer used for this work was a mercury-in-glass thermometer which has a bulb containing mercury attached to a glass tube of narrow diameter. This was used to measure the initial soaking water temperature.

2.1.8 A sieve

Another material that was used in this study is the sieve. It was used to sieve out water from the wet beans. A photograph of the sieve used is shown in Fig.7

Fig.6: A sieve.

2.1.9a Plastic Buckets

Some plastic buckets (Fig. 3.8), for soaking, some amount of water to be put into another container (Fig.9) used in heating the water using a boiling ring (Fig.10) to the inital water temperature needed.

Fig.7: Soaked Beans Seed at different time and temperature.

Fig.8: Boiled Water in a plastic container

2.1.9b Boiling ring

The boiling ring used for this work is a 1000W universal water heater.

2.2 Methods

2.2.1 Sample preparation

The cowpea seeds were procured from a local market in Enugu state, South Eastern Nigeria. The samples include three varieties namely: Iron beans (Sample A), Oloyun beans (sample B) and Potiskum (sample C). The seeds were cleaned manually; all foreign materials such as dust, stones, chaff, immature and broken seeds as well as bad seeds were removed by winnowing and picking. The sample selection was randomized all through the tests. The samples were numbered to avoid repeating measurements with the same seed. The moisture contents of the seeds as they were bought from the market were determined by drying the samples in an air circulating oven set at 105°C for 24 hours (Zewdu and Solomon, 2007).

The moisture content was determined by using equation (2.1)

Moisture content, $M_{DB} = M_W - M_D/M_D \times 100$.. (2.1)

Where M_{DB} = Moisture content in dry basis of the seeds.

M_W= Initial weight of the seeds.

M_D= Weight of the seeds after drying.

The moisture content of the samples was calculated for both wet basis and dry basis as a percentage dry basis (Mohsenin, 1970). Every test was repeated three times in other to determine the mean values for the mechanical properties described below for each moisture content level.

2.2.2 Soaking time

The soaking time of the beans were measured with the use of a stop clock. The soaking times used were: 10, 15, and 20 min for the three varieties.

2.2.3 Soaking temperature

The soaking temperature of the beans was measured with the thermometer. The soaking temperatures were: 30, 50, and 70°C.

2.3 Determination of physical properties

The physical properties that were considered in the course of this study include: size (major, intermediate and minor diameter, Arithmetic Mean Diameter, Geometric Mean Diameter, sphericity, weight, angle of repose, static co-efficient of friction, true density, surface area.

2.3.1 Seed size:

To determine the average size of the seed, a sample of 10 seeds for the different varieties were randomly selected. The three principal dimensions are the major diameter (length), the minor diameter (thickness) and the intermediate diameter (width) were measured with the use of a digital Vernier calliper. The geometric mean diameter (D_m) of the seeds was calculated using the following relationship in equation (3.2) (Nimkar and Chattopadhyay, 2001).

$D_m = (LWT)^{1/3}$.. (2.2)

And the arithmetic mean diameter D_a was calculated using the equation (2.3).

$D_a = (L+W+T)/3$.. (2.3)

Where L= Length (major diameter) in cm

T= Thickness (minor diameter) in cm

W= Width (intermediate diameter) in cm

To calculate the sphericity, Mohsenin (1986) has the following equation (2.4).

$Ø = (LWD)^{1/3}/L$ .... (2.4)

The size measurements were done for the seeds before soaking and after soaking.

2.3.2 Angle of repose

This was determined by the use of a tilting surface, with a smaller diameter 45mm, bigger diameter 200mm and height 350mm, having a discharge gate at the bottom. After filling the tube with seeds, the gate was quickly removed. The height of the seeds that piled above the floor and the radius of the heap (r) were measured and used to determine the angle of repose.

$$Ø = \tan^{-1} h/r \qquad (2.5)$$

Where; h = height of the surface

r = radius of the heap

Ø = Angle of repose.

2.4 Mechanical properties

The Universal Hounsfield Tensometer (UHT), manufactured by Testometric Co. Ltd in UK was used for the determination of the mechanical properties. The tests carried out using this equipment include: rupture force, bio-yield force, compressive strength and deformation at rupture, and energy of the seed. These tests were done at different moisture levels, soaking time and soaking temperature. These tests were carried out at the Civil Engineering Laboratory, University of Nigeria, Nsukka at an average room temperature of 30^{o}C. The faces of the compression plates of the UHT were properly cleaned to remove dust and any other foreign material. The machine was switched on. Each seed was placed in-between the compression plate. As the test proceeded, the graph of force deformation was plotted. As soon as the specimen cracked, the tests were stopped. The rupture force, deformation, bio-yield force were read on the graph.

3.0 Results and Discussion

3.1 Basic and Complex Geometric Characteristics of Cowpea Seed.

The moisture content of the seeds for the three samples was between 9.53% (db) and 10.70% (db). The basic geometric characteristics of the seeds before soaking and after soaking were weight, length, width, thickness, arithmetic mean diameter, and geometric mean diameter. The basic geometric characteristics of the seeds before soaking are presented in Table 1. The complex geometric characteristics of the seeds are shown in Figure 8.

Table 1: Basic geometric characteristics of cowpea seed samples.

Variety	Weight(g)	Major dim(mm)	Intermediate dim(cm)	Minor dim(mm)	Arithmetic diameter (mm)	Geometric diameter (mm)	Volume (mm^3)
Iron beans	0.35	9.04	5.73	4.20	6.32	6.01	15.94
Oloyun beans	0.31	9.06	5.46	3.33	5.95	5.48	13.23
Potiskum beans	0.30	8.83	5.32	3.77	5.97	5.61	13.87

Generally, from Table 1, it can be observed that Iron beans have the highest size (AMD of 6.32mm) and volume of 15.94mm^3 followed by Potiskum beans (AMD of 5.97mm) and volume of 13.87$mm^3$and then Oloyun beans (AMD 5.95mm; volume of 13.23mm^3. It also show that Iron beans weighed highest (0.35g) followed by Oloyun beans (0.31g) and then Potiskum (0.30g). Oloyun beans had the highest major diameter (9.06mm) followed by Iron beans (9.04mm) and then by Potiskum beans (8.83mm). Iron beans has the highest intermediate diameter (5.73mm) followed by Oloyun beans (5.46mm).

Table 2: Moisture content of seed samples both on dry basis and wet basis

Variety	Moisture Content(% db)	Moisture Content (%wb)
Iron beans	9.53	8.70
Oloyun beans	10.58	9.57
Potiskum beans	10.70	9.67

The moisture contents of the beans before soaking and after soaking are shown in Table 2. The moisture content of the three varieties before soaking ranges from 8.70 to 9.67% wb. Table 3

shows that as the soaking time and soaking water temperature increased, the moisture content also increased for all the varieties. At soaking water temperature of 30°C (ambient) and soaking time of 20 min, Potiskum beans attained the highest moisture content of 34.9%wb, followed by Iron beans (33.3%wb) and the Oloyun beans (28.2%wb). At soaking water temperature of 50°C and at soaking time of 20 min, Potiskum beans still attained the highest moisture content of 39.0% wb followed by Oloyun beans (37.5% wb) and then Iron beans (36.9% wb). The same positions were maintained at soaking water temperature of 70°C and soaking time of 20 min.
The basic physical properties of the seed varieties after soaking are shown in table 5.

Table 3: Physical properties of the seed variety after soaking.

Variety	**Weight (g)**	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Arithmetic mean (mm)**	**Geometric mean (mm)**	**Volume (mm^3)**
Iron beans							
At 30°C							
10 minutes	0.39	8.82	5.38	4.36	6.01	5.79	16.42
15 minutes	0.38	9.76	6.42	6.00	7.39	7.21	23.25
20 minutes	0.64	10.38	6.20	5.96	7.51	7.27	23.36
At 50°C							
10 minutes	0.52	9.06	5.66	5.32	6.68	6.49	18.67
15 minutes	0.50	9.68	5.62	4.98	6.76	6.47	18.45
20 minutes	0.52	9.28	6.30	5.26	6.95	6.75	20.28
At 70°C							
10 minutes	0.58	10.00	6.20	4.00	6.73	6.28	17.36
15	0.62	10.26	6.78	5.34	7.46	7.19	22.87
	0.66	10.48	6.76	6.04	7.76	7.54	25.22

minutes 20 minutes							
Oloyun beans At 30^{o}C 10 minutes 15 minutes 20 minutes At 50^{o}C 10 minutes 15 minutes 20 minutes At 70^{o}C 10 minutes 15 minutes 20 minutes	0.42 0.54 0.50 0.36 0.54 0.50 0.46 0.54 0.40	9.58 9.38 9.94 7.96 9.92 10.68 9.64 9.80 9.20	5.90 5.72 5.66 5.10 5.06 6.22 5.34 5.20 5.22	4.26 4.54 4.34 5.60 4.40 3.62 4.30 3.60 3.98	6.58 6.54 6.64 6.22 6.46 6.84 6.43 6.20 6.13	6.22 6.25 6.25 6.10 6.04 6.22 6.05 5.68 5.76	17.03 17.18 17.18 16.77 16.08 17.06 16.10 14.25 14.60

Potiskum beans							
At 30°C							
10 minutes	0.44	9.40	6.06	4.60	6.69	6.40	18.07
15 minutes	0.42	10.26	6.48	4.64	7.12	6.76	20.10
20 minutes	0.54	10.26	6.64	4.80	7.23	6.89	20.92
At 50°C							
10 minutes	0.52	9.66	6.16	4.10	6.64	6.25	17.18
15 minutes	0.38	9.72	6.34	4.16	6.74	6.35	17.93
20 minutes	0.34	10.02	6.54	4.64	7.04	6.72	19.92
At 70°C							
10 minutes	0.52	11.00	6.14	3.70	6.95	6.30	17.52
15 minutes	0.62	11.32	6.40	4.92	7.55	7.10	22.11
20 minutes	0.62	11.06	7.18	4.98	7.74	7.34	23.73

At soaking water temperature of 30°C, the weight of the Iron beans increased with soaking time most probably due to more water absorption. Potiskum and Oloyun beans behaved alike even at soaking water temperature of 50°C and 70°C. The seed size (AMD) of the three varieties followed the same trend except for Oloyun beans which showed a decrease at soaking water temperature of 50^{o}C as the soaking time increased. This was likely due to loss of some seed components like the hull at that temperature.

3.2 Mechanical Properties of the Cowpea Seed Samples.

The mechanical properties of the seed samples were measured using the horizontal loading position. These mechanical properties are very important as they help processing engineers to have an idea on the kind milling or processing machine design with respect to de-hulling. Table 8 gives the average values of some of the mechanical properties with respect to its soaking time and initial soaking water temperature.

Table 8: Mechanical properties of the cowpea variety with respect to the soaking time and initial soaking water temperature.

Variety	Rupture force (N)	Bio-yield force (N)	Deformation at rupture (mm)	Compressive strength (N/mm^2)	Energy of the seed (J)
Iron beans					
At 30^{o}C					
10 minutes	229.20	137.70	2.71	345.80	517.96
15 minutes	202.10	109.40	2.60	282.30	505.30
20 minutes	183.50	91.00	2.50	224.80	346.00
At 50^{o}C					
10 minutes	229.30	135.60	3.25	302.33	546.70
15 minutes	180.60	102.30	2.42	240.00	487.30
20 minutes	172.00	100.00	2.80	135.70	437.10
At 70^{o}C					
10 minutes	231.00	115.00	3.50	298.70	510.00
15 minutes	146.00	96.00	3.20	181.00	461.00
20 minutes	131.30	98.00	2.21	148.70	290.00
Oloyun beans					
At 30^{o}C					
10 minutes	281.00	113.70	3.71	379.30	447.00

15 minutes	141.70	108.70	2.60	267.00	417.00
20 minutes	127.00	68.70	2.51	208.70	349.70
At 50^{o}C					
10 minutes	190.00	112.30	2.70	252.70	519.70
15 minutes	189.70	107.30	2.60	219.00	487.00
20 minutes	152.00	77.10	2.56	191.00	396.00
At 70^{o}C					
10 minutes	214.00	148.70	3.00	258.00	595.00
15 minutes	198.00	138.00	2.400	256.00	487.00
20 minutes	198.90	133.70	2.300	250.00	380.00
Potiskum beans					
At 30^{o}C					
10 minutes	319.00	142.00	3.90	487.70	530.00
15 minutes	225.00	135.00	2.90	396.00	480.00
20 minutes	162.00	110.00	2.60	275.00	340.00
At 50^{o}C					
10 minutes	228.00	150.00	3.00	354.00	570.00
15 minutes	200.00	89.60	2.60	265.00	493.00
20 minutes	170.80	81.50	2.50	250.30	449.00
At 70^{o}C					
10 minutes	181.20	112.50	2.67	225.0	420.00
15 minutes	126.70	82.30	2.40	177.00	338.70
20 minutes	117.00	75.00	2.30	154.00	280.00

Iron beans has its lowest rupture force (131.3N) at soaking water temperature of 70^{o}C and soaking time of 20 min. The lowest rupture force (127.0N) for Oloyun beans occurred at 30^{o}C and soaking time of 20 min; while the lowest for Potiskum beans (117.0N) occurred at soaking water temperature of 70°C and soaking time of 20 min. The three varieties followed the same trend for bio-yield force. For compressive strength, Iron beans showed the lowest value of 135.7N/mm^2 at soaking water temperature of 50°C and soaking time of 20 min; Oloyun beans had its lowest at 191N/mm^2 at soaking water temperature of 50°C and soaking time of 20 min; while Potiskum beans lowest was 154.0N/mm^2 which occurred at soaking water temperature of 70°C and soaking time of 20 min. The lowest energy for the three varieties occurred at soaking water temperature of 70°C and soaking time of 20 min. This indicates that less heat energy is needed to cook beans pre-treated with hot water than beans that are not pre-treated.

The graphical plots of rupture force versus soaking time for the three cowpea varieties for 30, 50 and 70°C are shown in Fig.11, 12 and 13 respectively.

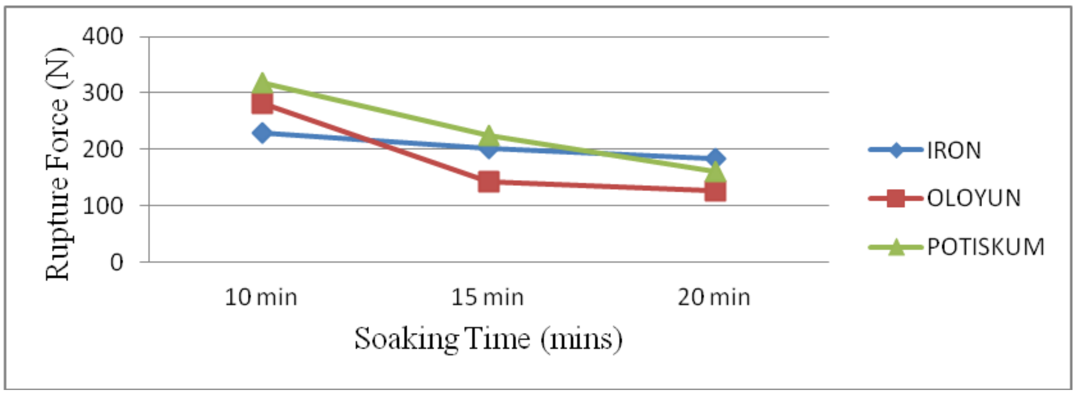

Fig.11: Rupture force (N) of seeds at 30°C

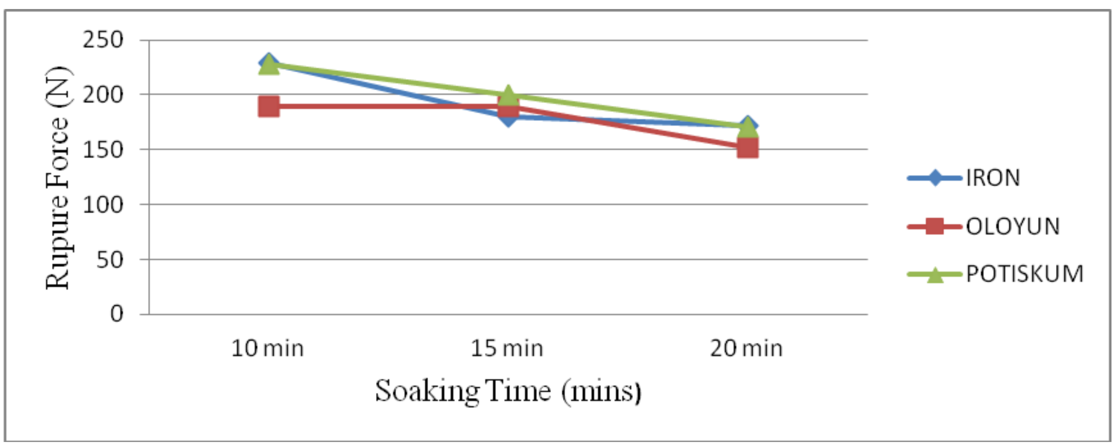

Fig.12: Rupture force (N) of seeds at 50°C

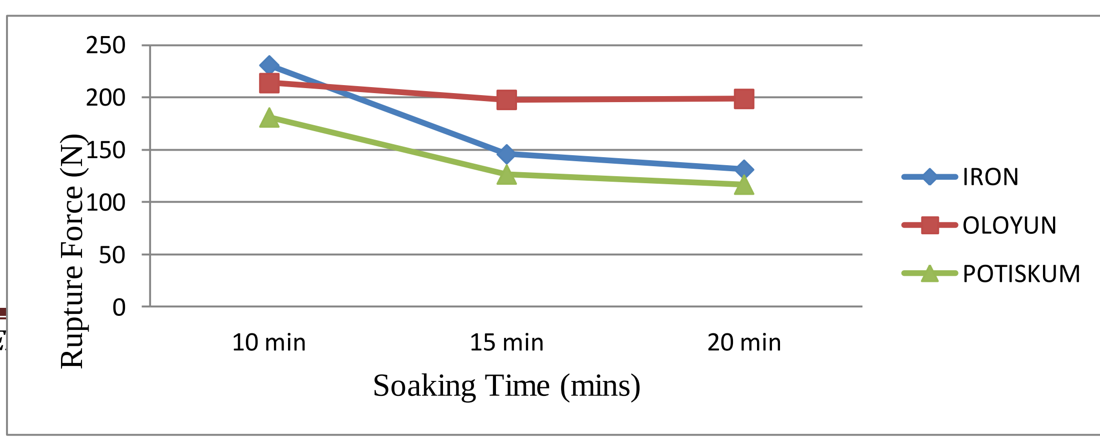

Fig. 13: Rupture force (N) of seeds at 70^oC

Fig.11 shows that: for soaking time of 10 min and soaking water temperature of 30^oC, Potiskum beans have the highest rupture force, bio-yield force, deformation at rupture, compressive strength, and energy, followed by Oloyun beans and then Iron beans.

And for soaking time of 15 min and soaking water temperature of 30^oC, Potiskum beans have the highest rupture force, followed by Oloyun and then Iron beans. And then for soaking time of 20 min and soaking water temperature of 30^oC, Iron beans have the highest rupture force followed by Potiskum beans and then Oloyun beans.

Fig.12 shows that: for soaking time of 10 min and soaking water temperature of 50^oC, Iron beans have the highest rupture force closely followed by Potiskum beans and then Oloyun beans. And for soaking time of 15 min and soaking water temperature of 50^oC, Potiskumbeans have highest with respect to rupture force, closely followed by Oloyun and then Iron beans. And then for soaking time of 20 min and soaking water temperature of 50^oC, Iron beans and Potiskum beans leads in rupture force, closely followed by Oloyun beans.

Fig.13 shows that: for soaking time of 10 min and soaking water temperature of 70^oC, Iron beans has the highest rupture force followed by Oloyun beans and then Potiskum. And for soaking time of 15 min and soaking water temperature of 70^oC, Oloyun beans has the highest rupture force followed by Iron beans and then Potiskum beans. And then for soaking time of 20 min and soaking water temperature of 70^oC, Oloyun beans have the highest rupture force followed by Iron beans and then Potiskum.

The graphical plots of bio-yield force versus soaking time for the three cowpea varieties for 30, 50 and 70^oC are displayed in Fig.14, 15 and 16 respectively.

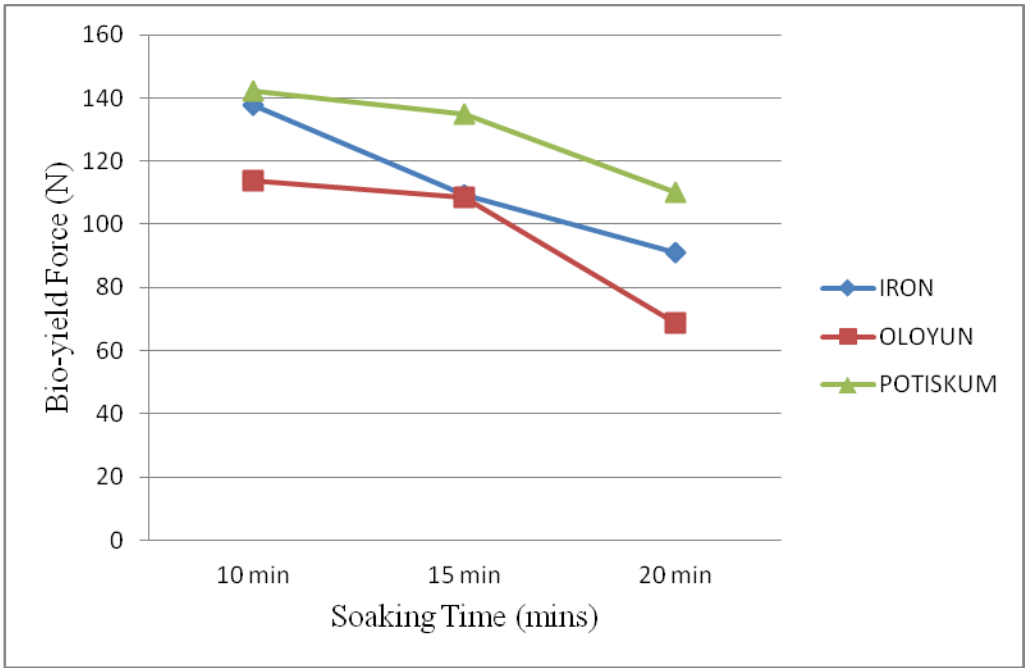

Fig. 14: Bio-yield force (N) of seeds at 30^{o}C

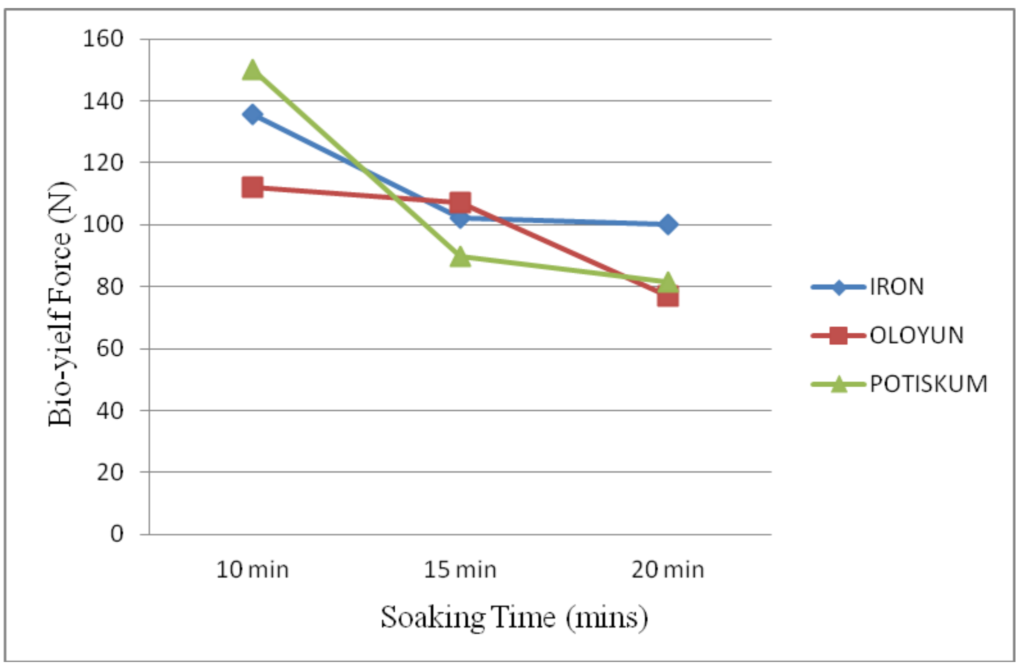

Fig.15: Bio-yield force (N) of seeds at 50^{o}C

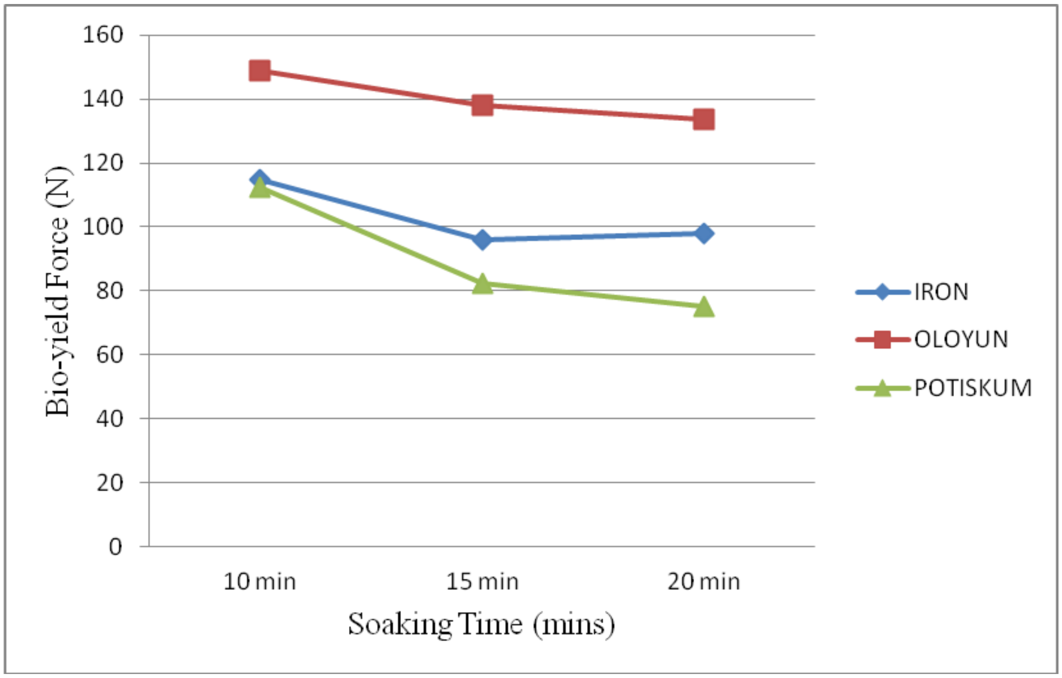

Fig.16: Bio-yield force (N) of the seeds at 70^{o}C

Fig.14 shows that: for soaking time of 10 min and soaking water temperature of 30^{o}C, Potiskum beans has the highest bio-yield force, followed by Iron beans and then Oloyun beans.

And for soaking time of 15 min and soaking water temperature of 30^{o}C, Potiskum beans leads followed jointly by Iron beans and Oloyun beans. And then for soaking time of 20 min and soaking water temperature of 30^{o}C, Potiskum beans leads followed by Iron beans and then Oloyun beans.

Fig.15 shows that for soaking time of 10 min and soaking water temperature of 50^{o}C, the order from highest to lowest in bio-yield force is Potiskum, Iron, and then Oloyun beans. And for soaking time of 15 min and soaking water temperature of 50^{o}C the order is Oloyun, Iron, and then Potiskum beans. And then for soaking time of 20 min and soaking water temperature of 50^{o}C, the order is Iron, Potiskum, and then Oloyun beans.

Fig.16 shows that: for soaking time of 10 min and soaking water temperature of 70^{o}C, the order is Oloyun beans, Iron beans, and then Potiskum beans. And for soaking time of 15 min and soaking water temperature of 70^{o}C, the order is Oloyun, Iron and then Potiskum beans. And then for soaking time of 20 min and soaking water temperature of 70^{o}C, the order is Oloyun, Iron, and then Potiskum beans.

The graphical plots deformation at rupture versus soaking time for the three cowpea varieties for 30, 50 and 70^{o}C are displayed in Figs.17, 18 and 19 respectively.

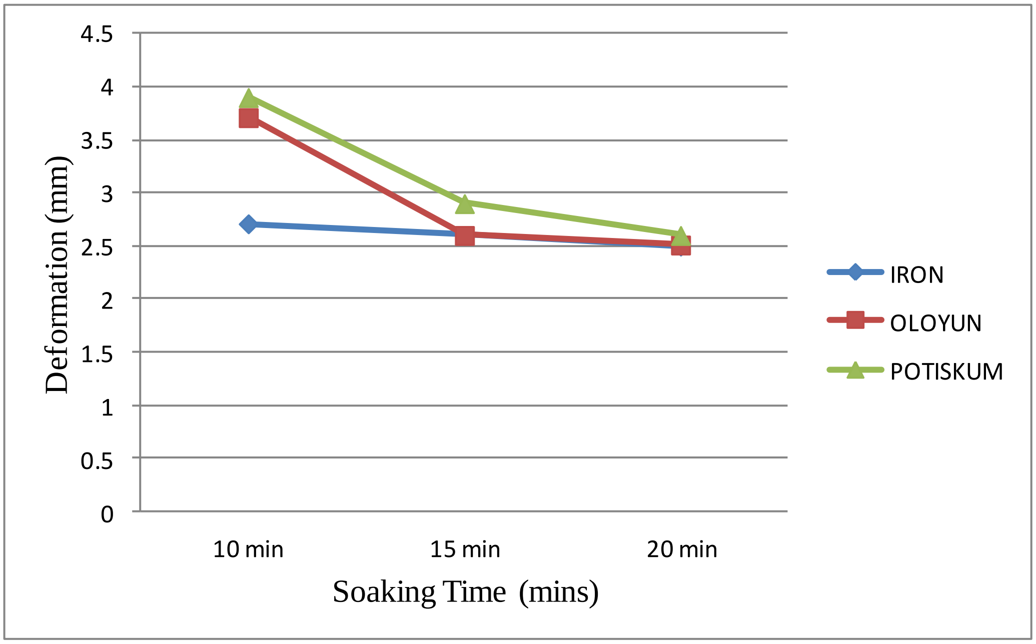

Fig. 17: Deformation (mm) of seed at 30^{o}C

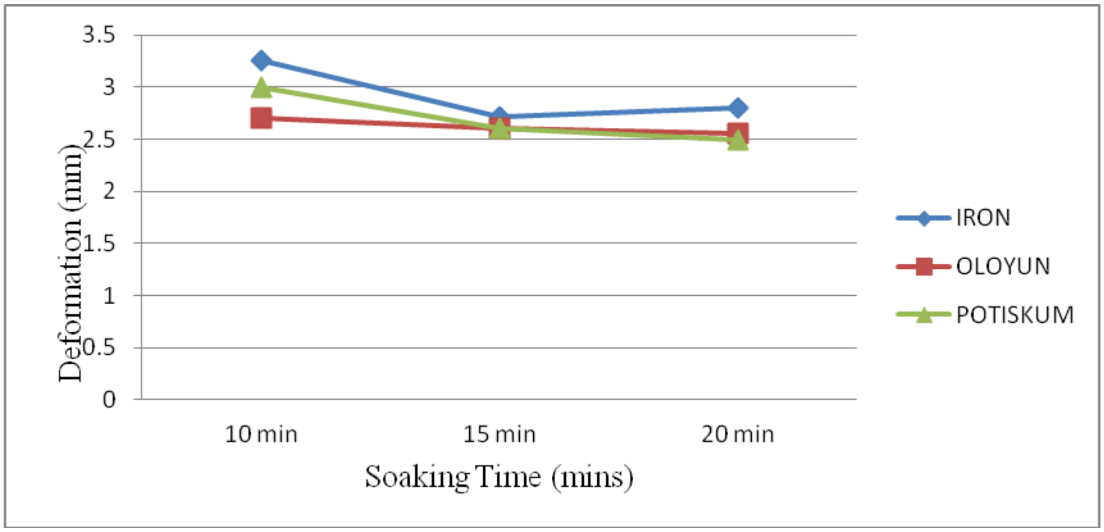

Fig. 18: Deformation (mm) of seed at 50^{o}C

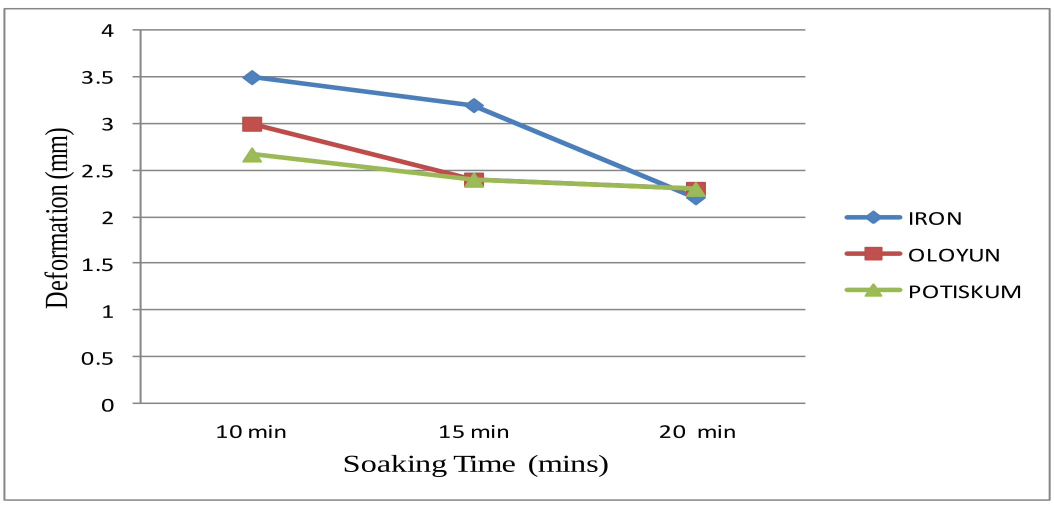

Fig.19: Deformation (mm) of seeds at 70^{o}C

Fig.17 shows that for soaking time of 10 min and soaking water temperature of 30^{o}C, the order is Potiskum, Oloyun and Iron beans. And for soaking time of 15 min and soaking water temperature of 30^{o}C, the order is Potiskum, closely followed by Iron and Oloyun beans. And for soaking time of 20 min and soaking water temperature of 30^{o}C, the order is Potiskum, again closely followed by Iron and Oloyun beans.

Fig.18 shows that for soaking time of 10 min and soaking water temperature of 50^{o}C, the order is Potiskum, Iron, and then Oloyun beans. And for soaking time of 15 min and soaking water temperature of 50°C, the order are Potiskum, Iron, and Oloyun beans. And then for soaking time of 20 min and soaking water temperature of 50°C, the order are Potiskum, Oloyun and then Iron beans.

Fig.19 shows that for soaking time of 10 min and soaking water temperature of 70°C, the order is Iron, Oloyun, and then Potiskum beans. And for soaking time of 15 min and soaking water temperature of 70°C, the order is Oloyun beans, jointly followed by Iron and Potiskum beans. And then for soaking time of 20 min and soaking water temperature of 70°C, the order is Oloyun beans, again jointly followed by Iron and Potiskum beans.

The graphical plots of compressive strength versus soaking time for the three cowpea varieties for 30, 50 and 70°C are displayed in Figs.20, 21 and 22 respectively.

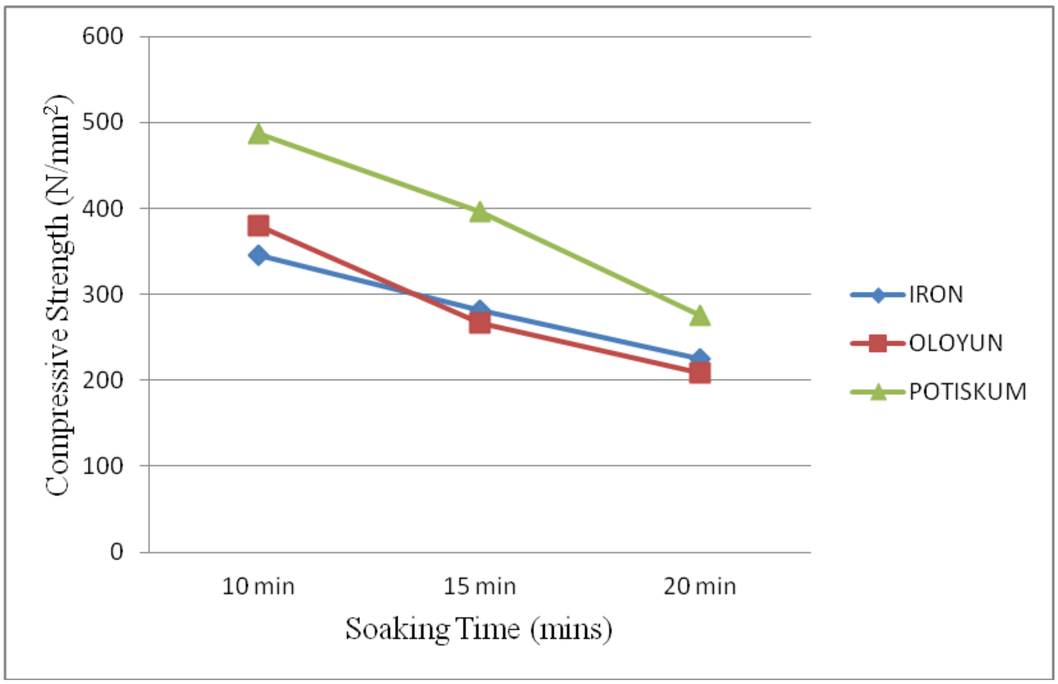

Fig.20: Compressive Strength (N/mm^2) of seeds at 30°C

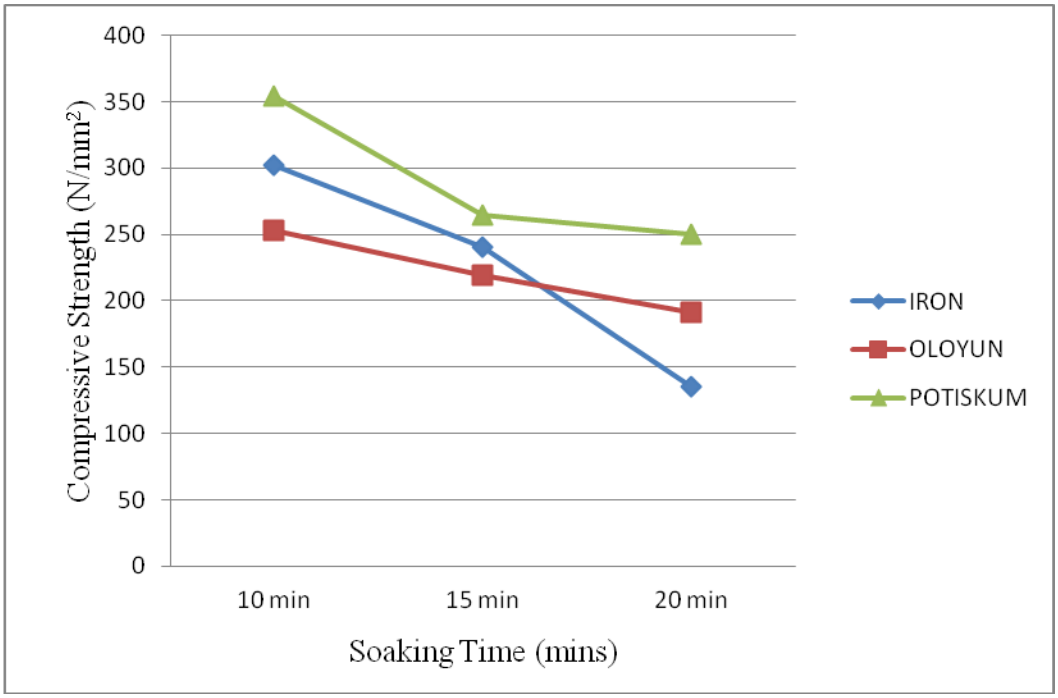

Fig.21: Compressive strength (N/mm^2) of seeds at 50^{o}C

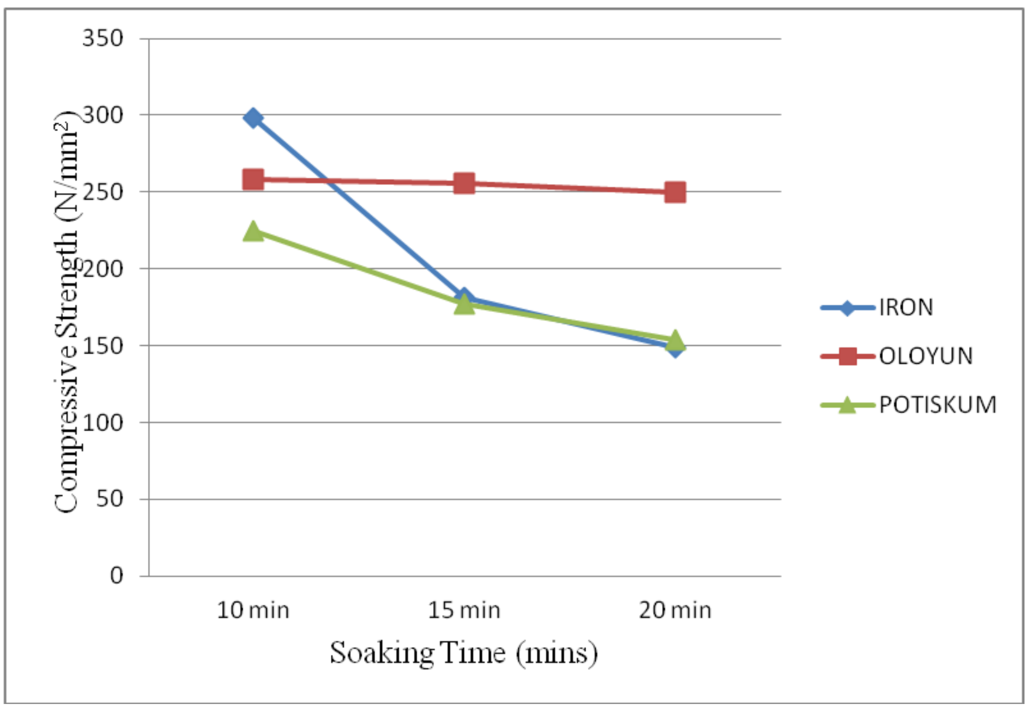

Fig.22: Compressive strength (N/mm^2) of the seed at 70^{o}C

Fig.20 shows that: for soaking time of 10 mins and soaking water temperature of 30^{o}C, Potiskum beans have the highest compressive strength followed by Oloyun and then Iron beans. And for soaking time of 15 min and soaking water temperature of 30^{o}C, the order is Potiskum, Iron and

Oloyun beans. And then for soaking time of 20 min and soaking water temperature of 30^{o}C, the order is Potiskum, Iron and Oloyun beans.

Fig.21 shows that: for soaking time of 10 min and soaking water temperature of 50^{o}C, the order is Potiskum, Iron and Oloyun beans. And for soaking time of 15 min and soaking water temperature of 50^{o}C, the order is Potiskum, Iron beans and Oloyun beans. And then for soaking time of 20 min and soaking water temperature of 50^{o}C, the order is Potiskum, Oloyun and Iron beans.

Fig.22 shows that: for soaking time of 10 min and soaking water temperature of 70^{o}C, Iron beans has the highest compressive strength, followed by Oloyun beans and then Potiskum beans. And for soaking time of 15 min and soaking water temperature of 70^{o}C, the order is Oloyun beans, Iron and then Potiskum beans.

And then for soaking time of 20 min and soaking water temperature of 70^{o}C, the order is Oloyun beans, followed by Iron beans, and then by Potiskum beans.

The graphical plots of energy versus soaking time for the three cowpea varieties for 30, 50 and 70^{o}C are displayed in Figs.23, 24 and 25 respectively.

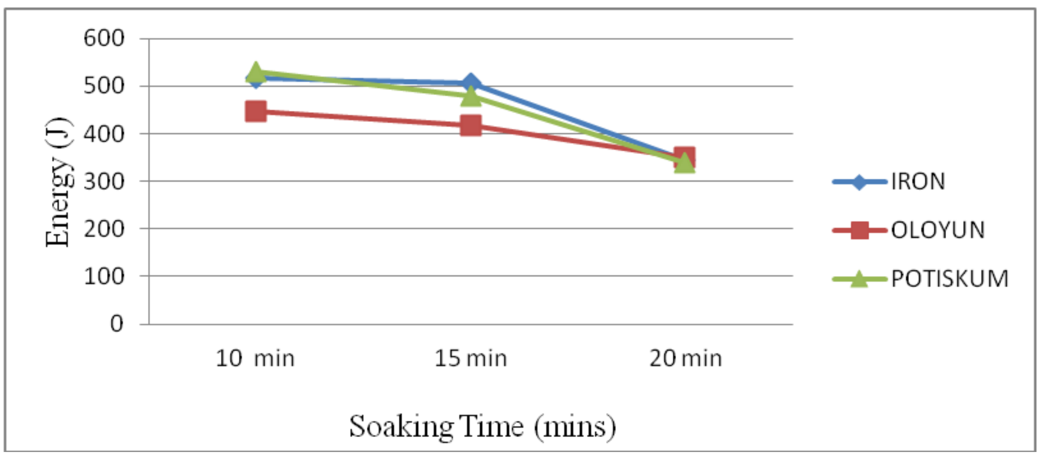

Fig.23: Energy (J) of seeds at 30^{o}C

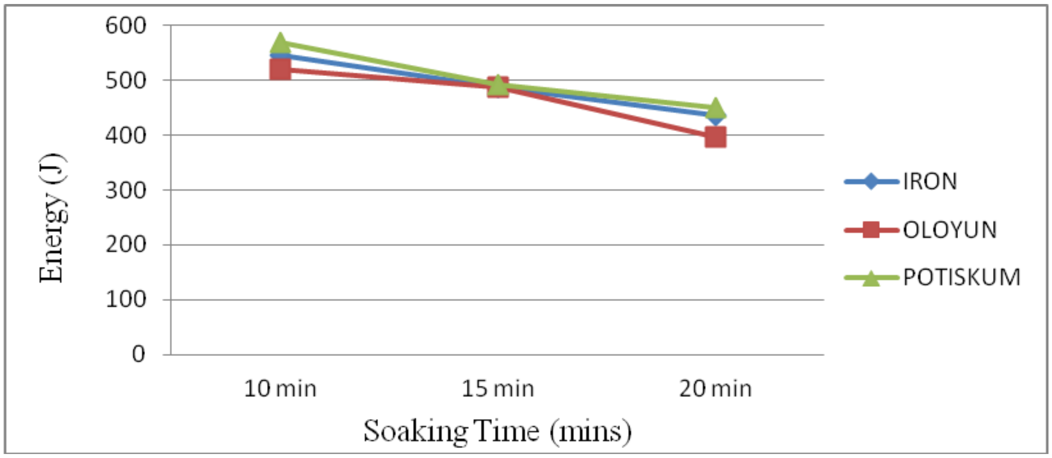

Fig.24: Energy (J) of seeds at 50^{o}C

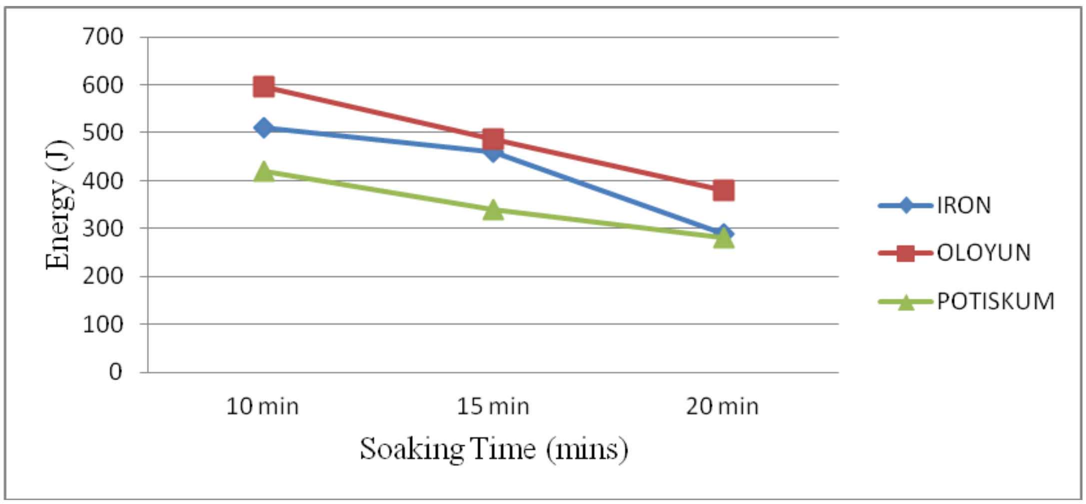

Fig.25: Energy (J) of the seed at 70^{o}C

Fig.23 shows that: for soaking time of 10 min and soaking water temperature of 30^{o}C, Potiskum and Iron bean have the highest energy followed by Oloyun beans. And for soaking time of 15 min and soaking water temperature of 30^{o}C, the order is Iron beans, Potiskum beans, and then Oloyun beans. And then for soaking time of 20 min and 30^{o}C, the three varieties have the same energy. Fig.24 shows that: for soaking time of 10 min and soaking water temperature of 50^{o}C, Potiskum beans has the highest energy followed by Iron beans, and then Oloyun beans. And for soaking time of 15 min and soaking water temperature of 50^{o}C, the three varieties have the same energy. And then for soaking time of 20 min and soaking water temperature of 50^{o}C, the order is Potiskum beans, closely followed by Iron beans, and then Oloyun beans.

Fig.25 shows that: for soaking time of 10 min and soaking water temperature of 70^{o}C, Oloyun beans has the highest energy followed by Iron beans and then Potiskum beans. And for soaking time of 15 min and soaking water temperature of 70^{o}C, the order is Oloyun beans, Iron beans, and then Potiskum beans. And then for soaking time of 20 min and soaking water temperature of 70^{o}C, the order is Oloyun, Iron and then Potiskum beans.

4.0 Conclusions and Recommendations

4.1 Conclusions

Soaking time affects positively the moisture content, weight, and the size of the cowpea seeds. Soaking time affects negatively the mechanical properties (rupture force, bio-yield force, deformation at rupture, compressive strength and energy) of the cowpea seeds. Soaking water temperature correlates positively with the moisture content, density, size (AMD), volume, sphericity, and the surface area of the cowpea seeds. Soaking water temperature affects negatively the rupture force, bio-yield force, compressive strength and energy of the cowpea seeds. Reduction of thermal energy for cooking beans could be achieved by pre-soaking in cold water (30^{o}C), or hot water (50 or 70^{o}C) for 10-15 min. Iron beans responds differently from Potiskum beans and Oloyun beans when soaked for a given time in either cold or hot water. Therefore, they should be soaked differently for better management of thermal cooking energy. Soaked in cold water (30 - 50^{o}C) Potiskum beans is adjudged stronger than Iron beans and Oloyun beans. Soaked in hot water (70^{o}C), Oloyun beans become stronger than Potiskum beans and Iron beans.

4.2 Recommendation

It is recommended that further studies be done to determine the shear strength of the hull or testa of cowpea and the effects of soaking time and soaking water temperature on it. Such data is important for the design of dehulling machine so as to reduce the present drudgery inherent in the processing of cowpea.

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EFFECT OF BOILING TIME ON SELECTED ENGINEERING PROPERTIES OF CASSAVA

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ABSTRACT
The engineering properties of cassava boiled at different times (20, 30 and 40 minutes) were investigated. The engineering properties of the tubers investigated include moisture content, density, %peel, hardness, compressive strength, stiffness moduli, toughness, shear strength, and coefficient of static friction on ply wood, mild steel and aluminum surfaces. As boiling time increased, the moisture content and stiffness moduli were seen to increase while all other properties measured were observed to decrease. The result from the study showed that boiling time had no significant effect ($p>0.05$) on the density, % peel, hardness, coefficient of static friction, stiffness moduli and shear strength. However, the moisture content, compressive strength, toughness and shear strength were significantly influenced ($p<0.05$) by the boiling time.
Keywords: Cassava, boiling, physical properties, mechanical properties.

1. INTRODUCTION
Cassava tubers are raw materials used for producing various products. Cassava is consumed only in its processed form due to its high hydrogen cyanide content which can be toxic to humans (Onwueme, 1978). These products include *fufu*, *garri*, chips, *abacha*. A lot of research has gone into processing of cassava into starch, garri, fufu(Etejere and Bhat, 1985) but not enough has been done in the processing into *abacha*. The unit operations involved in the processing into *abacha*includes boiling, peeling, slicing/shredding, washing and drying. This work aims at determining the effect of boiling times on the engineering properties of the tubers. This is to enable food engineers design and construct suitable slicing/shredding machine. This traditional technology of processing *abacha* slices involves a lot of drudgery with low throughput which reduces the market availability of the products. These desirable traits are being exploited by the farmers whichprobably accounted for the present position of Nigeria as theworld leading cassava producing nation (Kolawole et al., 2007). It is usually processed, locally, into *gari, lafun, fufu,abacha and akpu*in Nigeria, and, *kokonte* and *agbelima* in Ghana (Quaye et al., 2009).

The rising significance of agricultural products simultaneously with the complexity of modern technology for their processing need a better knowledge of their engineering properties so that machine's processing operations can be designed for maximum efficiency and the highest quality of the final end products ((Mohsenin, 1970). For instance, the application of physical properties such as shape which is an important parameter for stress distribution in materials under load is important in developing processing machines (Eşref and Halil, 2007). It is important to have an accurate estimate of shape, size, volume, density, surface area and other engineering parameters for a given biomaterial. Knowledge of mechanical properties such as, shear strength and compressive strength is vital to engineers in the design of processing equipment.

The successful design and development of postharvest handling and processing operations of the tubers, depends on comprehensive understanding of the engineering properties of the cassava root(Adetan et al., 2003; Kolawole et al., 2007). Therefore shredding has potentials to improve cassava products quality, even though the process is not widely used in cassava processing. Cassava shreds known within the Eastern parts of Nigeria as a*bacha* is a local delicacy. It is made from peeled and shredded cassava tubers, after steaming and fermentation for about 24 hours. The product is then washed and eaten as a snack or made into a main meal or dried for storage. Cassava shredding is still done manually. Peeled and steamed cassava is moved vigorously by hand over metallic shredding plates to effect the shredding action, or by the use of kitchen knives. The mechanization of cassava shredding introduces changes in the quality characteristics of the shreds produced. The nature of these changes will depend on the interaction of the machine, process and raw material variables. Therefore, a rational approach to the design of agricultural processing equipment (e.g. cassava shredding machine) will involve the knowledge of the engineering properties of the boiled tubers.

The objective of this study is to determine the effect of processing (boiling) times on some selected engineering (physical and mechanical) properties of cassava TME 419 grown in Crop Science Department, University of Nigeria, Nsukka, Enugu State, Nigeria, to establish a convenient reference data for their mechanization and processing. The knowledge of the engineering properties is useful for both engineers and food scientists; plant and animal breeders and it is also important in data collection in the design of machines, structures, processes and controls; and in determining the efficiency of a machine or an operation.

2. MATERIALS AND METHOD

A given variety of cassava, TME 419, was selected from Crop Science Department, University of Nigeria, Nsukka, Enugu State. One hundred and twenty (120) cassava tubers of this variety were randomly selected. Sixty three samples were randomly selected for physical properties test;

fifty four samples were randomly selected for mechanical properties test. Three groups were created for each engineering property tests (physical and mechanical), with three different boiling times of 20, 30 and 40 minutes respectively for each group. Each group contains six cassava tuber samples, except for coefficient of static friction, which contains three tuber samples in each group. The tubers in each group were peeled using a knife, washed thoroughly and boiled at their different time intervals using a cooking pot, and a stove as a source of energy and allowed to cool. The volume of water that was used to fill the cooking pot for boiling was the same. The samples were given identification marks to avoid the repeat of experiment. All experiments were carried out under standard laboratory conditions. All calculated values for physical properties test were rounded up to four decimal places. Figure 1 shows the geometry and sectional view of the tuber.

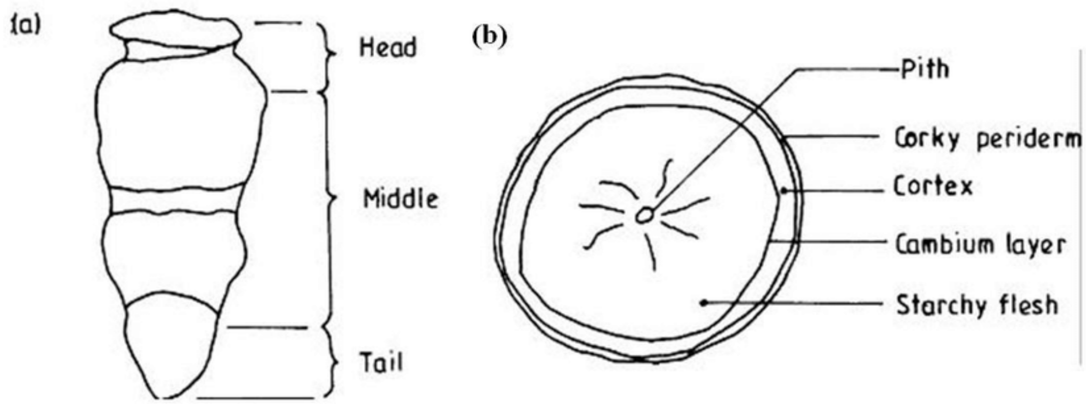

Fig. 1 Geometry of cassava tuber (a) sectional view of the tuber (b)

2.1 Moisture Content

Moisture content of the eighteen samples selected were determined using standard methods for oven drying as described by (Razavi et al., 2007).Six samples of boiled tubers were randomly selected across the three groups. A mass of 10g weighed using a weighing scale (Mettler Toledo JL 620-GLA01)of the six boiled samples randomly selected from group A, after boiling for twenty minutes and allowed to cool, were then oven dried to constant weight. The mass loss on oven drying of the 0.001kg boiled tuber samples in an oven at a temperature of 105^{o}C for 18 hours were then measured and recorded as recommended (Obi and Offorha, 2015; Razavi et al., 2007). The moisture content of these boiled tuber samples were determined, and an average value was taken. This process was carried out in group B, and C with boiling times 30 and 40 minutes respectively. The moisture contents (%) were calculated on wet basis usingeqn 1;

$$mc = \frac{m_1 - m_2}{m_1} \times 100 \qquad (1)$$

Where, $mc = $ %**moisture content** (wb)

$m_1 = $ **initial mass when boiled** (wet sample)(kg)

$m_2 =$ final mass when oven dried (dry sample)(kg)

2.2 True Density

The mass m(kg) of the tubers were determined after boiling them at their appropriate times using an electronic weighing balance (SHIMADZU BZ 32 OH, Japan) with an accuracy of 0.01g and the volume V(m^3) was gotten using liquid displacement method. The densities (ρ) of the six boiled tuber samples used for size tests, selected across the three groups were calculated by dividing their massesby their volume (V) obtained by water displacement. An average value was taken.

$$\rho\left(\frac{kg}{m^3}\right) = \frac{m(kg)}{V(m^3)} \quad (2)$$

2.3 Proportion by Weight of Peel

Proportion by weight of peel for the six boiled tuber samples selected for this test, across the three groups of eighteen boiled tuber samples were determined. The six boiled tuber samples in group A of 20 minutes boiling time, their mass (kg) before and after peeling were measured using electronic weighing balance as described by (Adetan et al., 2003). This process was repeated for group B and C for 30 and 40 minutes respectively. Proportion by weight of peel was calculated using;

$$w_p = \frac{m_{up} - m_p}{m_{up}} \quad (3)$$

Where, $w_p =$ proportion by weight of peel (%)

$m_{up} = mass\ of\ unpeeled\ cassava(kg)$

$m_p = mass\ of\ peeled\ cassava\ (kg)$

2.4 Coefficient of Static Friction

Three surfaces (plywood, aluminum sheet and mild steel) were used to determine the static coefficient of friction. The three boiled tuber samples selected from group A were boiled for 20 minutes and cooled, and were placed in horizontal and vertical positions on a small rectangular frame containing the different surface materials, positioned on an adjustable tilting surface. The surface was then raised gradually until the filled rectangular frame starts to slide down (Adetan et al., 2003; Dutta et al., 1988; Razavi and Milani, 2006). This process was repeated for group B and C with boiling times of 30 and 40 minutes respectively. The coefficient of static friction was calculated using the equation;

$$\mu = \tan \theta \quad (4)$$

Where, $\mu =$ coefficient of static friction

$\theta =$ angle of tilt of table (°)

2.5 Hardness Test

Grain hardness tester (Wenzhou Tripod) with ±1N precision was used to obtain the hardness of the six boiled tuber samples selected for this test, across the three different boiling time group. For group A of 20 minutes boiling time, the upper part of instrument slot was screwed downward to press 10mm diameter of the six boiled tuber samples individually. The first sound made by each tuber sample when tightly pressed indicates its hardness. The counter reading was taken when the sample was not making a total contact with the tester. Average values were taken. This process was carried out in group B and C of 30 and 40 minutes boiling times respectively.

2.6 Compressive strength and shear strength

The major diameters of the three boiled tuber samples for both loading positions for the three boiling time groups for compressive and shear strength tests were measured. The boiled samples were fixed on the compressive and shear chambers in their various loading positions respectively, and locked up. The mercury level was initialized and zero to the working fluid level. A gradual but continuous load was applied through the longer handle as the pulleys turn the attached machine graph round the graph drum. At intervals, the slider pin was pressed down to initiate the different force positions of the testing material. At rupture point, the material was removed and zero to the mercury level. The graph was then removed from the drum. The result was then read and interpreted for the various leading positions(Aluko and Koya, 2006). The beam used was 250kgf (2500N).

2.7 Tuber Stiffness Moduli and Toughness

The force–deformation curves obtained from each compression test of the three boiled tuber samples in the vertical and horizontal loading positions for their different boiling times were subsequently analyzed to determine stiffness moduli and material toughness. For each sample, stiffness was determined as the slope of the apparent linear elastic portion of the force–deformation curve and toughness, the area under the curve.

2.8 Statistical Analysis

A completely randomized design (CRD) was employed in this work while analysis of variance (ANOVA) was used to analyse the data obtained. Means were separated using least significant difference.

3. RESULTS AND DISCUSSION

The results of the boiling time on the Engineering properties of Cassava (TME 419) are discussed below. The boiling time ranged from 20 to 40 minutes.

3.1 Effect of Boiling Time of Physical Properties

The mean values recorded for the physical properties of boiled cassava are shown in Table 1. For moisture content, it was observed that it increased as boiling time increased. This could be as a result of moisture absorbed during boiling. The density of the tuber was observed to decrease as the boiling time increased, The %peel reduced as the boiling time increased; it ranged between 14 to 17% which falls within the range reported by (Adetan et al., 2003). And also the hardness decreased as the boiling time increased.

The analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) carried out revealed that there was no significant difference ($p>0.05$) between the moisture content of cassava boiled at 20 minutes and 30minutes but there was a significant difference ($p<0.05$) between the samples boiled at 40 minutes and those of 20 and 30 minutes respectively. However, there was no significant effect ($p>0.05$) of the boiling time on the density, %peel and hardness of the tuber.

Table 1: Physical properties of cassava at different boiling times

Time (mins)	MC	Density (kg/m^3)	% peel	Hardness (kg)
20	55.93^a	1287.5^a	17.73^a	2.07^a
30	58.86^a	1140.5^a	16.06^a	1.46^a
40	63.09^b	1002.40^a	14.41^a	1.23^a

3.2 Effect of Boiling Time on Frictional Properties of the Tuber

As shown in table 2, the coefficient of static friction increased with boiling time when positioned vertically against plywood and mild steel and when placed horizontally against mild steel. However, no clear trend was observed when it was placed against aluminum and horizontally against plywood. This suggests that there is no effect of boiling time on the coefficient of static frictions against these materials.

The analysis of variance (ANOVA)and Duncan Multiple Range Test (DMRT) done shows that there was no significant difference between the frictional properties of the tuber when boiled at the different times.

Table 2 Coefficient of static friction

	Plywood		**Mild steel**		**Aluminum**	
	(Horizontal position)	(Vertical position)	(Horizontal position)	(Vertical position)	(Horizontal position)	(Vertical position)
20	0.86a	0.22a	0.61a	0.21a	0.63a	0.25a

30	0.79a	0.28a	0.68a	0.28a	0.98a	0.36a
40	1.2a	0.48a	1a	0.41a	0.86a	0.33a

3.3 Mechanical Properties

As shown in table 3 and 4, as boiling time increased, it was observed that the horizontal and vertical compressive strengths of the tuber decreased. This was the same for other mechanical properties measured except the horizontal stiffness moduli which increased as the boiling time increased.

The analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) done revealed that there was a significant effect ($p<0.05$) of the boiling time on the horizontal compressive strength but no significant difference ($p>0.05$) was shown in the vertical compressive strength

Table 3 Mechanical properties

Time (mins)	Comp strength H (N)	Stiffness moduli H (N/mm)	Toughness H (J)	Comp strength V (N)	Stiffness moduli V (N/mm)	Toughness V (J)	Shear strength H (N)	Shear strength V (N)
20	425^{a}	150.57^{a}	1840.9^{a}	195.83^{a}	145.37^{a}	659.63^{a}	145.83^{a}	120.83^{a}
30	316.67^{b}	255.33^{a}	1479.4^{a}	175^{a}	120.37^{a}	454.97^{ab}	139.58^{a}	104.17^{a}
40	225^{c}	338.9^{a}	446.33^{b}	141.67^{a}	80.57^{a}	285.17^{b}	95.83^{a}	95.83^{a}

4. CONCLUSION

The effect of boiling time on the engineering properties of cassava boiled were investigated using cassava TME 419 specie. Some properties such as density, %peel, hardness, coefficient of static friction, stiffness moduli and shear strength were seen not to be significantly affected ($p>0.05$) by the boiling time. However, the boiling time is seen to have a significant effect on the moisture content, compressive strength and toughness.

The knowledge of the effect of boiling time on cassava could be used in the design of processing and handling equipment for the processing of *abacha* and cassava snacks.

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DETERMINATION OF SELECTED ENGINEERING PROPERTIES OF *MORINGA OLEIFERA* SEED

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ABSTRACT

Some selected engineering properties such as the physical and mechanical properties of *Moringa oleifera* seeds were studied at two moisture content levels of 1% and 1.5% (wet basis). Compressive strength characteristics were conducted under quasi-static compressive force at longitudinal and latitudinal (lateral) loading positions. The mechanical properties determined at various loading positions are the rupture forces, compressive strength, toughness, stiffness and force at bio-yield. Results indicated that volume (0.00017-0.0002mm^3), surface area (0.0087mm^2-0.01mm^2), geometric mean diameter (0.10mm-0.11mm), and weight (0.3g-0.31g) of the *Moringa oleifera* seed increased linearly with increase in moisture content. Also the bulk density, specific gravity (1764.7 -1550), sphericity (0.94-0.92), and aspect ratio (0.950-0.930) decreased with increase in moisture content. In the case of force deformation characteristics, result indicates that the force and corresponding deformation at rupture of *Moringa oleifera* seeds were found to vary from 319N, 1.63mm in longitudinal loading position to 112.50N, 0.38mm in lateral loading position at 1% moisture content and 119N, 0.75mm in longitudinal loading position to 110N, 0.63mm in lateral loading position at 1.5% moisture content. The bio-yield force, compressive strength, stiffness and toughness of the *Moringa oleifera* seed varied from 156.50N, 487.50N, 204.5N/mm, 3.42J/mm^3, in longitudinal loading position to 43.75N, 287.50N, 350N/mm, 0.261J/mm^{3}in lateral loading position at 1% moisture content and22.50N, 256.50N, 158.67N/mm, 0.58J/mm^3 in longitudinal loading and 19.00N, 212.50N, 180N/mm, 0.45J/mm^2 in lateral loading position at 1.5% moisture content (wb) respectively. Compressive strength of*Moringa oleifera* seed generally, is higher in the longitudinal loading position. It is recommended that for higher compressive strength of moringa seed, the longitudinal loading position should be adopted for designing machines that can break moringa seed, at a moisture content of 1.5% (wb).

KeyWords: Engineering properties, Physical Properties, Mechanical Properties, Moringa oleifera seed, Moisture content, Loading Positions

1. INTRODUCTION

Moringa oleifera is the most widely cultivated specie of the genus in the family moringaceae and a native to parts of Africa and Asia. In cultivation the trees are usually cut back annually to 1 – 2cm (3 – 6ft) and allowed to regrow so the pods and leaves remain within arm's reach. Fresh and raw moringa seeds are quite tender, but as soon as they get dried, they become hard and resembles bean seeds.

The common methods of extracting oil from grains have been identified,(Asoegwu, et al, 2006) these are; water assisted- when finely ground seed is either boiled in water and the oil that floats on the surface is skimmed off, or ground seeds are mixed with water and squeezed by hand to release the oil; manual pressing- when seeds usually pre-ground are pressed in a manual screw press; expelling- using an expeller which consist of a motor driven screw turning in a perforated cage, the screw pushes the material against a small outlet-"choke". The great pressure required to operate the machine can be provided through machine or animal power. Seed is fed slowly into the mortar and the pressure exerted by the pestle breaks the cells and releases the oil; and solvent extraction- where oil remaining in the seed cake after expelling is extracted with solvents and the oil is recovered after distilling off the solvent under vacuum.

Therefore, a fundamental knowledge of agricultural products behaviour under mechanical forces is essential in determining the power requirements for different operations (Graham, 1965). A thorough knowledge of the mechanical and physical properties of grains and other agricultural product is essential in the optimal design of handling, processing and storage equipment. Since most agricultural products are subjected to a series of static and dynamic forces during the course of handling and processing, such properties as compressive strength, force/deformation under static and dynamic loading constitute important characteristics or determining factors in the design of industrial equipment for these operation (Datrell and Walner, 1980). *Moringaoleifera* requires threshing, cleaning and grading. These unit operations require good knowledge of the physical and mechanical characteristics such as shape, size, volume, density, porosity, surface area, sphericity, roundness Hence, this work tries to determine selected engineering properties such as the physical and mechanical properties that are important in the design of industrial equipment for harvesting, handling, processing and packaging of *Moringaoleifera.*

2. MATERIALS AND METHOD

2.1 Sample Collection and Preparation

Moringaoleifera seeds used in this work were collected from Enugu State Polytechnic farm in Iwollo, Ezeagu Local Government Area of Enugu State, Nigeria. The sample were dehulled and cleaned to remove dirt. After cleaning, the seed were packed and taken to Agricultural and Bioresource Engineering laboratory,of the Enugu State University of Science and Technology(ESUT) where the physical properties were determined In the experiment, 30 seeds were randomly selected and the major diameter, minor diameter, intermediate and the weight were determined.

2.1.1 Determination of the physical properties of moringa seed

A 0-12cm range micrometer screw gauge used to measure the major, minor and intermediate diameters of the seeds. Physical properties, such as shape, size, volume, surface area, density, colour and appearance that are associated with design of a specific machine or analysis of thebehaviour of the product in handling processes were determined (Mohsenin, 1986). Some of these physical characteristics are inseparable in describing an object and were used to determine the size and sphericity of the bean using equations as reported by (Mohsenin 1986, Galenda r*et al.*, 2008). The average diameters were calculated using arithmetic mean and geometric mean of the three axial dimensions as expressed in equations (1) and (2);

$$AMD = \frac{a+b+c}{3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$GMD = (abc)^{1/3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Here, a, b and c respectively represents the major diameter, minor diameter and the thickness of the seeds while AMD and GMD represents the arithmetic andgeometric mean diameters.

2.1.2 Sphericity

The geometric foundation of the concept of sphericity rests upon the isoperimetric property of a sphere. According to (Curray, 1951), sphericity, (S) can be determined using equation (3);

$$S = \frac{(abc)^{1/3}}{a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

2.1.3 Surface area

The knowledge of the surface area and the diameter of agricultural products are essential for determination of terminal velocity, drag coefficient, and Reynolds number (Mohsenin, 1986) which are observed in conveying solid materials by air or water. According to (Garrett, and Brooker 1965), the surface area,(A) of the beans of spherical shape can be evaluated from the expression in equation (4);

$$A = \frac{\pi D^2}{4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In equation (4), A is surface area of bean of spherical shape in mm^2, D is the minor diameter of the sphere in mm and $\pi = \frac{22}{7}$

2.1.4 Volume

The unit volume of the 30 individual seeds was determined from the values of major, minor and intermediate diameters (a, b, c) from the following relationship in equation (5).

$$V = \frac{abc}{6} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (5)$$

A mettle toledo electronic weighing balance of model XP204 and 0.000lg sensitivity was used to determine the weight of the seeds. Measurements were replicated for 30 times and the total weight of the seeds was determined.

2.1.5 Bulk density and specific gravity

Density and specific gravity of food material and agricultural product play an important role in many application such as drying and sorting of hay (Day and Panda, 1966); design of silos and storage bins (Otis and Pomroy, 1967); mechanical compression of ensilage (Graham, 1965); separation from undesirable material and maturity evaluation (Muak, 1957) are some examples where bulk density has found application. The Bulk density could be determined from the expression given in equation (6)

$$Bulkdensity = \frac{Ws}{Vs} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (6)$$

Where Ws = weight of materials (g) and Vs = volume of material (mm^3)

2.1.6 Aspect ratio

A mettler toledo electronic weighing balance of model XP204 and 0.000lg sensitivity was used to determine the weight of the seeds. Measurements were replicated for 30 times and the total weight of the seeds was determined. The aspect ratio (Ra) is used in classification of grain or seed shape and it was calculated using equation (7).

$$Ra = \frac{b}{a} (7)$$

$where\ Ra = Aspect\ ratio,$ a = Major diameter(mm) and b = Minor diameter(mm)

2.1.7 Moisture content

The presence of moisture on rubbing surfaces may cause an increase in friction due to increase in adhesion (Osmak, 1954). The oven-drying method of moisture content (M.C.) determination was used to determine the moisture content (wet basis) of the seeds. The weight of dry samples Dw and the weight of wet samples Ww were determined and the moisture content evaluated from the expression given in equation (8);

$$M.C = \frac{Ww - Dw}{Dw} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (8)$$

2.2 Determination of Mechanical Properties Moringa seed

A Mettle Toledo electronic weighing balance of model xp204 used for all weight measure merits. According to Mohsenin (1986), mechanical properties are those properties (load-deformation characteristics) that have to do with the response or behavior of agricultural products when subjected to forces during handling and processing. A poor knowledge or inappropriate application of the mechanical and other properties of biomaterials in the designing of processing and handling equipment will cause mechanical damage to the products. Mechanical damage to seed and grain which occurs in harvesting, threshing and handling can seriously affect viability and germination power, growth vigor and quality of the final products from the study of (King and Osmak, 1954).

2.2.1 Compressive test

The compression test was performed at the Food and Bioprocess Laboratory of Agricultural and Bioresources Engineering materials laboratory, University of Nigeria, Nsukka (UNN). The test was carried out using Monsanto tensometer T10 to determine the force deformation characteristics of the moringa seed samples in longitudinal and lateral loading positions at two different moisture content of 1 and 1.5% (wet basis). Moringa seed samples were placed in two loading positions on the compressions jaws, making sure that the centre of the tools was in alignment with the peak of the curvature of the sample, force was applied by turning the load of the testing machine at 2.5mm/min and the seed load to a point of maximum breaking point (rupture point) this was accompanied by the corresponding drop on the force deformation graph, which was plotted concurrently by the cursor and its attached needle which punctured the graph sheet of frequent intervals, thereby recording the force and corresponding deformation. The resultant graph produced by joining the successive punctures shows force- deformation curve indicating bio yield points and the rupture force points which were measured at different loading positions and moisture contents. Three replications of the test were taken for moringa seed. The test room temperature was maintained at 29^{o}C After the experiments, the rupture forces, deformation energy, modulus of deformability toughness and stiffness of the test sample were determined. Figure 1 shows the block diagram of orientations of moringa seed under compressive loading.

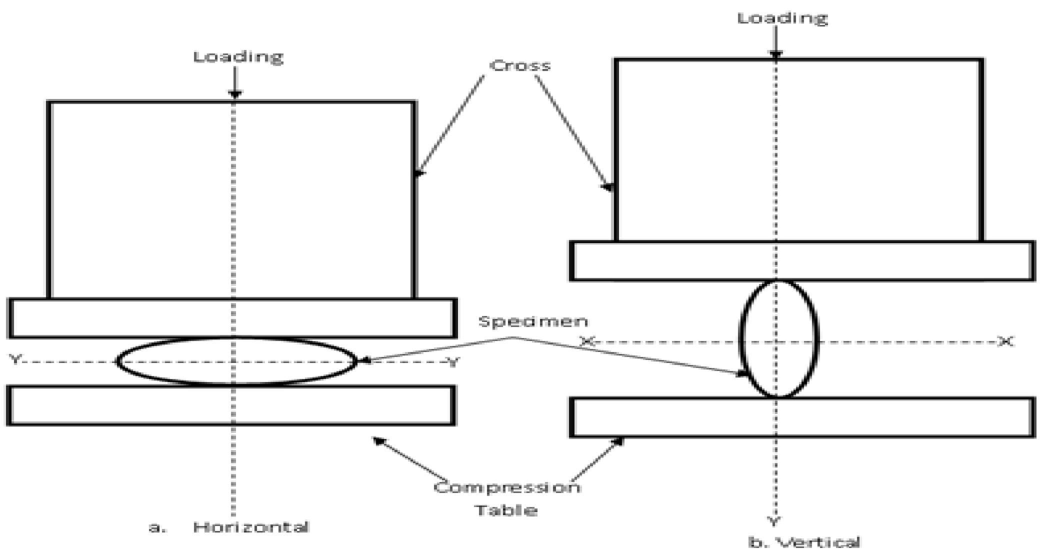

Figure 1: Block Diagram of Orientations of moringa seed under Compressive Loading

2.2.1 Toughness

Toughness is the amount of work or energy required to bring about rupture in a material. It was determined by computation of the area under the force-deformation curve before rupture expressed as obtained in equation(9) (Mohsenin, 1986).

$$Toughness = \frac{RuptureEnergy}{volumeofmaterial} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

2.2.2 Stiffness

Stiffness was computed using equation (10), as reported by [Maduako and Faborode, 1994].

$$Stiffness = \frac{Forceatrupture}{Deformationatrupture} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (10)$$

2.2.3 Deformation energy

Deformation energy was computed using equation (11);

$$Deformation\ energy = Rupture\ force \text{ x Deformation at Rupture} \dots\dots\dots\dots\dots.. (11)$$

2.2.4 Compressive strength

The maximum compressive stress (which a material is capable of sustaining) is the normal stress due to forces directed towards the plane on which it acts and was calculated from the maximum load during a compression test and the original cross sectional area of the specimen.

The compressive strength is calculated using equation (12);

$$rc = \frac{Fc}{a} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (12)$$

In equation (12),$rc\ is$ the compressive strength in $\frac{\text{N}}{\text{mm2}}$, $\text{Fc} =$ max load at fracture in N, $\text{a} =$ cross sectional area of specimen in mm2

2.2.5 Bio-yield point

This is defined as a point at which an increase in deformation is observed with a decrease or no change in force. In some agricultural products, the presence of this bioyield point is an indication of initial cell rupture in the cellular structure of the material (ASAE, 1980). The bio-yield point may occur at any point beyond the point of inflection (Linear Limit) where the curve deviates from the initial straight line portion.

2.2.6 Rupture point

The rupture point is a point on the force deformation curve at which the axial loaded specimen ruptures under a load (Mohsenin, 1986). In biological materials, rupture may cause punctures of shell or skin cracking or fracture planes. This point is detected by a continuous decrease of the load in the force deformation curve. In a force deformation curve the rupture point of specimen may occur at any point on the curve beyond the yield point (Kranzler and Witz,, 1976).

3. RESULTS AND DISCUSSION

3.1 Physical properties of moringa seed

The physical properties of moringa seeds were presented in table 1 and discussed below. It showed that, the dimensions of the mean physical properties of 30 samples of moringa seed increased with an increase in moisture content.

Sphericity of the Moringa seeddecreased with an increase in moisture content. At 1% moisture content, the sphericty was 0.94 but decreased at 1.5% moisture content to 0.92. This shows that relative proportional changes occurred in the dimensions of the Moringa seeds. The finding is similar to that of Asoegwu *et al.*, (2006) who reported that the sphericity increased with decrease in the seed size with the small sized seeds having the highest spherecity.

The volume of the moringa seed increased with an increase in moisture content. The volume increased from 625.72 mm^3 to 663.47 mm^3 at 1% and 1.5% moisture content respectively. This increase in volume may be attributed to expansion in size dimensions due the presence of more liquid (Mohsenin, 1986).

Bulk density of the moringa seeds varied from 0.0072g/mm^3 at 1% moisture content to 0.0007g/mm^3 at 1.5% moisture content while the specific gravity varied from 0.0072 to 0.0007 at 1% and 1.5% moisture content respectively. This result indicates a decrease in bulk density and specific gravity with an increase in moisture content. This implies that there was an increase in weight of the sample owing to the moisture in the moringa seed which was lower than the volumetric expansion of the bulk agro-material, as reported by (Mwithiga and Sifuna, 1986) for sorghum seeds. Similarly, the surface area of the seeds increased with an increase in moisture content. The surface area increased from 195.40mm^2 at 1% moisture content to 202.40mm^2 at

1.5% moisture content. This result indicates that the increase in the values may be attributed to their dependence on the size dimensions of the moringa seed which are similar to the report of Oluka and Nwube (2001) for cowpeas.

The weight of the seeds increased with an increase in moisture content. The weight increased from 4.49g to 4.62g at 1% and 1.5% moisture content respectively. The aspect ratio decreased with increase in moisture content. The aspect ratio was 9.950 at 1% moisture content, but decreased to 0.93 at 1.5% moisture content.

Table 1: The mean physical properties of Moringa seeds at different moisture contents.

Moisture Content (%)	Major Diameter (mm)	Minor Diameter (mm)	Intermediate (mm)	Geometric Mean (mm)	Sphericity	Weight	Volume (g/mm^3)	Bulk Density (g/mm^3)	Specific Gravity	Surface Area (mm^2)	Aspect Ratio
1%	16.59 (0.111)	15.77 (0.105)	14.35 (0.096)	15.54 (0.10)	0.94 (0.91)	4.49 (0.30)	625.72 (0.00017)	0.0072 (1764.7)	0.0072 (1764.7)	195.40 (0.0087)	0.950 (0.945)
1.5%	17.2 (0.1115)	16.05 (0.113)	14.42 (0.096)	15.85 (0.11)	0.92 (0.92)	4.42 (0.31)	063.47 (0.0002)	0.007 (15.50)	0.007 (1550)	202.4 (0.01)	0.93 (0.98)

3.2.Mechanical properties of moringa seed

The mechanical properties of *Moringaoleifera* seeds were as presented in table 2 and discussed below. It showed that at two different moisture contents (1% and 1.5%wb) and at two loading positions (longitudinal and lateral positions) showed that the rupture force increased significantly at 1% moisture content in lateral loading position. In longitudinal loading position at 1% moisture content, the rupture force records 319N while in lateral loading position at the same moisture content, the rupture force increased to 112.5N. At 1.5% moisture content, the rupture forces were 119N and 110N at longitudinal and lateral loading positions respectively.

The Bio-yield force indicates highest at 1% moisture content in longitudinal loading position and lowest in lateral at 1.5% moisture content. The bio-yield force at 1% moisture content were 156.50N and 43.75N in longitudinal and lateral loading positions respectively while at 1.5% moisture content they were 22.5N and 19.00N in longitudinal and lateral loading positions respectively.

Compressive strength indicates highest at 1% moisture content (w_b) in longitudinal loading position (487.5N/mm^2) and lowest at 1.5% moisture content (w_b) in lateral loading position (212.5N/mm^2). This indicates that little force is required to cause rupture on the seed as reported by Maduka*et al.*, (2001) on bambara groundnut.

The deformation energy of the seed was highest at 1% moisture content in longitudinal loading position. The deformation energy at 1% moisture content both in longitudinal and lateral loading positions were 525.50J and 40.63J respectively while at 1.5% moisture content they were 89.25J and 70J in longitudinal and lateral loading positions respectively.

The toughness of the moringa seed indicates highest at 1% moisture content in longitudinal loading position and lowest at same moisture content in lateral loading. At 1% moisture content, the toughness of the seed increases from lateral loading position (0.26J/mm^3) to longitudinal loading position (3.42J/mm^3) and increases from lateral loading position (0.45J/mm^2) to longitudinal loading position (0.58J/mm^2) at 1.5% moisture content.

The stiffness of the seeds increased at 1% moisture content in lateral loading position and decrease at 1.5% moisture content in longitudinal loading position. At 1% moisture content, the stiffness of the seed increased from (204.5N/mm) in longitudinal loading position to 350N/mm in lateral loading positions while at 1.5% moisture content, the stiffness were (158.57N/mm) and (180N/mm) longitudinal and lateral loading positions respectively.

The moringa seed easily deformed at 1.5% moisture content in longitudinal loading but less deformed at 1% moisture content in lateral loading position. The deformation at rupture at 1% moisture content in longitudinal and lateral loading positions were 1.63mm and 0.38mm respectively, while at 1.5% moisture content, the deformation at rupture both in longitudinal and lateral loading positions were 0.75mm and 0.63mm respectively.

Table 2: Mechanical properties of moringa seeds at different moisture content and at loading positions.

Moisture Content %	Loading position	Bioyield force (N)	Rupture force (mm)	Deform-ation Rupture (mm)	Compre-sive force (N)	Energy (J)	Toughness (J/mm^2)	Dragtime (N)	Stiffness (N/mm)	Hardness (N/mm)
1%	Longitudinal Lateral	156.50 43.75	319 112.50	1.63 0.38	487.50 287.50	525.50 40.63	3.42 0.26	262 175	204.5 350	28.84 30.93
1.5%	Longitudinal Lateral	22.50 19.00	119 110	0.75 0.63	256.50 212.50	89.25 70	0.58 0.45	137.50 102.5	158.67 180	29.24 30.37

Generally, considering the effects of moisture contents on the physical and mechanical properties, result shows that, at 1.5% (wb) moisture content, the values obtained were higher in the physical properties than at 1% moisture content. However, in compressive test (mechanical properties), the obtained values at 1% moisture content were higher than the values at 1.5% (wb) moisture content. Therefore, the deformation of the moringa seed was affected with increase in moisture content.

3.3 CONCLUSION

Physical and mechanical properties of moringa seed depended on its moisture content. The axial dimensions of moringa seeds increased with an increase in moisture content. This situation is due to water absorption by moringa seeds. Geometric mean diameter, volume, surface area and weight of the moringa seeds also increased with increasing moisture content. Bulk density, specific gravity, sphericity and aspect ratio of the moringa seeds decreased with an increase in moisture content. The toughness of the seed decreases as the moisture content increases from the initial value of 1% to 1.5% (wb) where it becomes easy to break. To break the seed, moisture content at 1.5% (wb) will be appropriate

It is recommended that for higher compressive strength of moringa seed, the longitudinal loading position be adopted for designing machines that can break moringa seed, at a moisture content of 1.5% (wb).

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RESPONSE SURFACE APPROACH TO FERMENTATION AND DRYING PROCESSES OF PALM FRUIT MESOCARP FIBRE FLOUR

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ABSTRACT
Palm mesocarp fibre (PMF) flour was produced from the tenera specie of oil palm fruit using fermentation and drying processes. The influence of fermentation process independent variables of temperature, pH, mass and time as well as drying process independent variables of temperature and time on quality parameters of water absorption capacity (WAC) was examined and optimised usingresponse surface methodology (RSM).The optimum WAC obtained in the studywas 54%(experiment) and 54.13% (RSM) at the experimental conditions of fermentation temperature (40^{o}C), pH (5.0), fermentation time (5 days), fermentation mass (60g), drying temperature (45^{o}C) and drying time (30 minutes).The result of the study showed that RSM was an excellent tool in modelling and optimising the PMF flour produced.

Keywords: Fermentation, Drying, Palm Mesocarp Fibre

1.0 INTRODUCTION
Palm mesocarp fibre (PMF) is a solid waste obtained by separating the mesocarp fibre from other solid wastes after processing of oil palm fruits into crude palm oil (CPO)(FAO 2006; Marsin-Sanagi*et al.,* 2005). The PMF which is mostly left by CPO processors as waste is an attractive feed stock for dietary fibre because it is produced in large volumes from a renewable source. The PMF is also a lignocellulosic biomass that can be used as raw materials for fermentation processes (Kumar*et al.,* 2012). Fermentation due to microbial activities produces desired result in food raw materials if the process conditions are right (Ohimain and Izah, 2014). When the desired end product of fermentation involves the evaporation of water drying methods are applied. Thedrying method applied in food processing determines the final quality of a product (Mujumdar, 2007).

Zhang *et al*. (2004) successfully used the response surface methodology (RSM) to optimise a fermentation process. The central composite design (CCD) found in response surface methodology (RSM) is a statistical technique used in designing experiments to test for lack of fit and study the optimum conditions of variable factors that influence response (Demirel and Kayan, 2012). Therefore, this research is aimed at optimisingthe independent variables of temperature, *pH*, mass and time for the fermentation process. Also optimised were the independent variables of temperature and timefor the drying process. The dependent variable for the fermentation and drying processes. The independent variables were maximised because the dependent variable determines the functional properties and cooking qualities of the PMF.

2.0 MATERIALS AND METHODS

2.1 Methods

2.1.1 Preparation of Sample

Palm Mesocarp Fibre (PMF) derived from *tenera* (thin shell) species were obtained from processors of oil palm fruit in Isuochi, Umunneochi LGA, Abia State of Nigeria. The freshly processed PMF (2000g) collected were transferred into two different containers. One portion (1000g) was fermented, the other portion (1000g) served as the control sample. The substrate solution used for the fermentation process was prepared using the method adaptedbyMohammed*et al*. (2011). Glucose solution of 100g/l used as the substrate solution was prepared by dissolving 100g of glucose in one litre of distilled water. The p*H* of the solution was adjusted to acidic condition with concentrated HCl and alkaline condition with NaOH. The fermented PMF samples and the control sample were dried in an electric oven (Electric oven SL-9 Infrared Food Oven, Hubert, China), ground into flour and stored in hermetically sealed plastic containers.

2.2 Experimental Design and Optimisation

The influence of fermentation process independent variables of temperature, pH, mass and time as well as drying process independent variables of temperature and time on water absorption capacity of the PMF were studied. The study was done using the Central Composite Design (CCD) method found within the Response Surface Design (RSD)withMinitab Inc. (2010) (Minitab Statistical Software, Release 17 for Windows). The experimental matrix of CCD and the constraints levels of factors consideredfor fermentation and drying processesare given in Table 1 and 2. The data obtained were estimated in triplicate determinations and the means were used for analysis. Water absorption capacity(WAC) which is the response was determined by the method adopted by Kamaljit*et al*. (2011). The coefficient of determination R^2 was used to determine the model adequacy.

Table 1: Experimental matrix of Central Composite Design (CCD) for fermentation and drying processes

Run	Fermentation Temperature (^{o}C)	Fermentation *pH*	Fermentation Time (days)	Fermentation Mass (g)	Drying Temperature (^{o}C)	Drying Time (minutes)
1	50	6	6	40	30	40
2	50	4	4	40	30	40
3	40	5	5	60	45	30
4	40	5	5	12	45	30
5	50	4	6	80	60	20
6	63	5	5	60	45	30
7	40	5	5	60	45	6
8	30	6	4	40	30	40
9	40	7	5	60	45	30
10	30	6	6	80	30	40
11	40	5	5	60	9	30
12	30	4	6	80	60	40
13	40	5	5	60	45	30
14	30	6	4	40	60	20
15	40	5	5	60	45	30
16	30	4	4	80	60	20
17	30	4	6	80	30	20
18	30	4	6	40	60	20
19	50	6	6	80	30	20
20	40	2	5	60	45	30
21	50	6	4	80	30	40
22	40	5	5	60	45	53
23	16	5	5	60	45	30
24	30	6	6	80	60	20
25	40	5	5	60	80	30
26	40	5	5	60	45	30
27	40	5	2	60	45	30
28	30	6	6	40	30	20
29	40	5	5	60	45	30
30	30	6	4	80	60	40

31	50	4	6	80	30	40
32	50	6	4	40	30	20
33	50	4	4	40	60	20
34	50	6	6	80	60	40
35	30	6	4	80	30	20
36	40	5	5	60	45	30
37	40	5	5	60	45	30
38	30	4	4	40	60	40
39	30	4	6	40	30	40
40	50	6	4	80	60	20
41	30	6	6	40	60	40
42	50	6	4	40	60	40
43	40	5	5	60	45	30
44	30	4	4	80	30	40
45	50	4	6	40	30	20
46	40	5	5	60	45	30
47	50	4	6	40	60	40
48	50	4	4	80	30	20
49	40	5	7	60	45	30
50	50	6	6	40	60	20
51	50	4	4	80	60	40
52	40	5	5	107	45	30
53	30	4	4	40	30	20

Table 2: Constraint Level for optimisation of the fermentation and drying processes

Level	**Fermentation Temperature (o C)**	**Fermentation *pH***	**Fermentation Time (days)**	**Fermentation Mass (g)**
High	50	6	6	80
Low	30	4	4	40

3.0 RESULTS AND DISCUSSIONS

3.1 Effect of Fermentation Temperature on Water Absorption Capacity

The highest WAC (54%) obtained in this study from the experimental runs in table 1 as shown in Figure 1 was recorded at a fermentation temperature of 40^{o}C. The result obtained in the study could be linked to microbial activity which is at their best at temperatures within and slightly above room temperature. This finding is within the proximity of fermentation temperature range of 30°C to 45°C as observed by Bandaru*et al.* (2006). Mutreja*et al.*(2011) reported that fermentation process can occur at different temperatures depending on the environmental conditions. Liang *et al.* (2010) reported that if fermentation temperature increases above 50°C in a multi microorganism environment, stress is induced on microbial activity due to unfavourable conditions of competing reactions for substrates and production of undesirable products.

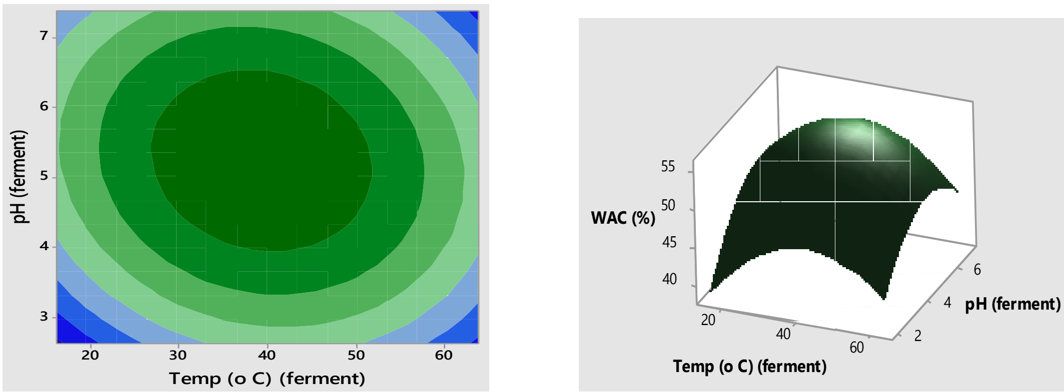


Figure 1: Contour and surface area plot of interaction between *pH* and temperature

3.2 Effect of Fermentation pH on Water Absorption Capacity

Figure 2 shows the contour and surface plots for the interaction between fermentation p*H* and fermentation time obtained in the study from experimental runs in Table 1. The highestWACvalue from Figure 2 was obtained at *pH*of 5.0.The WAC increased between the *pH* of 2.0 to 5.0 and decreased thereafter.

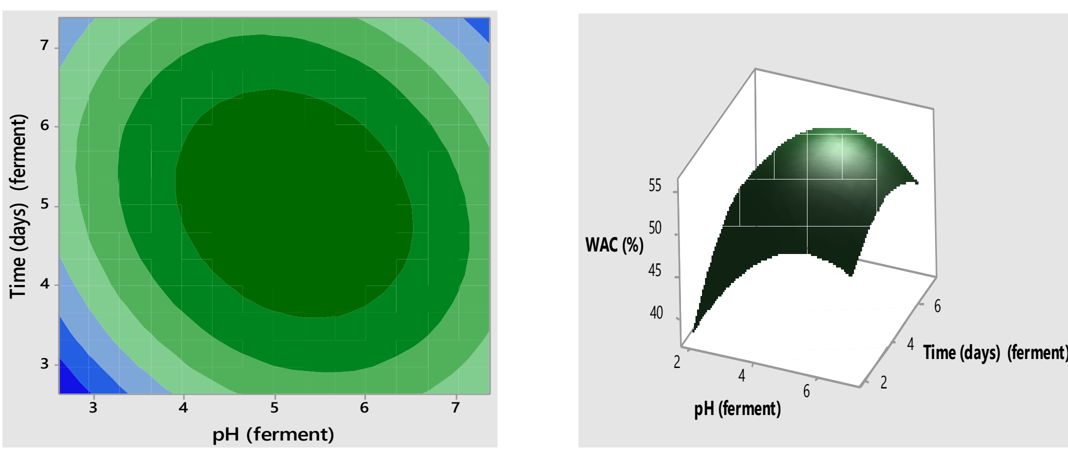
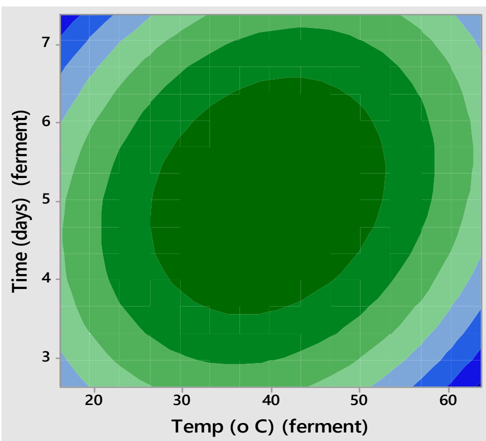


Figure 2: Contour and surface area plot of interaction between time and*pH*

The trend observed from the result of this study could be because enzymes that facilitate the metabolism of glucose functions are known to be more effective in an acidic condition (Liang *et al.* (2010). This result closely agrees with the work of Mohammed *et al.* (2011) that reported the pH of 4.0 to 5.0 as the optimum *pH* range for any fermentation processes. Mohammed *et al.* (2011) further reported that as the *pH* of a reaction medium moves from acidic to alkaline the microbial enzymes that catalyse the metabolism of glucose losses their ability to function efficiently

3.3 Effect of Fermentation Time on Water Absorption Capacity

The result of the study as shown in Figure 3indicated that the WAC value increased from 2days to 5 days and thereafter started to decreased. The highestWAC was thus recorded after 5 days of fermentation. The trend of the result obtained could be because day 5 marked the apex of the exponential growth rate of enzyme activity when there was little or no stress on microbial activity due to unfavourable conditions of competing reactions for substrates and production of undesirable products. The result of this study is closely related to K´ad´ar*et al.*(2004) and Reddy *et al.* (2010) that noted 5 days as the optimal number of days required for a fermentation process.



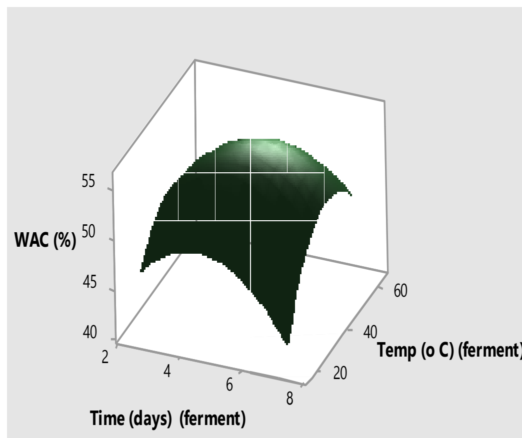
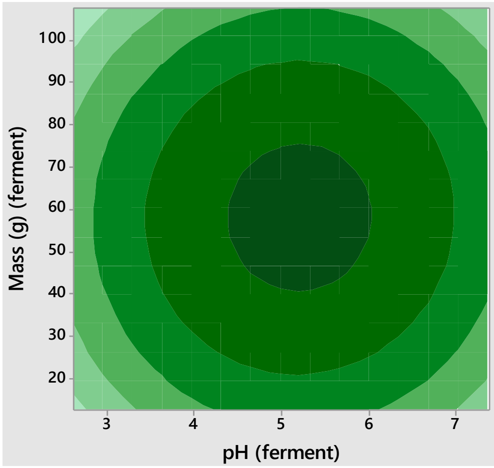


Figure 3: Contour and surface area plot of interaction between time and temperature

3.4 Effect of Fermentation Mass on Water Absorption Capacity

Results from the study as shown by the contour and surface plots for the interaction between fermentation mass and fermentation p*H* presented in Figure 4 reveals that fermentation mass of 60g gave the highestwater absorption capacity value.



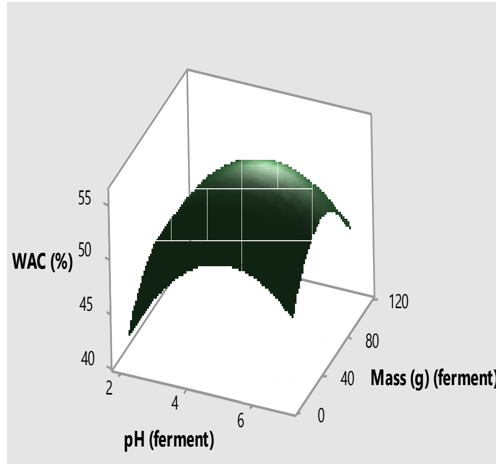


Figure 4: Contour and surface area plot of interaction between mass and*pH*

The result obtained in this study indicates that there was reduced WAC at low masses of the PMF. This pattern of result observed in the study could be attributed to the fact that microbial activity during the fermentation process was overwhelmed by the high substrate concentration. Fermentation masses beyond the optimumfermentation mass also showed reduced percent yield of WAC. This is an indication that the microbial activity was overwhelmed by reduced substrate concentration. The optimum fermentation mass pattern in this study shows proximity with the work of Reddy *et al.* (2010);Mohammed *et al.* (2011)and Mutreja*et al.* (2011)in their study of bioethanol yield.

3.5 Effect of Drying Temperature on Water Absorption Capacity

The results of this study indicate that the highest value for WAC was obtained at a drying temperature of 45^{o}C as shown Figure 5. This result obtained in the study could be attributed to the increase in the soluble dietary fibre and change in the starch and amino acid content of the PMF. The result obtained in this study is within the proximity of temperature range as observed by Capitani*et al.* (2012) in their study of chia seeds of Argentina. It also agrees with the work of Mahadevamma and Tharanathan (2004) which reported that heat processing led to an increase in non-polar amino acid and soluble dietary fibre thus increasing the presence of hydrophilic starch content.

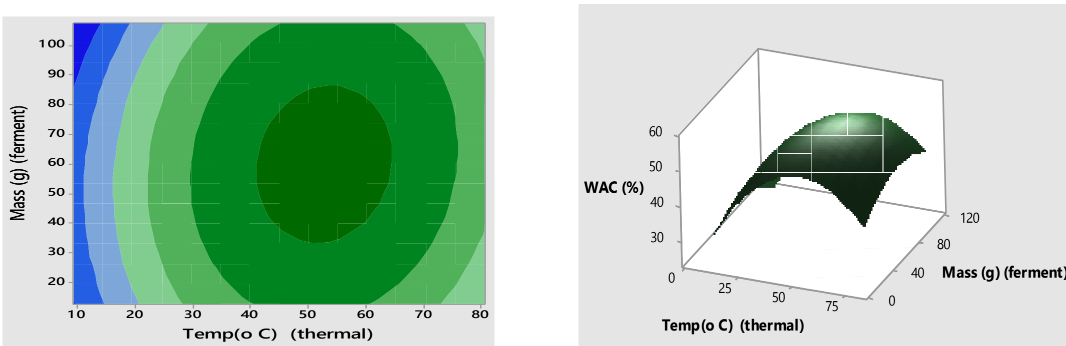


Figure 5: Contour and surface area plot of interaction between temperature and mass

3.6 Effect Drying Time on Water Absorption Capacity

The results obtained from the study for the effect of drying time on WAC is illustrated in Figure 6 which shows that the highest value for WAC was obtained at a processing time of 30 minutes. The results obtained from this study may be attributed to the starch content of the PMF and the retention of moisture with more hydrophobic groups within the matrix of the PMF being analysed. The result of this work shows an agreement with the works of Chukwuneke*et al.* (2013);Mutreja*et al.* (2011) and Reddy *et al.* (2010) that reported similar thermal processing time for agro-waste fibrous materials.

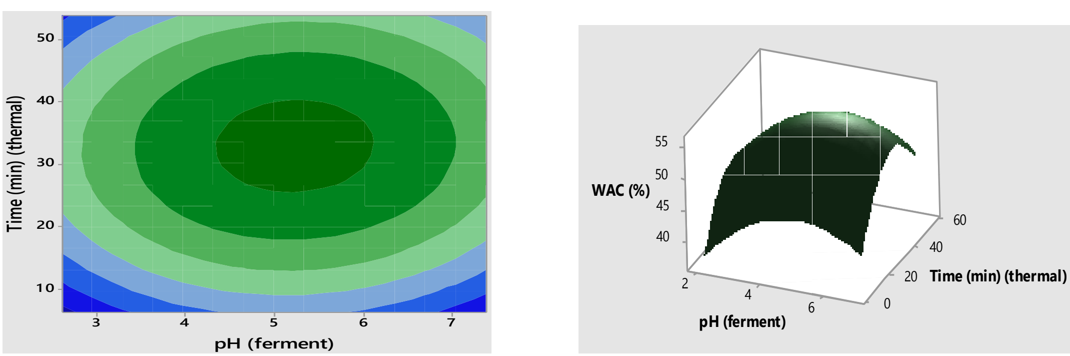


Figure 4.9: Contour and surface area plot of interaction between time and*pH*

3.7 Regression CoefficientandAnalysis of variance

The experimental plan used data from analysis of variance to build a verifiable mathematical model with diagnostic plots which estimated the relationship between the independent variables and the response. The relationship between independent variables and the response (Y) for the regression modelling obtained in this study is given by Equation (1):

$Y\ (WAC)\ (\%) = -\ 60.1 + 1.027\,A + 12.60\,B + 4.31\,C + 0.025\,D + 1.377\,E + 1.058\,F - 0.01169\,A^2 - 0.933\,B^2 - 0.643\,C^2 - 0.002387\,D^2 - 0.01263\,E^2 - 0.01545\,F^2 - 0.0219\,A{*}B + 0.0406\,A{*}C + 0.00016\,A{*}D - 0.00187\,A{*}E - 0.00406\,A{*}F - 0.344\,B{*}C + 0.0016\,B{*}D -$

*0.0188 B*E + 0.0094 B*F + 0.0266 C*D + 0.0146 C*E - 0.0031 C*F + 0.00115 D*E + 0.00172 D*F - 0.00062 E*F* (1)

Where:

A = Fermentation Temperature (^oC), B = Fermentation *pH*, C = Fermentation Time (days), D = Fermentation Mass (g), E = Drying Temp (^oC), F = Drying Time (min)

Table 4 shows the analysis of variance and regression coefficients of the linear terms, quadratic equation terms as well as the interaction terms obtained from the study for the WAC. The fermentation*pH* (2.16) had the highest effect on the WAC while fermentation mass (- 0.99) had the least effect during the fermentation process. The drying process had drying temperature (14.11) as the variable with the highest effect on the WAC while drying time (3.77) had the least effect. Similarly, the interactions of the process of CD (6.01) had the highest effect on the WAC. The interactions of AF (- 4.60) had the least effects respectively. The process variables and their interactions that have positive regression coefficients depicts that they have a direct proportionality to the WAC. The process variables with negative coefficient values show an inverse proportionality relative to WAC. The terms that showed statistically significant difference at $p< 0.05$ were the drying temperature (0.000) for linear model; fermentation temperature (0.012), fermentation p*H* (0.031) and drying time (0.001) for the square model.

Table 4: Analysis of Variance and Regression coefficient for WAC

Source	Effect	Degree of Freedom	Sums of Square	Means of Square	Regression coefficient	F-Value	P-Value
Model		27	1110.18	41.118	55.64	4.22	0.000
Linear		6	419.71	69.951		7.17	0.000
A	- 0.38	1	0.28	0.281	+0.977	0.03	0.867
B	2.16	1	8.91	8.914	+13.66	0.91	0.348
C	0.51	1	0.49	0.493	+6.420	0.05	0.824
D	- 0.99	1	1.87	1.870	+0.017	0.19	0.665
E	14.11	1	380.99	380.990	+1.356 [a]	39.06	0.000
F	3.77	1	27.16	27.159	+1.009	2.78	0.108
Square		6	650.75	108.459		11.12	0.000
A^2	- 12.48	1	72.23	72.233	- 0.11030 [a]	7.41	0.012
B^2	- 11.48	1	61.12	61.120	- 1.01500	6.27	61.12
C^2	- 9.48	1	41.68	41.677	- 0.83800	4.27	41.68

D^2	- 10.48	1	50.93	50.935	- 0.00232 [a]	5.22	0.031
E^2	- 31.48	1	459.65	459.650	- 0.01237	47.13	459.65
F^2	- 16.48	1	125.96	125.963	- 0.01457 [a]	12.92	0.001
2-Way Interaction		15	39.72	2.648		0.27	0.994
A*B	- 2.47	1	1.53	1.531	- 0.0219 0	0.16	0.695
A*C	4.60	1	5.28	5.281	+ 0.04060	0.54	0.469
A*D	0.35	1	0.03	0.031	+ 0.00016	0.00	0.955
A*E	- 3.18	1	2.53	2.531	- 0.00187	0.26	0.615
A*F	- 4.60	1	5.28	5.281	- 0.00406	0.54	0.469
B*C	- 3.89	1	3.78	3.781	- 0.34400	0.39	0.539
B*D	0.35	1	0.03	0.031	+ 0.00160	0.00	0.955
B*E	- 3.18	1	2.53	2.531	- 0.01870	0.26	0.615
B*F	1.06	1	0.28	0.281	+ 0.00940	0.03	0.867
C*D	6.01	1	9.03	9.031	+ 0.02660	0.93	0.345
C*E	2.47	1	1.53	1.531	+ 0.01460	0.16	0.695
C*F	- 0.35	1	0.03	0.031	- 0.00310	0.00	0.955
D*E	3.89	1	3.78	3.781	+ 0.00115	0.39	0.539
D*F	3.89	1	3.78	3.781	+ 0.00172	0.39	0.539
E*F	- 1.06	1	0.28	0.281	- 0.00062	0.03	0.867
Error		25	243.82	9.753			
Lack-of-Fit		17	235.82	13.872			
Pure Error		8	8.00	1.000			
Total		52	1354.00				
R^2	83.77						
R^2 (Adjusted)	76.25						

A = Fermentation Temperature (^{o} C), B = Fermentation *pH*, C = Fermentation Time (days), D = Fermentation Mass (g), E = Drying Temp (^{o} C), F = Drying Time (min), a = all data are significant at $p \leq 0.05$

The optimal condition for WAC from the model used in the study are at the experimental variations of fermentation temperature of 38^{o}C; fermentation *pH* of 5.0; fermentation time of 5 days; fermentation mass of 61g; drying temperature of 53^{o}C and drying time of 32 minutes.The R^2 result for WAC from Table 4 was 83.77% an indication of the adequacy of the model to be used for predicting any value of the parameters within the experimental design. The R^2 result from the study agree with Chinma*et al.* (2014) that noted that models are considered adequate when their R^2> 80% in their study of rice bran fermentation conditions.

4.0 CONCLUSION

Fermentation and drying modified the structure of PMF used in this study. The study performed using RSM for the optimization of the effect of fermentation and drying on PMF flour showed that RSM was an efficient tool to detect the optimal levels of temperature, p*H*, fermentation days, fermentation mass, drying temperature and time. The PMF flour produced from the optimal experimental variations of fermentation temperature of 38^{o}C; fermentation pH of 5.0; fermentation time of 5 days; fermentation mass of 61g; drying temperature of 53^{o}C and drying time of 32 minutes could serve as raw materials for food product formulations.

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FOOD ANALYSIS USING IMAGE PROCESSING AND CLUSTERING TECHNIQUES

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ABSTRACT

This paper presents a framework for mitigating some of the issues associated with food safety and quality inspection in Nigeria. The proposed approach is based on computerized imaging and analysis of foods for detection of diseases and defects. The algorithm combines several procedures for automated fault detection and outputs a decision that could be transmitted via existing communication devices to relevant personnel for immediate action. It has been developed and will be implemented as a mobile phone application that captures and analyzes food image data and determines the quality of the food product. The system is a low-cost solution to reduce food inspection costs and can be utilized by few regulatory officers. Currently, it can be used for inspection of fruits without manual or physical contact with the products being analyzed. Experimental results are promising and indicate feasibility for rapid deployment.

Keywords: Food quality inspection; food defect monitoring; image processing-based analysis; image edge filtering; segmentation; fuzzy clustering

1. Introduction

Food safety underpins food security, which is essential to national security of any country and the world at large(Uyttendaelea, et al., 2016)(Ojinnaka, 2011)(Eme, et al., 2014). Consequently, food contamination and resulting illness or deaths can have grave public health consequences for a country(Ojinnaka, 2011)(Omojokun, 2013)(Eme, et al., 2014). Additionally, food spoilage, wastage and insufficient food production can lead to malnutrition, war and famine (Eme, et al., 2014). This is well understood and addressed in developed countries by concerted efforts of government, businesses, research scientists and engineers. This has led to the incorporation of computerized technology in ensuring food quality(Group, 2012)(Sabliov, et al., 2002)(Rafiqa, et al., 2013)(Valous & Sun, 2012)(Yorulmaz, 2012), while reducing costs in certain aspects. However, in developing countries such as Nigeria, the problems of ensuring food safety are compounded by a myriad of factors. These include lack of proper enforcement of laws addressing food quality and standards by the regulatory agencies and government bodies(Ojinnaka, 2011)(Omojokun, 2013). Poor or inadequate funding of such agencies to recruit, train and retain suitable personnel in order to perform their duties effectively. Additionally, food inspection equipment and training of personnel is usually expensive and budgetary allocations are non-existent. Furthermore, manual inspection is a slow and expensive process, which requires a lot of field personnel to implement effectively.Other issues peculiar to the Nigerian operating environment include;

- Inconsistent government policies and legislation(Eme, et al., 2014).
- Insecurity, violence, weather and climate change(Eme, et al., 2014).
- Expired, substandard or fake products in circulation(Ojinnaka, 2011).
- Poor handling of food and dehydration(Ojinnaka, 2011)
- Absence of production details and deceptive labelling on products(Ojinnaka, 2011).
- Overpriced goods and foreign-language-based instruction manuals(Ojinnaka, 2011).
- Differences in the quality of raw materials available to the food processors(Omojokun, 2013)
- Numerous middlemen/womenincreasing the risk of food contamination(Omojokun, 2013)
- inadequate power, transport facilities and road network infrastructure(Omojokun, 2013)
- Inadequate research laboratory equipment facilities, personnel and expertise(Omojokun, 2013)
- Poor coordination of food safety and quality activities in value chain(Omojokun, 2013)
- poor post-harvest handling by food handlers with insufficient knowledge(Omojokun, 2013).
- inadequate storage facilities, cold stores or conditioned warehouses due to absence or shortage of electricity supply and clean water(Omojokun, 2013).
- Lack of critical knowledge and expertise in good agricultural practices at farm level(Omojokun, 2013).
- Poor hygienic and manufacturing practices at the production level and no traceability(Omojokun, 2013).
- Wrong usage of agrochemicals by traders of food commodities, resulting in failure of passing minimum safety standards for local human consumption or foreign export(Omojokun, 2013).
- Improper handling and storage of products leading to fungal growth, etc., which endanger public health(Omojokun, 2013).
- Street vended foods prepared in unhygienic conditions with poor food handling, unhygienic surroundings and limited water supply causing microbiological contamination and illness for the consumer(Omojokun, 2013).

Several recommendations have been proposed to address these challenges(Ojinnaka, 2011)(Omojokun, 2013)(Eme, et al., 2014). However, we focus on the technological aspects, which can be developed by local engineers in Nigeria. These can be applied in process control, design and simulation; computerized food inspection systems; and computer-based nutrient analysis, information storage and retrieval systems(Ojinnaka, 2011). This is a viable approach due to some work done in this area by researchers in other countries. These include measurement of produce volume and area using image processing(Sabliov, et al., 2002), image-based segmentation of colour food images (Mery & Pedreschi, 2005), image processing-based food inspection(Yorulmaz, 2012), image-based quality assessment of pork and beef meat(Valous & Sun, 2012)(Streeter, et al., 28-29 November 2005), multispectral imaging and analysis of meat, cremes and olives(Tsakanikas, et al., 2015), image-based banana fruit maturity assessment(Prabha & Kumar, 2015), image-based analysis of fruits, vegetables, cereals, animal products, tea and pizza topping(Rafiqa, et al., 2013)in addition toimage-based food dietary assessment(Probst, et al., 2015).

In this paper, we focus on the quality inspection and analysis of fruits using image processing and clustering algorithms. Furthermore, we wish to develop a fast, low-cost image-based software-based solution to the issue of local food inspection for quality monitoring purposes. The scope of the work described in this paper focuses on defects observable under visible light radiation-based imaging. The key contributions and advantages of the work include:

- Utilization of relevant image processing algorithms for food inspection without expensive and destructive analysis techniques.
- Reduction in cost in terms of both manual inspection and equipment.
- Use of morphological attributes to detect defects in fruits
- Clustering-based analysis for classification.

2. Materials and methods

The basic setup(Mery & Pedreschi, 2005) for image-based analysis of fruit is as shown in Fig. 1. The proposed algorithm can be implemented with a camera linked to a laptop computer, which is used to process the image data obtained from the camera. Alternatively, it can be implemented as a mobile phone application for portability.

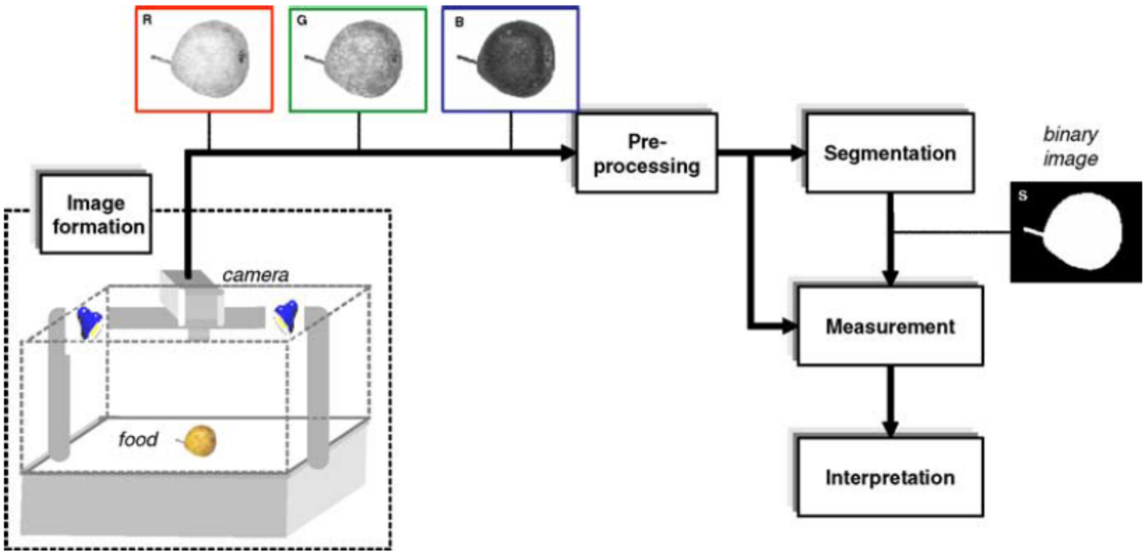


Fig. 1. Setup for image-based food analysis(Mery & Pedreschi, 2005)

2.1 Relevant image processing and analysis methods

The modified setup for the work in this paper involves the pre-processing stage consisting of conversion, edge enhancement and illumination normalization. The segmentation stage in this case is comprised of the edge detection and binary thresholding schemes. The measurement stage involves the area computation of the segmented shape, while the interpretation stage involves the classification and decision stages of the algorithm.

2.1.1 Edge detection and sharpening filters

These type of filters enhance the high frequency content of the input image to yield enhanced features. The edge detectors are examples of high frequency boost filters.

2.1.2 Segmentation

The proper use of segmentation-based processing yields relevant and vital features crucial for object identification and description. Thresholding involves converting the image to a bi-tonal image (i.e. black and white pixels).

2.1.3 Illumination normalization

The algorithms in this class are employed in the elimination of shadows, normalizing illumination present in the acquired image scene and better resolution of hidden details in the once shadowed image regions.

2.1.4 Clustering and machine learning approaches

Clustering techniques are used to classify datainto groups using some feature set, yielding a clear view of a system's operations(Mathworks, 2013). Machine learning involves the usage of statistics to train artificial computing systems to learn from available data and realizing relationships which are not mathematically tractable(Arthur, 1959).

2.2 Methodology of proposed approach

We focus on fruits such as the golden apples variety prevalent, which ideally should have a smooth texture. Thus, a completely smooth apple would be seen as not having blemishes. Any blemish would be amplified by the illumination of the camera system used in capturing the fruit. These would show up as spots, lines or curves on the surface of the apple. We first convert the image to a greyscale version, eliminating extraneous colour information. The image is then sharpened to highlight further any defects or blemishes on the surface of the fruit. Then the image is subsequently corrected for illumination to eliminate shadows, which will interfere with the evaluation process. Finally, the edge image is obtained from which the area is computed and used in decision-based output. For smooth, unblemished fruit image, we ideally should see only the outline of the fruit. Conversely, any damaged fruit will be easily detected based on the internal marks or features on the surface of the obtained edge map. The Area is used as a classification feature and fed into the classifier. This determines whether the fruits are damaged or not and leads to a decision. The proposed scheme for the algorithm is presented in Fig. 2.

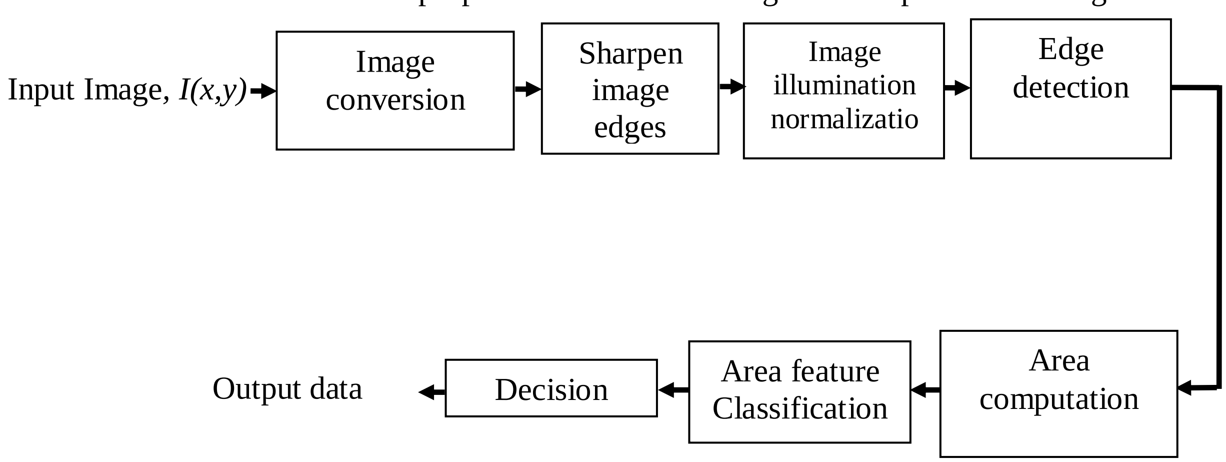
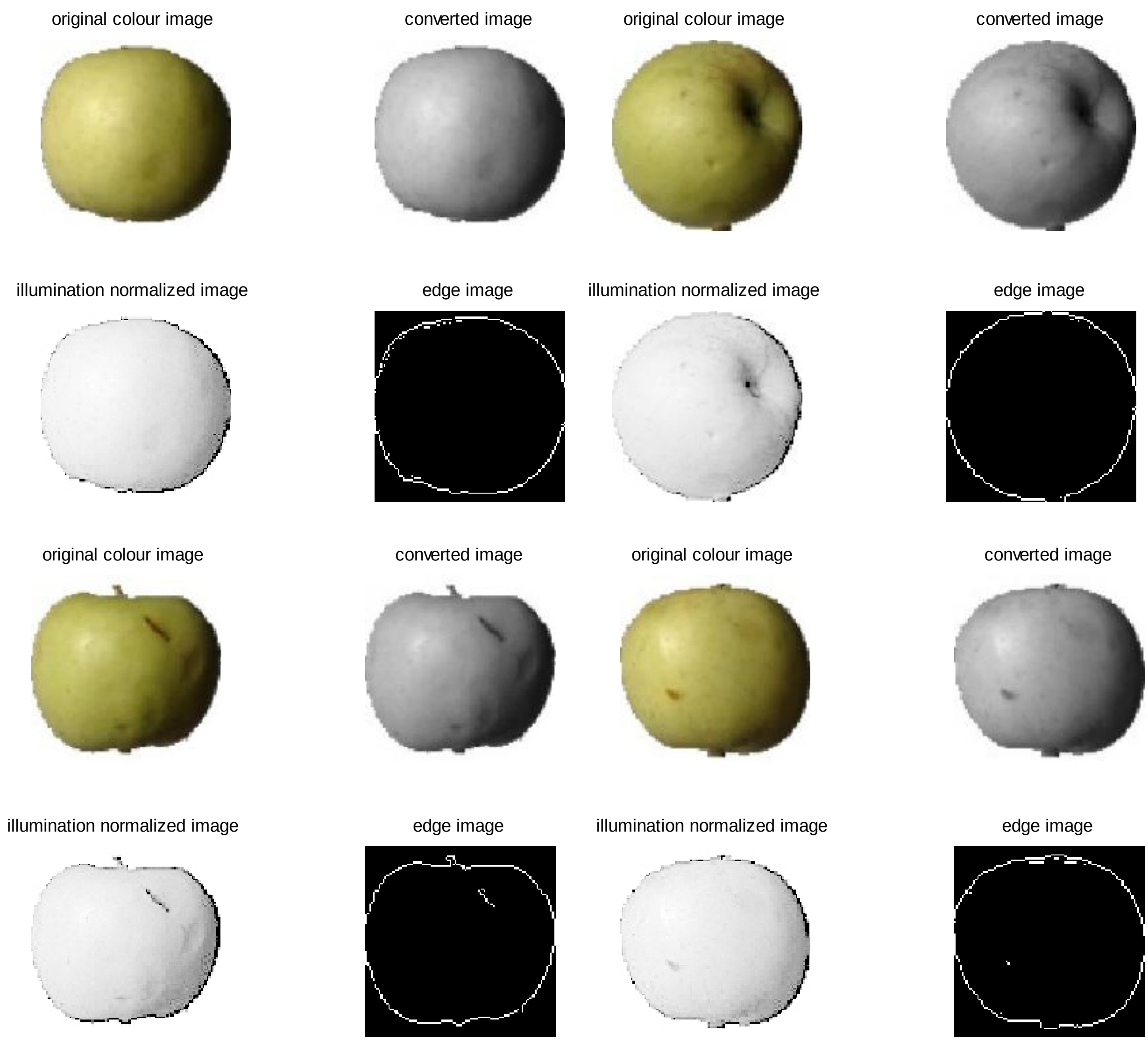


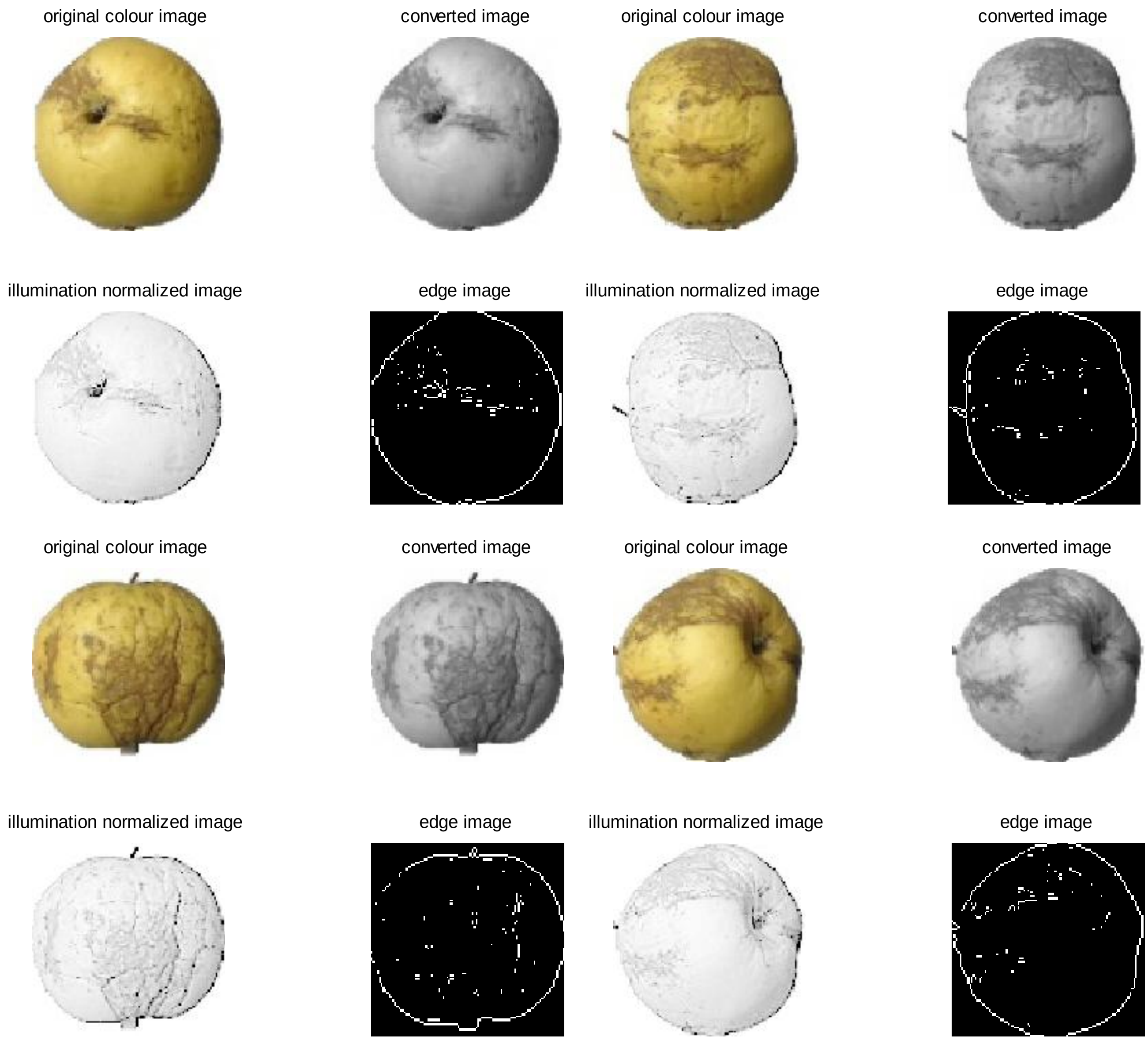
Fig. 2. Proposed image-based food analysis algorithm

3. Experimental results and discussion

We evaluate the algorithm using a food image dataset(Muresan & Oltean, 2017) consisting of 28736 training imagesof 60 fruit categories at various stages and varieties. We present the samples of typical images for the apples as those of no defect, minimal defect and high degree of defect. and samples are shown in Fig. 3. Note that we could also utilize colour features to determine the highly defective fruits since discolouration is a typical trait. However, this would not register the depressions or bruises on the fruit surface, which would have the same colour as unblemished fruit. The structural attributes of lines, spots and curves are much more reliable in this case for defect detection.



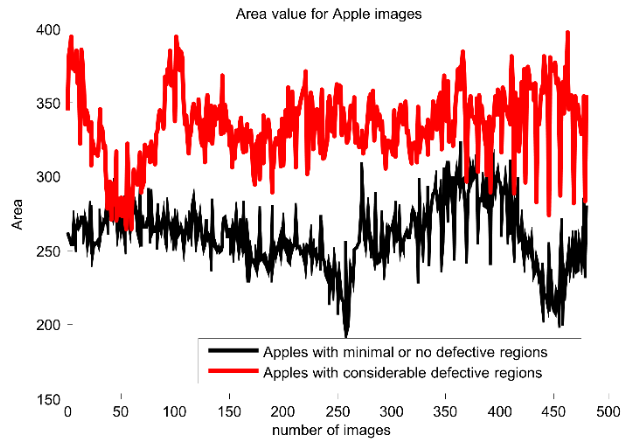
(a)



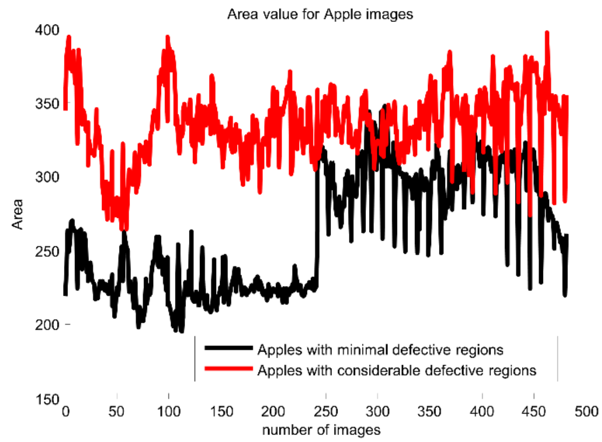
(b)

Fig. 3. Samples of (a) apples with no or minimal defective regions (b) apples with considerable or significant defective regions.

A sample of results are presented in Fig. 4 using the apple fruit category from two different datasets of more than 900 images in each sample test set. Observing the area distribution for both no-defective and fully defective apples, we can see that there is an observable trend in most cases.



(a)



(b)

Fig. 4. Images from (a) test set 1 (b) test set 2

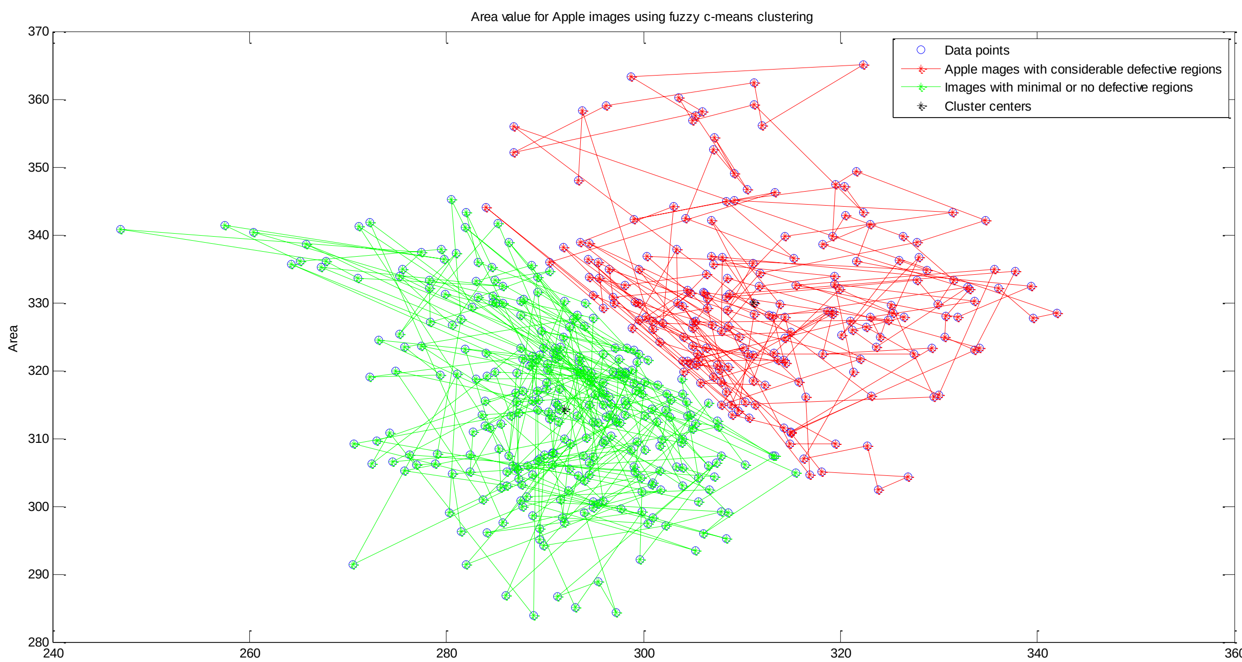


Fig. 5. Results of fuzzy c-means classifier showing the two distinct classes of apple conditions

For example, in Fig. 4(a), the apples with smooth and unblemished surfaces have an overall lower area than those with observable blemishes. For Fig. 4(b), we compare those with minimal defects and high defects and observe a similar trend, though not as pronounced since several of the apples with minimal defects are in various stages of decay. We utilize this area data to perform classification using fuzzy c-means clustering algorithm(Mathworks, 2013). The results are shown in Fig.5. We can see that there is a partitioned space between the two categories of apples. Any new apple data fed into the system and classified as either in the first or second cluster, indicating its quality.

Conclusion

We have presented a software-based apple fruit inspection algorithm for defect detection using image processing. The proposed scheme shows that indigenous solutions can be implemented at reasonably low-cost. Furthermore, current and future work would focus more on the machine learning aspect to widen the applications to other types of fruits and agricultural products. Moreover, the goal is to develop the entire software scheme as a mobile phone application for ease of use, increased portability and efficiencyof regulatory personnel.

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PROCESS OPTIMIZATION OF FOAM MAT DRIED MORINGA AND GINGER INSTANT POWDERED TEA.

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ABSTRACT
Tea is one of the most popular beverages in the world due to its taste, aroma and health effects, herbal tea is a term used for any non-caffeinated beverage made from the infusion or decoction of herbs, spices or other plant material in water. The study investigated the optimization of the foaming process in the formulation/development of moringa/ginger instant powdered tea. The investigation was conducted using an eight factor general factorial design with 42 randomized experimental runs. The numerical optimization yielded a desirability index of 0.968 with optimized levels of independent variables as moringa 53.578%, ginger 20.01%, soy protein isolate 20%w/w, methyl cellulose 3.999%w/w, whipping time 14.999 min, drying temperature 60.037ºC, foam thickness 7.986mm, whipping speed 10000.007 rev/min, foam expansion 54.568% and foam stability 74.863%.

KEYWORDS
Moriga/Ginger extract, Tea, Soy protein, Methyl cellulose, Foam expansion, Foam stability

1.0 INTRODUCTION
Tea [*Camellia sinensis*(L.)O.Kuntze] is one of the most popular beverages worldwide due to its taste, aroma, and health effects (Khokhar and Magnusdottir, 2002).Tea has historically been promoted for having a variety of positive health benefits and recent human studies suggest that green tea may help reduce the risk of cardiovascular disease and some forms of cancer (Peters *et al.*, 2001). Herbal tea is a term used for any non-caffeinated beverage made from the infusion or decoction of herbs, spices or other plant material in water. These drinks are distinguished from caffeinated beverages like coffee and the true tea (black, green, white, yellow, oolong, etc.) or from a decaffeinated tea, in which the caffeine has been removed. In addition to serving as a beverage many are also consumed due to a perceived medicinal benefit (Merriam W, 2003).
Moringa oleifera is known as one of the world most useful trees, because all the parts of the tree can be utilized for industrial purposes, food and medication (Khalafalla*et al.*, 2010). It has been reported that *Moringa* leaves contain four times the calcium of milk, three times the potassium of

bananas, seven times the vitamin c of oranges, two times the protein of yogurt and four times the vitamin A of carrots (Jed and Fahey, 2005).

Ginger (*ZingiberOfficinale*Roscoe) is a herbaceous perennial specie that belongs to the order *Scitamineae*and family *Zingiberaceae*and also a tropical monocotyledon. It is the most established rhizome broadly domesticated as a spice. The long history of the cultivation of ginger plant started in China and afterwards spread to South East Asia, India, Caribbean and West Africa (McGee, 2004).

Foam–mat dehydration is one of the emerging drying techniques suitable for food preservation. It involves drying of liquid or semi liquid food concentrate in the form of stabilized foam, prepared by the addition of foam agents and/or stabilizer in small quantity, followed by whipping in a continuous mixer to stiff foam. The stable foam is dried in heated air at relatively low temperature under atmospheric pressure (Kadam*et al*., 2010; Orishagbemi*et al*., 2010).

Foam-mat dried products are comparatively stable against microbiological, chemical and biochemical deterioration and have high retention of color, flavor, vitamin and sensory characteristics (Kadam and Balasubramanian, 2011; Kadam*et al*., 2012).

Since the success of foam-mat drying is dependent on the achievement of stable foam, the aim of this study is to optimize the foaming process involved in the formulation/development of moringa/ginger instant powdered tea.

2.0 MATERIALS AND METHODS

2.1 Source of Raw Material

Fresh*Moringaoleifera* leaves were harvested from moringa trees around River Basin environs Minna, Nigeria; while dried Ginger (*ZingiberOfficinale*Roscoe) was purchased from Kure market Minna, Nigeria. The fresh Moringa leaves were washed and shade dried until completely dried. The dried Moringa leaves and dried Ginger root were milled using electric blender and then sieved. The extraction process for Moringa and Ginger was done with slight modification, one hundred grams of both powdered Moringa and Ginger was soaked in 1000ml boiled distilled water; shaken and left for 24 hours. The solution was filtered using muslin cloth (Harbourne, 1998). Soy protein isolate was purchased from Health wellness shop in Minna, and used as foaming agent and food grade carboxymethyl cellulose (CMC) was used as foam stabilizer at different concentrations.

2.2 Experimental Techniques.

2.2.1 Experimental Design using General Factorial Design.

The design of the experiment was conducted using eight-factor general factorial design with forty two randomized experimental runs to determine the effect of independent variables on response variables. Response surface methodology was used to establish the effects using Design Expert – version 10.0.3 (Statease Inc., Minneapolis, USA). The independent variables and their coded levels are 40% ≤ moringa leaf extract (x_1)≤ 68%, 20% ≤ ginger root extract (x_2) ≤ 48%, 10%w/w ≤ soy protein isolate (x_3) ≤ 20%w/w, 2%w/w ≤ methyl cellulose (x_4) ≤ 4%w/w, 5 min ≤ whipping time (x_5) ≤ 15 min, 60ºC ≤ drying temperature (x_6) ≤ 70ºC, 2mm ≤ foam thickness (x_7) ≤ 8mm, and 10000 rev/min ≤ whipping speed (x_8) ≤ 13000 rev/min.

2.2.2 Analysis of Data

The response surface models were fitted to the data and the statistical significance of the model terms were examined through analysis of variance (ANOVA). The adequacy of the models were established, the lack-of fit test were conducted and the coefficients of determination were estimated.

2.2.3 Process Optimization of Parameters

Both numerical and graphical optimizations were carried out for the responses. The optimization criteria were maximization of foam expansion and foam stability and the optimum process conditions were established.

Table 1: Recorded response for foaming process of moringa/ginger powdered tea.

Sample code	Soy Protein Isolate (%w/w)	Methyl cellulose (%w/w)	Foam Expansion (%)	Foam Stability (%)
1	20	4	34.76	74.86
2	10	4	44.19	47.33
3	10	2	52.07	26.96
4	20	4	40.11	54.74
5	10	4	52.18	40.36
6	20	2	56.18	27.69
7	20	4	50	72.94
8	20	2	40.9	30.72
9	20	4	44.44	55.73
10	20	2	49.54	18.73
11	10	4	52.17	54.64
12	20	4	46.07	49.12
13	20	2	54.55	32.99
14	10	4	52.17	40.54

15	10	2	42.39	41.87					
16	20	4	55.56	58.48					
17	20	2	52.22	23.44					
18	20	4	51.14	49.65					
19	20	4	45.45	51.72					
20	20	4	43.37	71.28	21	10	4	46.74	56.86
22	20	4	56.81	51.99					
23	20	4	54.55	48.24					
24	20	4	52.33	55.2					
25	20	4	48.31	62.53					
26	20	4	46.07	51.16					
27	20	4	48.86	56.92					
28	10	4	46.74	49.57					
29	20	4	47.73	43.73					
30	20	4	56.82	36.39					
31	20	4	44.44	53.91					
32	20	4	52.28	49.12					
33	10	2	53.91	41.33					
34	20	2	42.17	20.67					
35	20	4	55.81	48					
36	10	4	62.04	38.03					
37	10	4	53.33	35.71					
38	20	4	38.89	37.78					
39	10	2	51.09	35.62					
40	10	2	47.37	31.43					
41	20	2	53.33	34.93					
42	20	2	45.56	25.56					

2.3 Foaming Process

2.3.1 Foam Expansion

Foam expansion was calculated to determine the amount of air incorporated into the solutionduring whipping. It was calculated using the following equation, as described by (Kato *et al.*, 1983):

$$\text{Foam expansion (\%)} = \left[\frac{V1-V0}{V0}\right] \times 100 \qquad (1)$$

where v_0 is the initial volume of moringa/ginger solution (cm^3) and v_1 is the final volume of foamedmoringa/ginger (cm^3).

2.3.2 Foam Stability

The foam obtained was placed in a transparent graduated cylinder and kept at room temperature for 3 h. The volume of liquid, which was separated from the foam as a result of drainage, and the reduction in foam volume, were measured. Foam stability was calculated using the following relationship, as described by (Marinova*et al*., 2009):

$$\text{Foam stability (\%)} = \frac{V1}{V0} \times 100 \qquad (2)$$

Where $v_1$is the volume of foam after 3 h (cm^3) and v_0 is the initial volume of foam (cm^3).

2.4 Foam mat Drying of Moringa/Ginger Foam

The Moringa/Ginger foam was spread on aluminum drying trays at foam thickness off 2 mm, 5 mm and 8 mm and dried in an air dryer. The foam was dried at temperature of 60 ºC, 70 ºC and 80 ºC the foam were taken out of the dryer at regular interval and weighed using an electronic balance and quickly returned back into the air oven, drying was terminated when dried product attained constant weight.

3.0DISCUSSION OF RESULTS

3.1 Effect of Concentration of Soy Protein isolate on Foam Expansion

From the foam expansion ANOVA table (Table 2), linear model is significant with an F-value of 22.6, the lack of fit F-value of 1.08 is good because it is not significant relative to pure error and we want the model to fit. The predicted R^2 of 0.7337 is in reasonable agreement with the adjusted R^2 of 0.7867and adequacy precision of 14.7489 indicates an adequate signal which means the model can be used to navigate the design space, a ratio greater than 4 is desirable. The standard deviation, mean and coefficient of variation are 5.04, 42.38 and 11.88%. The significant model terms for foam expansion are soy protein isolate (x_3), drying temperature (x_6) and foam thickness (x_7) with ($p < 0.05$).

The fitted linear model equation for foam expansion is represented below

$$\mathcal{Y}_{FE} = +39.74 + 3.79x_1 + 2.94x_2 + 12.17x_3 + 0.7299x_5 - 2.25x_6 + 2.39x_7 - 0.3602x_8 R^2 = 0.8231 \qquad (3)$$

Table 2: ANOVA table for foam expansion linear model

Source	Sum of Squares	df	Mean Square	F-value	pvalue	
Model	4014.15	7	573.45	22.6	<0.0001	significant
x_1	2.48	1	2.48	0.0977	0.7565	
x_2	1.46	1	1.46	0.0576	0.8118	
x_3	184.81	1	184.81	7.28	0.0108	
x_4	0	0				
x_5	15.39	1	15.39	0.6065	0.4415	
x_6	150.97	1	150.97	5.95	0.0201	
x_7	215.46	1	215.46	8.49	0.0063	
x_8	4.92	1	4.92	0.1939	0.6625	
Residual	862.62	34	25.37			
Lack of Fit	743.44	29	25.64	1.08	0.5238	not significant
Pure Error	119.18	5	23.84			
Cor Total	4876.78	41				

The contour and 3-D plots of foam expansion are presented in Figure 1.

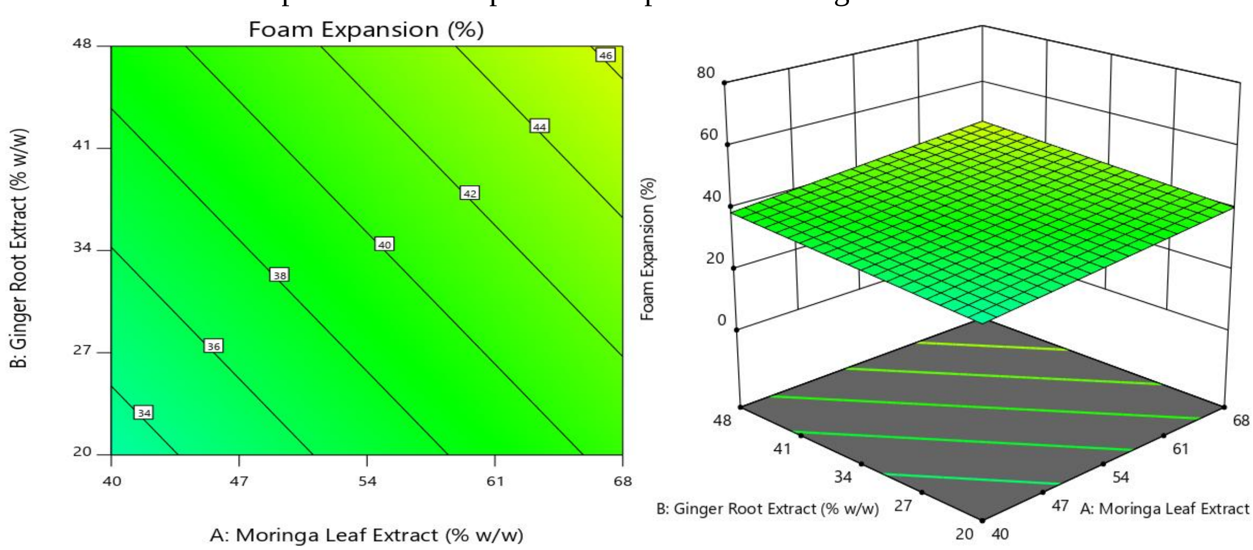

Fig. 1: Contour and 3-D plots of foam expansion

3.2 Effect of Methyl cellulose on Foam Stability

There was no significant effect of methyl cellulose on foam stability as seen from the ANOVA table this might be because the range chosen was narrow in the experimentation. From the foam stability ANOVA table (Table 3), the foam stability linear model had a significant F-value of 12.66.The lack of fit F-value of 1.03 is good because it is not significant relative to the pure error and we want the model to fit. The predicted R^2 of 0.5678 is in reasonable agreement with the adjusted R^2 of 0.6656and adequacy precision of 12.3603 indicates an adequate signal which means the model can be used to navigate the design space, a ratio greater than 4 is desirable. The standard deviation, mean and coefficient of variation are 7.9, 44.96 and 17.57%. The significant model terms for foam stability are moringa (x_1), ginger (x_2), soy protein isolate (x_3) and whipping time (x_5)with ($p < 0.05$).

The fitted linear model equation for foam stability is represented below

$$\mathcal{Y}_{FS} = -29.11 - 165.52x_1 - 166.39x_2 - 57.43x_3 - 5.99x_5 + 1.49x_6 - 1.64x_7 + 0.7481x_8 R^2 = 0.7227 \quad (4)$$

Table 3: ANOVA table for foam stability (linear) model

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5531	7	790.14	12.66	<0.0001	significant
x_1	4731.2	1	4731.2	75.79	< 0.0001	
x_2	4665.39	1	4665.39	74.74	< 0.0001	
x_3	4117.9	1	4117.9	65.97	< 0.0001	
x_4	0	0				
x_5	1035.89	1	1035.89	16.6	0.0003	
x_6	66.15	1	66.15	1.06	0.3105	
x_7	101.65	1	101.65	1.63	0.2106	
x_8	21.21	1	21.21	0.3398	0.5638	
Residual	2122.33	34	62.42			
Lack of Fit	1818.78	29	62.72	1.03	0.5465	not significant
Pure Error	303.55	5	60.71			
Cor Total	7653.33	41				

The contour and 3-D plots of the foam stability are presented in Figure 2.

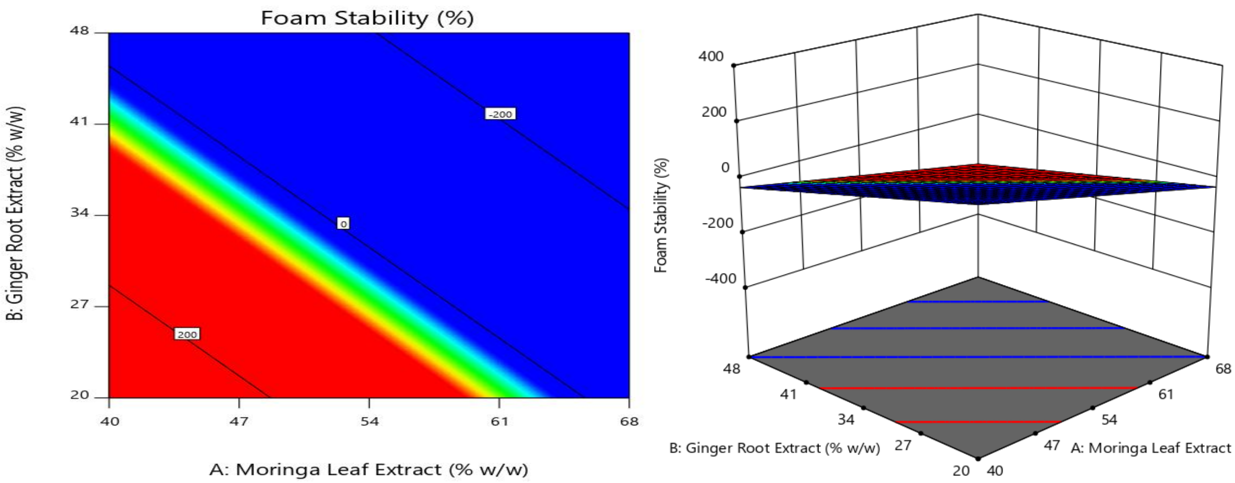

Fig. 2: Contour and 3-D plots of the foam stability

3.3 Optimization of the Process Parameters

Optimization was conducted in order to achieve the maximum foam expansion and maximum foam stability. The numerical optimization yielded a desirability index of 0.968 with optimized levels of independent variables as moringa 53.578%, ginger 20.01%, soy protein isolate 20%w/w, methyl cellulose 3.999%w/w, whipping time 14.999 min, drying temperature 60.037ºC, foam thickness 7.986mm, whipping speed 10000.007 rev/min, foam expansion 54.568% and foam stability 74.863%.

The optimized foam expansion and foam stability 3-D plots are presented in Figure 3.

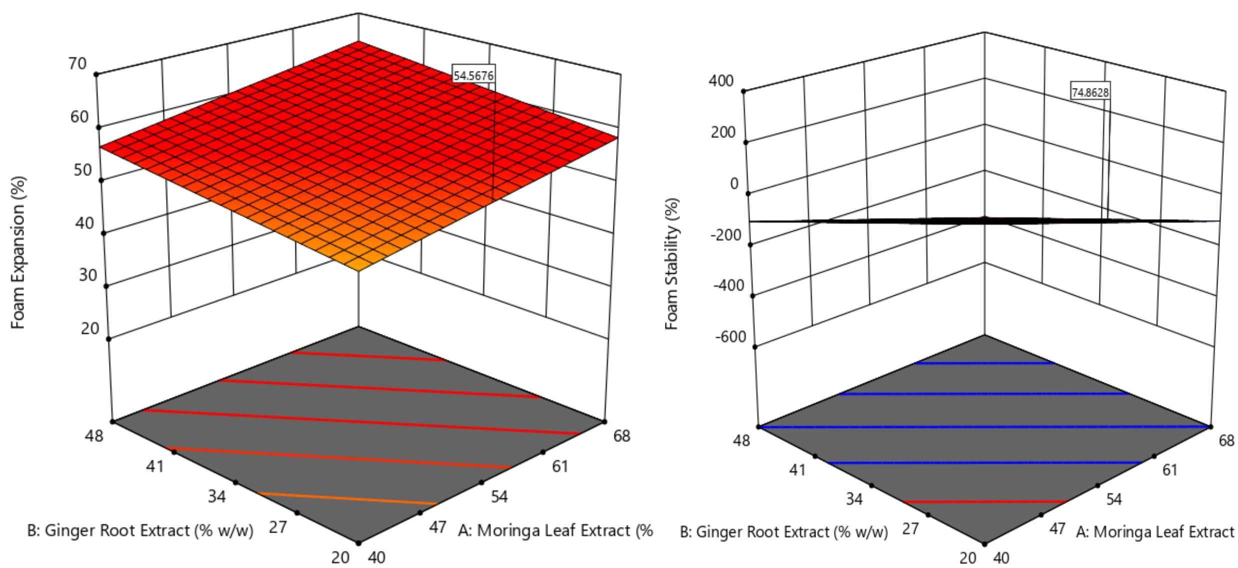

Fig. 3: Optimized foam expansion and foam stability 3-D plots

The desirability and overlay plots are represented in figure 4.

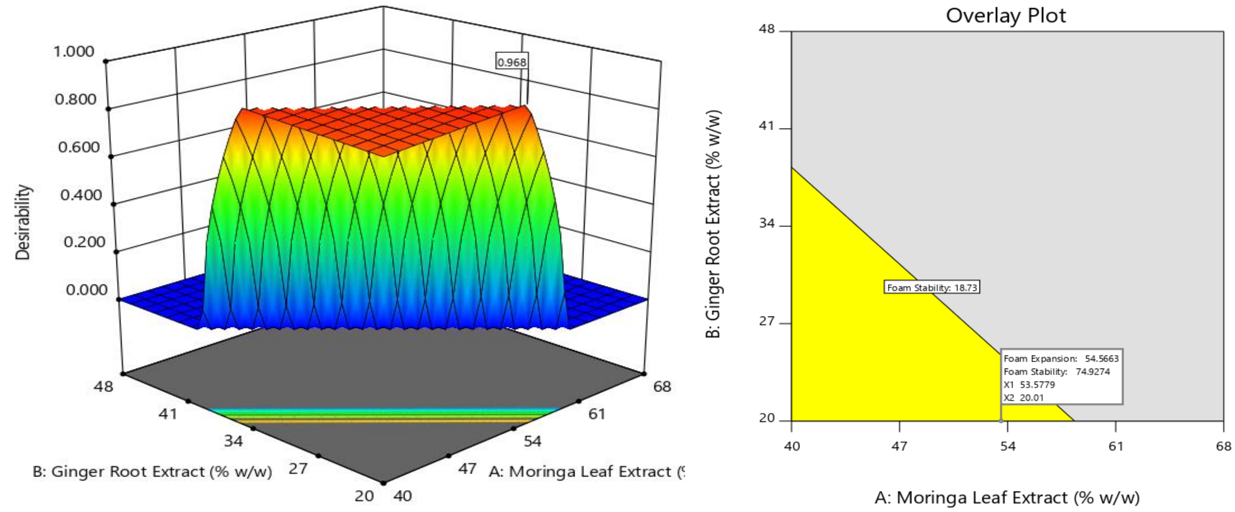

Fig. 4: Desirability and overlay plots

4.0 CONCLUSION

The study has shown that moringa/ginger extract may be foamed using soy protein isolate as a foaming agent and methyl cellulose as foam stabilizer. It was also found that increasing the soy protein isolate from 10% to 20% significantly increased the foam expansion of the moringa/ginger extract., However methyl cellulose has no effect on foam stability this might be because the ranges chosen for the experimentation is narrow. The numerical optimization yielded a desirability index of 0.968 with optimized levels of independent variables as moringa 53.578%, ginger 20.01%, soy protein isolate 20%w/w, methyl cellulose 3.999%w/w, whipping time 14.999 min, drying temperature 60.037^{o}C, foam thickness 7.986mm, whipping speed 10000.007 rev/min, foam expansion 54.568% and foam stability 74.863%.

ACKNOWLEDGEMEMT

The author thank Mrs. Lois Thomas for financial support and Dr. S. T Olorunshogo for his effort in supervising this project.

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STUDIES ON THE OIL YIELD AND NUTRITIONAL PROPERTIES OF SOME LOCAL SEEDS: EFFECTS OF DRYING SYSTEMS

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ABSTRACT

This study was undertaken in order to determine the oil yield and nutritional properties of oils extracted from the seeds of melon, Africa star apple, and tropical almond seeds. The oils were extracted from the corresponding seeds in a sohxlet extractor with Hexane and analyzed for moisture content, oil yield, protein, vitamin A,D,E and K, phenolic and flavonoid compounds, nitrogen, potassium, phosphorous, zinc, chloride and magnesium. The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying (80^{o}C) and no drying (i.e control) from the Africa star apple seed oil were (7.12, 55.89), (8.89, 50.13), (8.94, 54.12), (8.38, 52.76) and (6.39, 51.13) respectively. The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying (80^{o}C) and no drying (i.e control) from the tropical almond seeds were (8.56, 58.92), (8.54, 52.33), (8.40, 54.11), (8.38, 54.67) and (7.64, 59.64) respectively. The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying (80^{o}C) and no drying (i.e control) from the melon seeds were (8.87, 61.22), (8.40, 60.83), (8.89, 62.36), (8.59, 60.13) and (8.36, 56.27). It is found that temperatures of the drying system affected the oil yield and also nutritional properties of the extracted oil. Oils could serve as feedstock for many industrial applications.

Key words: Flavonoid, Phenolic, Oil yield, Hot air oven, Protein content, Soxhlet extractor

1. INTRODUCTION

Nigeria, as a tropical country, has a wide variety of domestic plants that produce oil-bearing seeds of sufficient volume potential; for example, edible seeds like soya bean, (Aluyor and Audu 2009) peanuts and corn. According to Oderinde et al. (2009), Nigeria has one of the most extensive flora in continental Africa. Unfortunately, however, the vast majority of the seed oils have not been adequately characterized. Examples include Huracrepitans, (otherwise known as sandbox tree), neem, castor, rubber seed, et cetera Otoikhian (2008). Others are Melon, Tropical almond, and African star apple seeds.

Good nutrition is a basic human right. In order to have a healthy population that can promote development, the relation between food, nutrition and health should be reinforced. In developing countries, one of the ways of achieving this is through the exploitation of available local resources, in order to satisfy the needs of the increasing population. Knowledge of the nutritive value of local seeds local is necessary in order to encourage the increased cultivation and consumption of those that are highly nutritive. Several studies have been carried out including that of Teugwa et al. (1992) who determined the chemical composition of some local crops of the Far North Province of Cameroon (“Gniri/Follèré”, “Gniri/Lalo” and “Gniri/Tasba”, where “Gniri” is millet fufu were unbalanced due to excess carbohydrates and shortage of lipids, but with good levels of proteins, minerals and fibres. The chemical and functional properties of the kernels and defatted cakes of Ricinodendronheudelotii and Tetracarpidiumconophorum, which are two underexploited oilseeds, largely consumed by the western and coastal populations of Cameroon were also analyzed. They showed that these oilseeds were good sources of lipids and proteins and that their defatted cakes could be used as protein supplement in human nutrition. On the other hand the demand for drying is one of the most relevant and challenging processes of food industry, since a great number of food products are subjected to at least one drying step during its production (Wankhade et al., 2013). Dehydration or drying of foods is described as any process that involves thermal removal of volatile substances to obtain a dry solid (Xiao et al., 2010). The main purposes of drying crops are to increase its shelf life, to better its quality, to simplify the handling, storage and transport of the products and also to prepare the product to subsequent processes. Drying of Agricultural crops is done in most farms by sun-drying (Lasisi et al., 2013). This results into contamination by insects and dust. Therefore, there is need to introduce the use of different drying system. This study will therefore provide adequate information about a suitable drying method that will give the maximum nutrient retention of melon, tropical almond and African star apple seeds will also guide Engineers in designing storage facilities for the seeds for various medicinal and nutritional uses. Solar, open sun, hot air, microwave drying are the mostly drying method used in drying theses seed, sun drying being the most common practice (Matazu and Haroun, 2014). These four drying system (Solar, open sun, hot air, microwave) utilize heat to remove water from food by evaporation. The removal of water by heat has been reported to affect the oil and nutrient contents of the seeds in various ways. It can either increase the concentration of some nutrients by making them more available or decrease the concentration of some nutrients (Hassan et al., 2007). These study is therefore carried out to establish the effect of these varying drying system on the oil and nutrition content of these seeds in order to determine the most suitable system that will not only increase their shelf life but also retain their nutrients adequately.

2. MATERIALS AND METHODS

The freshly harvested seed was sourced from the eastern part of Nigeria, Nsukka and Awka precisely during their various season of harvest. Materials used are: 1kg of different seeds, weighing balance thermometer, Solar over dryer, Hot air oven dryer, Soxhlet extractor, Beakers, Chemical and reagents

2.1 Methods

2.1.1 Raw Material Preparation

The Melon, Africa star apple and tropical almond seeds undergo various processing in the course of its preparation for extraction. Some foreign materials and dirt which are separated by hand picking. The seeds were cracked to separation the shells from the kernel. The seeds were dried under the varying system to reduce its moisture content, Manually grinded obtain a size of 2 mm sieve size in order to weaken or rupture the cell walls to release castor fat for extraction

2.1.2 Weighing and drying of the seeds

Different quantities of the seeds were weighed using electronic sensitive weighing balanced before drying, in other to calculate the moisture loss after drying. The samples been weighed are dried using different drying system at varying temperatures.

2.1.3 Determination of Moisture Loss

The moisture loss (g) in the sample was determined by the measurement of the loss in weight due to drying at different temperature (Equation 1).

$$ML = (A - B) \qquad (1)$$

Where, A is original weight of sample and B is weight of dried sample.

2.1.4 Oil extraction from the seed

The seed oil was obtained by extraction using (n-hexane) at 50-70-90°C in a Soxhlet extractor for the different seeds dried using hot air oven and at 90°C for seeds dried using solar dryer. Each milled sample is filled in a thimble. The round bottom flask is filled with the solvent (n-hexane) up to two-third of the flask. The reflux condenser was fitted to the top of the extractor and the water flow is turned on. The round bottom flask was placed in the heating mantle at the temperature as listed above for 3 hours. After the extraction, the solvent was evaporated at 50 °C until the solvent evaporates.

2.1.5 Characterization of the seeds oil

Determination of oil yield in percentage (%): The percentage yield was calculated using the Equation (2)

$$Percentage\, yield\, of\ oil = \frac{Weight\, of\ oil\,(g)}{Weight\, of\ sample\, analyzed} \times 100 \qquad (2)$$

Determination of Protein: The crude protein content was determined using the micro kjedahl method.

Determination of vitamin A: 1 g of each analysis oil was dissolved with 10 cm^3 of acetone in a 50 cm^3 conical flask and allowed to stand for 20 minutes, and was shaken gently for every 4 minutes interval to extract the colour substance in the sample. After agitation, the mixture was allowed to settle and was decanted to obtain a clear solution in a test tube. 5 cm^3 of hexane was added and shaken gently. Two distinct layers was observed. The upper layer was obtain by separation with a separating funnel and collected in a glass curvet and read off the absorbance at 453 nm in an Ultraviolet spectrophotometer

Determination of Vitamin E: about 0.5 cm^3 of the oil sample was introduced into test tube with tight stopper and 0.5 cm^3 of anhydrous ethanol, Shaken for 1minutes. Also added was 3 cm^3 of xylene, the test plugged and shaken for 1 minute, centrifuged (1500 rpm for 1 minute), Measured 0.25ml of batophenanthio was introduced into the test tube, 1.5 cm^3 of extract (upper layer) was collected from test tube mix, 0.25 cm^3 of $FeCl_3$ and 0.25ml of H_3PO_4 solutions were added, mixed and the absorbance at 539nm was measured

Determination of vitamin K: about 1g of the oil sample was analyzed oil and then homogenized with 10cm^3 of distilled water. 1cm^3 of the supernatant pipette. 2 cm^3 of 0.04%, 2,4 dinitrophenylhyrazine was added in 1:5 Hydrochloric acid was added, heated in boiling water for 45 minutes and cooled, diluted to 10 cm^3 with 1:30 ammonium hydroxide and the absorbance at 635nm was measured.

Determination of vitamin D: 1g of the oil sample was analyzed and then homogenise with 20cm^3 ethanol. Centrifuge for 10minutes at 300rpm. 1cm^3 of the supernatant was pipette and 0.5 cm^3 of 1% furfural was added. diluted to 2.5 cm^3 with ethanol and1cm^3 of conc. H_2SO4 added, mixed and after 2minutes the absorbance at 525nm was measured.

Determination of minerals: about 5 g of oil sample was introduced into a conical flask for analysis. About 20 cm^3 of conc. HNO_3 and $HCLO_4$ were mixed in a conical flask and digest on a hot plate at 130°C. The digestion was continued until the color appears clear, the silica became white and white fumes of $HCLO_4$ appeared in the flask. The solution was mixed and made up to 50 cm^3 with distilled water, transfered to 250 cm^3 volumetric flask and diluted to mark with distilled water.

Determination of nitrogen: The micro-Kjedahl method as described in Pearson (1976) was used in the determination of the nitrogen content.

Determination of phosphorous by ascorbic acid method: 2 cm^3 of the analysis oil was pipetted into a test tube. Lcm^3 of ascorbic acid solution and 1cm^3 of 2.57 ammonium molybdate reagents was added to the sample and mixed well. The well-mixed sample was boiled in a water bath for 5 minutes for the blue colour to develop. The absorbance was read at 620nm

The phosphorus content was calculated using Equation (3):

$$Phosphorus = \frac{Absorbance of\ samples - Absorbance of\ blank \times D.F}{Slope} \quad (3)$$

Determination of magnesium: Magnessium content was determined by AOAC (2000)**.** 1 cm^3 of oil sample was pipette into 250 cm^3 conical flask with 25 cm^3 of distilled water, 25 cm^3 Ammonia – ammonium chloride buffer and a 2-3 drops of Erichrome black-T indicator; titrate against 0.01N EDTA. Equation (4) was used to calculate magnesium content (%)

$$Magnesium content\,(\%) = \frac{Volume\ of\ EDTA \times Weight\ of\ magnesium \times D.F}{100 \times Weigth\ of\ oil\ sample \times 10} \times 100 \quad (4)$$

Determination of potassium: Potassium was determined by running the sample filtrate in a flame photometric with standard potassium according to the method described by AOAC (2000).

Determination of zinc: Zinc content was determined according to the method described by (Pearson1976)

Determination of chloride: 12.41g of sodium thio-sulphate ($Na_2S_2O_4$ $5H_2O$) was dissolved in 1 litre of distilled water and 3 drops of chloroforms added for preservation. Standard N/10 potassium iodide solution- Standard 10N of 16.6 g of potassium iodide in distilled water, concentrated HCL of Specfic gravity 1.18 and Na_2HCO_3 were added. Starch paste was prepared with distilled water. 100 cm^3 was made with water and boiled by stirring and cooled.

2.1.6 Determination of anti-nutritional factors

Total phenolic content: The concentration of phenolics was determined using spectrophotometric method. Folin-Ciocalteu assay method was used for the determination of the total phenol content. The reaction mixture consists of 1 cm^3 of oil sample and 9 cm^3 of distilled water was taken in a volumetric flask (25 ml). 1 cm^3 of Folin-Ciocalteu phenol reagent was treated to the mixture and shaken well. After 5 minutes, 10 cm^3 of 7 % Sodium carbonate (Na2CO3) solution was treated to the mixture. The volume was made up to 25 cm^3. A set of standard solutions of gallic acid (20, 40, 40, 60, 80 and 100 μg/ml) were prepared in the same manner as described earlier. Incubated for 90 min at room temperature and the absorbance for test and standard solutions were determined against the reagent blank at 550 nm with an Ultraviolet (UV) /Visible spectrophotometer. Total phenol content was expressed as mg of GAE/100g

Total flavonoid content: Total flavonoid content was measured by the aluminum chloride colorimetric assay. The reaction mixture consists of 1 cm^3 of analysis oil and 4 cm^3 of distilled water was taken in a 10 cm^3 volumetric flask. The flask was added 0.30 ml of 5 % sodium nitrite and was treated and after 5 minutes, 0.3 cm^3 of 10 % aluminum chloride was mixed. After 5 minutes, 2 cm^3 of 1M Sodium hydroxide was treated and diluted to 10 cm^3 with distilled water. The absorbance for test and standard solutions were determined against the reagent blank at 510 nm with an UV/Visible spectrophotometer. The total flavonoid content was expressed in mg by 100g

3. RESULTS AND DISCUSSION

3.1 Results

Tables 1-3 present the values for oil and nutritional properties for tropical almond seeds, melon seeds and African star apple seeds at varying drying systems.

Table 1: Oil and nutritional content of African star apple seeds at varying drying systems and temperature.

Properties	Hot Air Oven drying at 50°C	Hot Air Oven Drying at 70°C	Hot Air Oven Drying at 90°C	Solar Drying at 80°C	Control at Ambient Temperature.
Moisture loss (g)	3.553	6.469	17.663	8.819	-
Oil yield (%)	25.498	25.450	24.966	25.690	26.241
Protein content (%)	0.550	0.544	0.494	0.481	0.444
Vitamin A (mg/g)	1.043	1.123	1.107	1.116	1.136
Vitamin D (mg/100g)	0.106	0.121	0.127	0.133	0.133
Vitamin K (mg/100g)	0.037	0.021	0.034	0.022	0.039
Vitamin E (mg/100g)	0.521	0.532	0.510	0.558	0.674
Nitrogen (%)	0.079	0.077	0.071	0.087	0.088
Zinc (mg/100g)	1.413	1.267	1.242	1.438	1.663
Magnesium (mg/100g)	37.920	37.574	33.866	38.550	37.839
Chloride (mg/100g)	0.056	0.051	0.057	0.036	0.023

Phosphorous (mg/100g)	131.110	123.606	123.584	129.641	137.770
Potassium (mg/100g)	76.580	77.691	72.425	76.961	83.640
Phenolic compound mg/100g	7.120	8.885	8.937	8.381	6.390
Flavonoid compound (mg/100g)	55.891	50.128	54.121	52.763	51.128

Table 2: Oil and nutritional content of melon seeds at varying drying system and temperature.

Properties	Hot Air Oven drying at 50°C	Hot Air Oven Drying at 70°C	Hot Air Oven Drying at 90°C	Solar Drying at 80°C	Control at Ambient Temperature.
Moisture loss (g)	19.10	31.259	45.928	39.969	-
Oil yield (%)	44.972	44.864	44.477	44.977	45.595
Protein content (%)	0.544	0.550	0.450	0.556	0.569
Vitamin A (mg/g)	1.583	1.292	1.310	1.712	1.764
Vitamin D (mg/100g)	0.126	0.129	0.121	0.139	0.210
Vitamin K (mg/100g)	0.042	0.033	0.044	0.047	0.063
Vitamin E (mg/100g)	0.613	0.621	0.618	0.737	0.879
Nitrogen (%)	0.087	0.088	0.072	0.089	0.091
Zinc (mg/100g)	1.330	1.427	1.398	1.762	2.064
Magnesium (mg/100g)	35.064	32.129	30.642	34.912	36.647
Chloride (mg/100g)	0.026	0.016	0.025	0.021	0.057
Phosphorous (mg/100g)	131.660	132.261	133.991	131.647	138.647
Potassium (mg/100g)	75.690	83.421	84.420	83.330	84.420
Phenolic compound mg/100g	8.876	8.393	8.885	8.592	8.361
Flavonoid compound (mg/100g)	61.216	60.833	62.361	60.128	56.271

Table 3: Oil and nutritional content of tropical almond seeds at varying drying systems and temperature.

Properties	Hot Air Oven drying at 50°C	Hot Air Oven Drying at 70°C	Hot Air Oven Drying at 90°C	Solar Drying at 80°C	Control at Ambient Temperature.
Moisture loss (g)	42.689	74.668	75.932	74.936	-
Oil yield (%)	31.041	30.995	30.442	31.220	31.939
Protein content (%)	0.475	0.462	0.437	0.475	0.494
Vitamin A (mg/g)	1.342	1.413	1.328	1.369	1.550
Vitamin D (mg/100g)	0.113	0.107	0.109	0.122	0.127
Vitamin K (mg/100g)	0.033	0.025	0.020	0.029	0.057
Vitamin E (mg/100g)	0.663	0.571	0.542	0.693	0.810
Nitrogen (%)	0.076	0.074	0.070	0.076	0.079
Zinc (mg/100g)	1.422	1.369	1.371	1.443	1.564
Magnesium (mg/100g)	31.423	30.646	31.129	31.227	33.330
Chloride (mg/100g)	0.030	0.039	0.041	0.038	0.024
Phosphorous (mg/100g)	141.392	140.016	136.761	140.391	147.220
Potassium (mg/100g)	71.112	70.327	70.047	760.428	75.676
Phenolic compound mg/100g	8.556	8.540	8.397	8.381	7.642
Flavonoid compound (mg/100g)	58.921	52.332	54.112	54.667	59.640

3.2 Discussion

3.2.1 Moisture loss

From the Tables 1-3, the moisture loss for African star apple seeds were obtained and found to vary with drying temperatures- hot air oven (50, 70 and 90 °C), solar drying (80^{o}C) and open air drying.

3.2.2 Oil yield

Increase in temperature of the dryer results in decrease in oil yield for all the seeds analyzed. The amount of oil yield in melon seeds is higher than that of Africa star apple seeds and tropical almond seeds. This could be due to genetic nature of the seeds. The optimum oil yield was obtained from the control sample at ambient temperature with the yield of 45.595%, 31.939% and 26.241% for melon, tropical almond seeds and Africa star apple seeds respectively. The lowest oil yield for the same drying system was recorded at 90°C with the oil yield of 44.477%, 30.442% and 24.966% for melon, tropical almond seeds and Africa star apple seeds respectively. For African star apple, the oil yield of the seed vary from 25.498% to 26.241% indicating there is possibility of oil cell to break down and oil particles escape with the heat, however statistically, the value are not significantly different. The value of oil yield in this study is high compared to the values reported by Adejumo et al. (2012) and Agbede et al. (2011). This indicates that the seed may not be a good source of abundant oil. However, genetically modified breeds may be developed which could produce seeds with more oil yield. For melon, the amount of oil contain in this study is high compared to Yanty et al. (2008), they found out that melon contain lower contents of oil (25.0%). This difference arises from geographical conditions. De Melo et al. (2000) and De Mello et al. (2001) had earlier reported 30.83% and 32.3% in seeds of *Cucumis melo* hybrid and *Cucumis melo var. saccharinus* respectively. The highest content (40%) was reported by Sorho et al (2006) in seeds *Cucumis amaris.*

3.2.3 Nutritional properties of the African star apple seed oil

The nutritional properties results are presented in Table 1 .The result showed that different levels of nutrient are contained in each seeds oil at varying drying temperature. For African star apple seed some of the nutrient properties are not really high compared to that of other seeds because of the genetically modification. The result for zinc is affected by the temperature as can be seen from the table. The zinc content is higher on the oil gotten from the control sample (open air drying) reading 1.663mg/100g and the lowest is that of oil gotten from the seed dried at 90°C using hot air oven dryer reading 1.242mg/100g. This show that temperature has effect on the zinc content and this is applicable to the oil gotten from tropical almond and melon seed as well. For chloride, the highest yield is that of the oil gotten from the seeds using hot air oven dryer at 90°C (0.057mg/100g) and lowest from oil gotten from the open air drying (0.023mg/100g). This is also the same for the entire oil sample and this show that temperature doesn't have effect on the chloride content. For phosphorous, the highest yield is on the oil gotten from the open air drying (137.770mg/100g) and lowest yield is that of the oil gotten from the seeds dried using hot air oven dryer at 90°C (123.584mg/100g). This results agreed with Umelo (1997) who stated that *C. albidum* is an excellent source of vitamins, iron, and flavours to diet.

3.2.4 Nutritional properties of tropical almond seed oil

The nutritional properties results are presented in Table 3. The result showed that different levels of nutrient are contained in each seeds oil and the effect of temperature. For tropical almond seed the difference in the protein values are not significant as drying temperature doesn't affect the protein content. These values are low when compared to that of almond nut which is within the range 23.78–29.4 % (Ezeokonkwo and Dodson 2004; Omeje et al. 2008; Kimbonguila et al. 2010; Oliveira et al. 2000; Akpakpan and Akpabio 2012). It can be deduced from the results that an increase in temperature bring about a reduction in the vitamins content i.e vitamin D and K reading 0.5113 and 0.663 at 50°C and 0.57 and 0.810 for control sample. The reduction rate varies with the drying process for all the seeds. The decrease in the vitamin also varies with method of drying and nature of the vitamins. From the results, temperature has effect on the zinc content Proximate analysis of the tropical almond shows that it is rich in protein (18.39–40.9 %) and oil (43.36–63.65 %). Similar studies has been done by Oliveira et al. (2000), Ezeokonkwo (2007), Biego et al. (2012), Monnet et al. (2012) and Atsu Barku et al. (2012). Ezeokonkwo and Dodson (2004) reported that the seed has essential amino acids that can support growth and a high dietary protein quality. Ezeokonkwo (2007) found out that the limiting amino acids in the tropical almond seed were tyrosine, lysine and methionine.

3.2.5 Nutritional properties of melon seed oil

The nutritional properties results are presented in Table 2. The result showed that nutritional properties of melon seed oil vary with drying temperature. The variation of protein content with drying temperature for the different systems is not significant. Increase in temperature bring about a reduction in the vitamins content i.e vitamin E and K reading 0.042 and 0.613 at 50°C and 0.063 and 0.879 for control sample. The reduction rate varies with the drying process for all the seeds. The decrease in the vitamin also varies with method of drying and nature of the vitamins. Temperature has effect on the zinc content also. The mineral composition results of the seeds for potassium at lowest value reading 75.690mg/100g for hot air oven at 50°C. From the analysis, temperature doesn't have much effect on the value gotten from potassium as the value varies with changes in temperature. These results are not really in close agreement with those reported by Olaofe (1994) and Milovanovic (2005). Manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn) accounted for minor contents i.e. 1.59, 0.83, 4.90 and 4.65 mg/100g respectively.

Those percentages are comparable to those reported by Olaofe (1994) and Milovanovic (2005). The presence of such chemical elements as K, Ca, Zn, Na and traces of nickel in foodstuffs was already reported for their important contribution to the maintenance of normal glucose levels and tolerance . These elements might contribute to the fight against the resistance to the release of insulin from the body. Only traces of cadmium (Cd), cobalt (Co) and nickel (Ni) were found.

4. CONCLUSION

Oil yield was successfully extracted from tropical almond seeds, melon seeds and African star apple seeds at varying drying system and temperature. The study showed that the oil was highest at 90^{o}C for melon (45.60%), tropical almond seeds at (31.94%) and African star apple seeds (26.24%). Also, the oil yield is influenced by the temperature and genetic nature of the seeds. Most of the nutritional properties tested is highest for oil gotten from melon seeds. These seeds are good sources of some vital nutrient and very rich in oil. Drying system and temperature had significant effect some of the nutritional properties of the oil gotten from the seeds. The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying 80^{o}Cs and no drying (i.e control) from the Africa star apple seed oil were (7.120, 55.89), (8.885, 50.13), (8.94, 54.12), (8.38, 52.76) and (6.390, 51.13) respectively. The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying (80^{o}C) and no drying (i.e control) from the tropical almond seeds (8.57, 58.92), (8.54, 52.33), (8.40, 54.11), (8.381, 54.68) and (7.64, 59.64). The total flavonoid and phenolic compounds at drying temperatures of 50, 70, 90^{o}C, solar drying (80^{o}C) and no drying (i.e control) from the melon seeds (8.88, 61.22), (8.39, 60.83), (8.89, 62.36), (8.59, 60.13) and (8.36, 56.27). The high oil and nutritional content of these seeds studied showed that they can be good feedstock for bio fuel production and rich source of valuable nutrient to man.

RECOMMENDATION

It is recommended that further study should be done to determine the physio chemical properties of the oil from these seeds, in other to ascertain their suitability for biofuel purposes.

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THE EFFECT OF SELECTED BIOPESTICIDES AND PACKAGING MATERIALS ON SOME QUALITY PARAMETERS OF STORED COWPEA

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ABSTRACT
A study to assess the effect of some locally available biopesticide on some quality parameters: Level of infestation, weight loss and seed germination of stored cowpea was carried out over a 12 weeks period. The test materials consist of three storage media namely polypropylene bag, Jute bag and plastic container with cloth covering and three biopesticide namely Lemon grass, garlic bulb and Orange peel at three different levels of concentration of 2.5g, 5.0g and 10.0g and three control (no biopesticide).The biopesticide had varying degree of effects on the level of infestation and weight loss on stored cowpea. Cowpea treated with lemon grass gave better results than the control in the level of infestation and weight loss and was followed by garlic bulb powder and orange peel powder been the least at similar level. Cowpea stored in jute bag had more damaged seed and weight loss compared with other storage media which makes it less suitable for storing the treated cowpea seed. The different treatment had no adverse effect on the germination.

Keyword: Biopesticide, Storage media Lemon grass, Orange peel, Garlic, infestation.

1.0 INTRODUCTION

Legumes including Cowpea (*Vigna unguiculata* L.) are important crops in Nigeria. The green parts of the plant are used as a vegetable or as fodder for cattle. The seeds contain a high amount of protein and B-vitamins (Phillips and McWatters, 1991) and help to prevent starvation among low resource farmers and the poor urban population (Duke, 1985). Globally a minimum of 10% of cereals and legumes are lost after harvest (Boxall *et al.,* 2002). Insect pests cause heavy economic losses to stored grains throughout the world and their impacts are more devastating in poor countries (Boxall *et al*., 2002)

Humans have used insecticides to control these insect pests for many years but there are significant problems associated with application of insecticides. They are hazardous to humans, and the natural environment. On the other hand, control of stored food insects face serious challenges worldwide, not only for food safety, but also for government regulation, and biological pressure because insects become more and more difficult to control due to growing resistant to this insecticide by most of these insect pests. The high cost of purchasing insecticides is also another factor .Thus the need to study plant source material with insecticidal effect. The objective of this study is to do a comparative evaluation of the effect of different biopesticides and storage media on some quality parameter of stored cowpea

2.0 MATERIALS AND METHOD

2.1 Material

Samples of cowpea seed was obtained directly from Farmers field in Gaba, Niger state and the seeds were checked to ensure that they were not infested by visual observation for presence of eggs or any suspicious material. Whole seeds free of puncture and eggs was selected and refrigerated for 96 hours at $4^{o}C$ to ensure the death of any unseen egg. The seeds were allowed to dry for an hour and weighed prior to treatment with plants extracts.

2.1.1 Plant Products

Garlic (*Alium sativum)*, Orange peel (*Citrus sinensis)* and lemon grass (*Cympobogon citratus)* were used as treatments for this study was obtained from around Bida and Minna and taken to the laboratory for processing. Moisture content of the cowpea and all the plant products used were determined prior to the experiment using oven dry method (Pixton, 1967). Each plant product was cut into small pieces using a blade and a chopping board. The product except garlic bulbs was then ~~be~~ dried for 3 days at room temp and then grounded in a hammer mill and was then ~~be~~ sieved into a fine powder using 0.1 mm sieve size. They were then ~~be~~ separately packed in white polythene bags and stored in a refrigerator at $4^{o}C$ until required for use.

2.2 Methods

The methods that were used for the study are explained as follows:

2.2.1 Experimental Layout

The experimental design was a split plot experiment in a randomized complete block design. One hundred grams of cowpea each was placed in three storage media namely Jute Bag, plastic container with cloth covering and polypropylene bag. Each of the samples was treated with any of the three biopesticides (Garlic, Orange peel and Lemon grass) at three different levels of 2.5g, 5.0g and 10.0g and vigorously shaken to ensure proper mixing. Another 100g of the cowpea samples was left as it is without application of biopesticide and stored in the storage media. All samples was carefully labeled and stored at room temperature for a period of 12 weeks

2.2.2 Data Collection and Analysis

Seed samples were taken weekly from the various storage media and assessed. Weight of the stored cowpea was measured using sensitive digital weighing balance. Moisture content of the stored cowpea was determined by oven drying method. Number of damaged grains was determined by randomly counting 100 grains from each sample and manually counting the number of holes in each grain, after sorting them out according to the number of holes (Okeke, 1996). All the Data was subjected to analysis of variance (ANOVA)

At the end of every week the percentage of infested (damaged) grains and weight losses from the same sample was evaluated by randomly picking 100 seeds from each storage medium and recording the number of emergence holes in them as well as weighing the entire cowpea grains with a sensitive digital weighing scale. The data for each replicate was recorded and subjected to analysis of variance tests.

To calculate the percentage of damaged seeds and loss in weight Equations 1 and 2was used.

i. Percentage of damaged seeds

$$= \frac{InitialNumberofseeds - NumberofUndamagedseeds}{InitialNumberofseeds} X\ 100 \qquad (1)$$

Source: Okeke (1996)

ii. Percentage loss in weigh

$$= \frac{Initialseedweight - Finalseedweight}{Initialseedweight} X\ 100 \qquad (.2)$$

Source: Okeke (1996)

At the end of the trial period (12 weeks), 20 undamaged seeds from different treatment was picked and placed on whatman filter paper in sterilized Petri dishes, moistened and kept on the laboratory bench under room temperature. Germination counts were taken on the 7th day and data obtained which will be subjected to analysis of variance after transformation (equation 3).

$$\text{Viability index (\%)} = \frac{\text{number of grains germinated}}{\text{number of grain tested in each petri dish}} \text{x100} \qquad (3)$$

3.0 RESULTS AND DISCCUSION

3.1 Effect of biopesticide and storage media on level of infestation

The Results presented in Figure 1-3 shows That percentage damage was least in cowpea stored in the plastic container cover with cloth cover compared with the other stored in polypropylene bag and Jute bag. This was followed by those stored in polypropylene bag and jute bag with the highest damaged grains. It was also observed that the damage seed of cowpea in jute bag were more than the ones in plastic container and polypropylene which makes it less suitable for storage of cowpea. Statistical analysis (Table 1& 5) showed that both storage media and Biopesticides has very high significant effects ($P<0.05$) on the damage seed of the cowpea but insignificant at their interaction. The percentage damage (holes in the grains) was least on cowpea treated with lemon grass stored in plastic container with cloth covering at the three concentrations (2.0%, 1.0%, and 0.0%) for the low, middle and highest concentration respectively at the 12th week. All treatment stored with lemon grass had least damaged grains compared to other treatment stored with garlic bulb and orange peels. This was followed by those stored with garlic bulb and orange peel with the highest damaged grains. All treatment had less than 30 percent cowpea damage grain compared to the controls. Statistical analysis (Table 2& 6) revealed that the different Biopesticides and their level of concentration used in this study had very high significant effect ($P<0.05$) on the damage seed but insignificant at their interaction. The level of infestation of the treated cowpea in the three storage media increased as the week increased.

These Observation are similar to those of Dike and Mbah (1992), Dike and Msheila (1996), Onu and Sulyman (1997) and Taylor (1975) using lemon grass stem powder, Eucalyptus leaf powder and citrus peels powder respectively to protect stored grains.

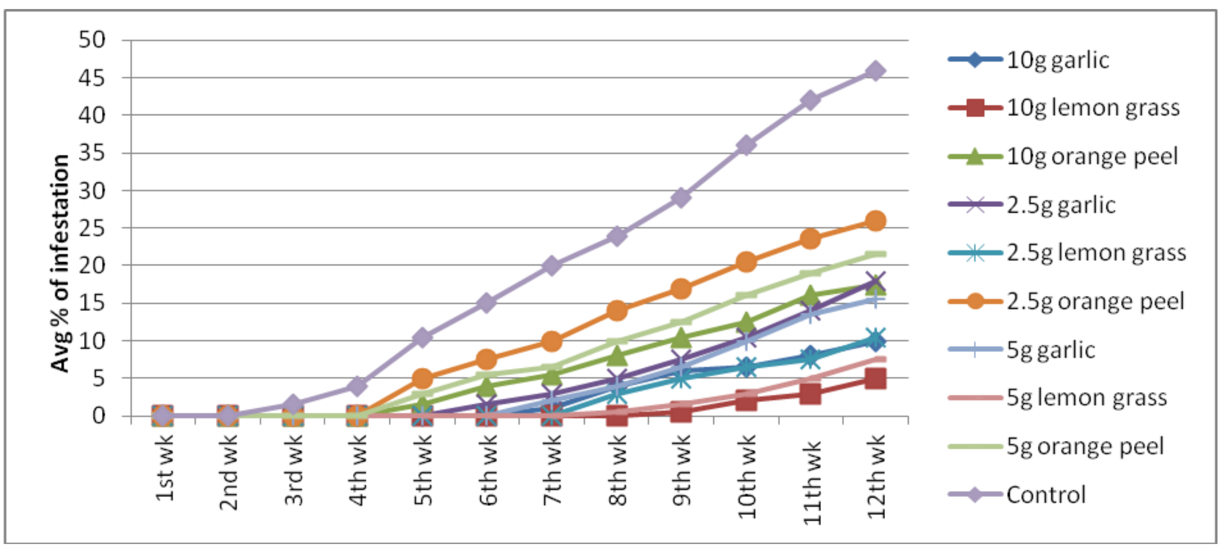

Figure 1: Effects of biopesticides on the level of infestation of cowpea stored in Jute Bag

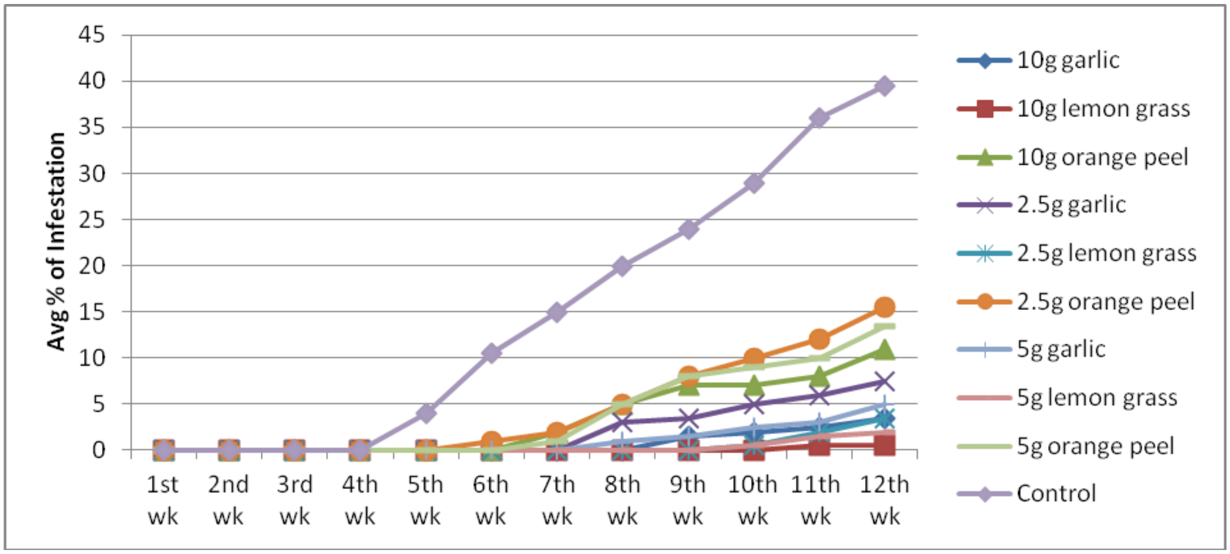

Figure 2: Effects of biopesticides on the level of infestation of cowpea stored in Plastic container with cloth covering

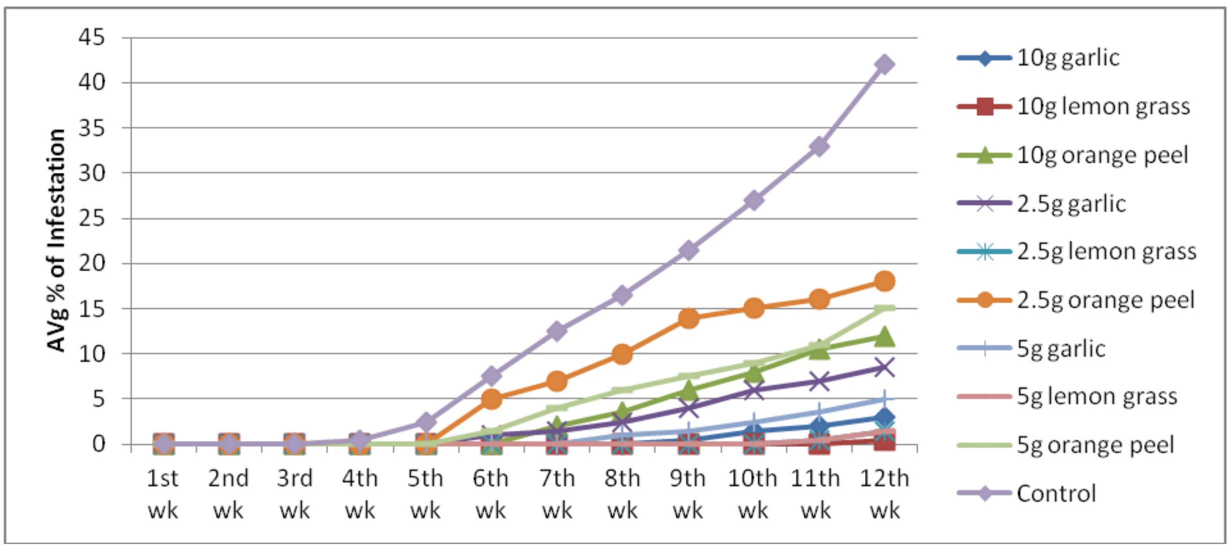

Figure 3: Effects of biopesticides on the level of infestation of cowpea stored in Polypropylene Bag

The effectiveness of lemon grass, garlic bulb and Orange peel in protecting cowpea stored for three months against insect pest attack may be due to the suppression of progeny development, through oviposition detterrance and ovicidal action (Ivbijaro, 1983). Dike and Mbah (1992) reported the efficacy of Lemon grass products in protecting cowpea grains stored for two months and inferred that at the three concentration studied (5.0g, 10.0g and 20.0g) per 100g cowpea seeds lemon grass stem and leaf powder significantly protected cowpea grains from damage by insect pest.

Table 1: ANOVA for the effects of storage media and Biopesticide on the level of infestation

Source	df	Adj ss	Adj ms	f-value	p-value
storage media	2	525.69	262.84	41.01	0.000*
Biopesticide	3	7422.71	2474.24	386.01	0.000*
storage media*Biopesticide	6	38.12	6.35	0.99	0.442**
Error	48	307.67	6.41		
Total	59	8486.93			

Note * Is Significant at ($P<0.05$)

** Is Not Significant at ($P<0.05$)

Table 2: ANOVA for the effects of Biopesticide and Biopesticide level on the level of infestation

Source	Df	Adj ss	Adj ms	f-value	p-value
Biopesticide	2	1568.48	784.241	46.06	0.000*
Biopesticide Level(g)	2	235.15	117.574	6.91	0.002*
Biopesticide*Biopesticide Level(g)	4	17.41	4.352	0.26	0.905**
Error	45	766.17	17.026		
Total	53	2587.20			

Note * Is Significant at ($P<0.05$)

** Is Not Significant at ($P<0.05$)

3.2 Effect of biopesticide and storage media on weight loss

The weight loss detected is variable according to the treatment and as the concentration (Rate of treatment) increased the weight loss decreased. The biopesticides powder reduced the percentage weight loss of cowpea during the 12 weeks storage period compared to the control. The percentage weight loss was least on stored cowpea treated with lemon grass stored in plastic container with cloth covering at the three concentrations (5.0%, 4.0%, and 3.0%) for the low, middle and highest concentration respectively at the 12th week. All treatment stored with lemon grass had least weight loss compared to other treatment stored with garlic bulb and orange peels. This was followed by those stored with garlic bulb and orange peel with the highest weight loss. All treatment had less than 30 percent cowpea weight loss compared to the controls

The percentage weight loss was least in cowpeas stored in the plastic container with cloth covering compared with the other stored in Polypropylene bag and Jute bag. This was followed by those stored in Polypropylene Bag and Jute Bag with the highest weight loss. Statistical analysis proved that there is highly significant difference in the percentage weight loss of treated seeds and control in the different storage media (Table 3& 5) but insignificant at their interaction. Analysis of variance (ANOVA) also shows that biopesticides and their level of concentration had very high significant effect on the weight loss but insignificant at their interactions (Table 4& 6).The pattern of decrease in the amount of cowpea weight loss may be due to insect pest attack as the concentration of treatment powders is increased. The percentage reduction in cowpea weights in all the treatments could be attributed to a similar reduction in degree of infestation of the grains. Nevertheless other factors such as moisture loss in cowpea during the 12 weeks storage period may also play an important role in reducing grain weight.

Table 3: ANOVA for the effect of storage media and Biopesticide on the weight loss

Source	**df**	**Adj ss**	**Adj ms**	**f-value**	**p-value**
storage media	2	702.3	351.15	49.89	0.000*
Biopesticide	3	9144.8	3048.26	433.10	0.000*
storage media*Biopesticide	6	58.6	9.77	1.39	0.239**
Error	48	337.8	7.04		
Total	59	10294.8			

Note * Is Significant for ($P<0.05$)
** Is Not Significant for ($P<0.05$)

Table 4: ANOVA for the effect of Biopesticides and Biopesticide level on the weight loss

Source	**Df**	**Adj ss**	**Adj ms**	**f-value**	**p-value**
Biopesticide	2	1536.04	768.019	48.29	0.000*
Biopesticide Level(g)	2	230.26	115.130	7.24	0.002*
Biopesticide*Biopesticide Level(g)	4	21.30	5.324	0.33	0.853**
Error	45	715.67	15.904		
Total	53	2503.26			

Note * Is Significant for ($P<0.05$)
** Is Not Significant for ($P<0.05$).

Table 5: Effects of storage media on damage seed and Weight Loss

storage media	% of Infestation	% of weight loss
Jute bag	17.75 ± 11.56^{b}	18.95 ± 8.36^{bc}

Plastic container	11.19±10.15[a]	11.75±7.77[ab]
Polypropylene bag	12.25±10.70[a]	11.70±8.21[ab]

Values are Mean ± Standard deviation. Values followed with different superscript down the column are significantly different at $P<0.05$ level of significance.

Table 6: Effects of biopesticide on damage seed and weight loss

Biopesticide	% of Infestation	% of weight loss
Garlic	8.44±5.15[b]	11.23±4.93[bc]
Lemon grass	3.61±3.40[a]	6.33±3.71[ab]
Orange peel	16.67±4.68[c]	19.28±4.34[cd]
Control	32.34±4.78[d]	38.74±4.41[de]

Values are Mean ± Standard deviation. Values followed with different superscript down the column are significantly different at $P<0.05$ level of significance.

3.3 Effect of biopesticide on the percentage of germination

The obtained data in Table 3 shows the effect of the biopesticide on the viability of the cowpea after 12 weeks of storage. All the biopesticide had no significant adverse effect on the viability of the cowpea seeds after 12 weeks storage except for the garlic bulb powder treatment applied at the highest concentration of 10g where the percentage germination was not affected at all and it reached 100%.

Table 3: Effect of Biopesticides on the percentage of cowpea germination

Biopesticide	**2.5g**	**5g**	**10g**
Garlic	95.4	95.4	100
Lemon grass	88.3	92.7	98.7
Orange peel	93.3	90.0	98.7
Control	100		

4.0 CONCLUSION

From the study the different biopesticides has significant effect on the cowpea seed infestation with the least damage been recorded in cowpea stored with lemon grass powder. The storage media used was also of significant effect on the cowpea with more infestation recorded in cowpea stored in jute bags. The weight loss shows slight correlation between percentage infestation and percentage weight loss. Lemon grass, garlic bulb and orange peel can be used to store cowpea which is relatively less poisonous, readily available, affordable and less detrimental to the environments.

ACKNOWLEDGEMENT

The authors wish to thank the staffs of the Department of Agricultural and Bio Resources Engineering, Federal University of Technology, Minna for their support in carrying out this research work.

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STUDIES ON ORANGE PEEL AND PULP FLOURS AS A COMPLEMENT TO WHEAT FLOUR

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ABSTRACT

Sweet orange (*Citrus sinensis*) fruits were washed, peeled manually, the juice extracted. The peels and pulps were sliced into thin slices of about 2cm thick, sun dried (30±2°C) to constant weight, milled and sieved to obtain orange peel and orange pulp flours, respectively which was comparatively analyzed with wheat flour for their chemical composition, such as proximate composition, mineral and phytochemical contents. The results show that flours can be obtained from both orange peel and pulp and these flours contain valuable bioactive substances. Orange pulp flour was significantly higher (p = 0.05%) in fibre, ash and moisture but lower in fat and carbohydrate contents than the orange peel flour, wheat flour was higher than both orange peel and pulp in fat, protein and carbohydrate contents. The mineral contents of the flours were not significantly different (p = 0.05%). However, orange peel flour was significantly higher (p = 0.05%) than the pulp flour in alkaloids, flavonoids, anthocyanins and carotenoids.

Keywords: Orange, Peel, Pulp, flour, minerals, phytochemicals

1.1 INTRODUCTION

Sweet orange (*Citrus sinensis*) is one of the most important fruits in the tropical and sub-tropical regions of the world. The fruits are usually eaten fresh but are also used for making canned orange juice, frozen juice concentrate, jams, jellies among others. Orange processing industries generate huge amounts of orange peel and pulp as by products from the industrial extraction of orange juices. These peel and pulp contain among other things high levels of vitamin C, dietary fibre and flavonoids. Dietary fibre has been used for the treatment of various gastrointestinal disorders and for such possible health benefits as lowering cholesterol levels, reducing risk of colon cancer and losing weight (Friedman, 1989). Dietary fibre has also been reported to have some nutraceutical potentials (Weingartner *et al.*, 2008). Orange peel and pulp also contain other phytochemicals such as polymethoxylated flavones (PMF) and hesperidin which have hormonal and antioxidant actions and are also involved in enzyme stimulation (Gardon, 1990).

The juice obtained from orange fruits is widely taken while the pulp and peel are discarded. The amount of peel and pulp obtained from citrus fruit processing accounts for up to 50% of the original amount of the whole fruit (Chon and Chon, 1997). These Peel and Pulp contain some bioactive substances believed to have nutraceutical potentials. Peel is the thick skin of some fruits and vegetables. Orange peel contains soluble sugars 16.9%, cellulose 9.21%, hemicellulose, 10.5%, and pectin 42.5% (Beatriz *et al.*, 2008). Most of the phytonutrients are found in the peel and inner white pulp of the orange rather than in the juice (Brett, 2011). Although not as juicy or delicious as the inside of an orange, the peel is edible, and has been consumed particularly in environments where there is scarcity of resources and where maximum nutritional value must be derived and minimal waste generated (Gargulinski,2011). However In addition to the skin, which is an important source of fibre in most fruits, the pulpy part of the fruit is also a source of fibre, and other nutrients. The orange pulp contained total pectin 26.0 to 45.6%, neutral detergent 15.8 to 31.0% and crude fiber 9.9 to 20.6% (Porzio and Blake, 1983). The white pulpy part of the orange is the primary source of its flavonoids.

When the pulpy white part of the orange is removed in the processing of orange juice the flavonoids in the orange are lost in the process. This loss of flavonoids is one of the many reasons for eating the orange in its whole food form (Birt *et al.*, 1996).

The objective of this work is to produce edible orange peel and pulp flours, which can be used in varying proportions to complement wheat flour in food processing in order to control wastage of valuable bioactive substances, improving health due to its neutraceutical potentials and also improve the acceptability of certain foods by improving flavour.

2.1 MATERIALS AND METHODS

2.1.1 *Material procurement*

The sweet orange fruit was purchased from Nkwo-Ibagwa market in Igboeze-South Local Government Area of Enugu State. Wheat flour was purchased from Ogige market in Nsukka Township, Enugu State.

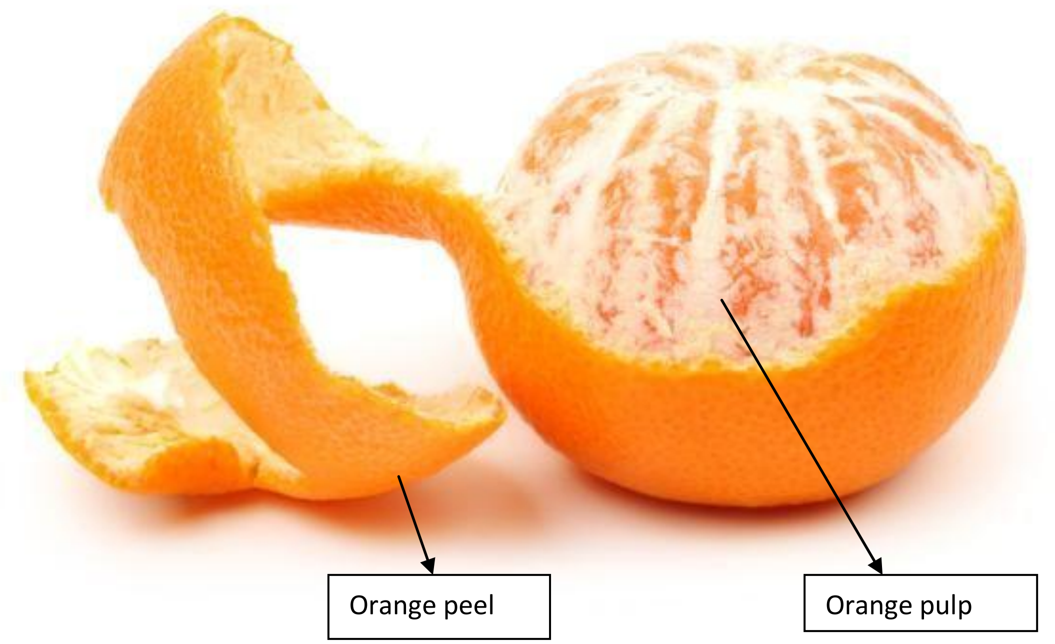

Fig. 1 Diagram of orange peel and pulp

2.1.2 ***Preparation of orange peel and pulp flours*** The fruits were washed thoroughly with water, to remove dirt and adhering extraneous materials, peeled manually with kitchen knife. Kitchen juice extractor was used to extract the juice. The remaining peel was separated from the pulp. The peel and pulp were cut into tiny pieces of about 2 cm and then sun dried (30±2°C) to constant weight milled in attrition mill and sieved with muslin cloth to obtain the flour samples. The flow diagram for the preparation of orange peel and pulp flours is shown in Fig. 2.

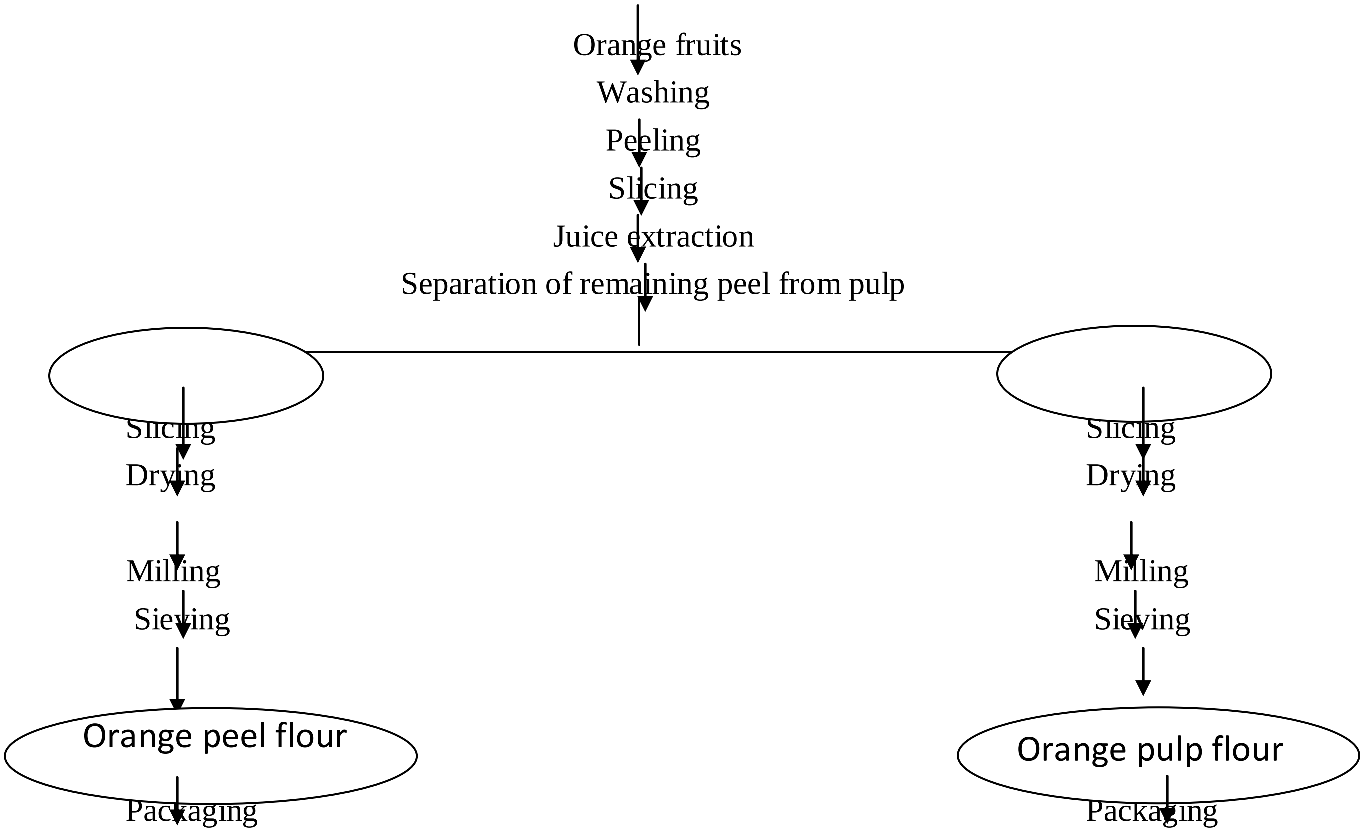

Fig. 2: Flow diagram for preparation of orange peel and pulp flours.

2.2 ***Chemical evaluation***

2.2.1 Proximate analysis: proximate composition analysis (moisture, protein, ash, fat, crude fibre, carbohydrate and calorific value) was carried out by the method described by AOAC 2010.

2.2.2 Minerals: Selected minerals (copper, iron, calcium, zinc, sodium and potassium) were determined using atomic absorption spectrophotometer (AAS) as described by AOAC (2010).

2.2.3 Phytochemical analysis: Quantitative assay for flavonoids, saponins, carotenoids, tannins, alkaloids, anthocyanins, were carried out. Using standard methods flavonoids, alkaloids and anthocyanins were carried out using the method of Harbone (1980), carotenoid carried out using the method of Onyeka and Nwambekwe (2007) and saponin carried out using AOAC (2010).

3.1 EXPERIMENTAL DESIGN

The experimental design that was employed for the study was Complete Randomized Design (CRD). Using the Statistical Package for Service Solution (SPSS) software version 17.

3.1.1 ***Statistical analysis***

Data was subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1980). Significant means was separated by Duncan's New Multiple Range Test (DNMRT). Significance was accepted at 5 % level of significance (p = 0.05%).

4.1 RESULTS AND DISCUSSION

4.1.1 *Proximate Composition of Flours*

The proximate composition of orange peel, orange pulp and wheat flours were shown in Table 1. The moisture content of orange pulp flour (13.85%) was higher (p = 0.05%) than those of orange peel flour (7.91%) and wheat flour (12.32%). The pulp which is referred to as endocarp consists of series of segments, which contain thin walled juice vesicles, which are fibrous (Ihekoronye and Ngoddy, 1985). This fibrous structure probably caused the pulp to retain more moisture than the peel on drying. The fat contents of the orange peel flour and orange pulp flour were 2.08% and 0.58%, respectively. Wheat flour had higher fat content (2.17%) than the orange based products. The low level of fat in the orange pulp and peel flours is expected as fruits and vegetables are not good sources of fats and oils. Orange peels contain essential oils and this may have contributed to its higher fat content over the pulp. The 2.08% fat obtained for the orange peel flour in this study was higher than 1.5% (Ali and Hassan, 2010), but lower than 4.09% (Bacha *et al*., 2011) and 9.52% (Magda *et al*., 2008) reported previously for the peel of navel orange. These variations may be attributed to varietal differences, origin and degree of ripeness of the fruits (Ali and Hassan, 2010). The low fat contents of orange peel and orange pulp flours as well as the wheat flour is believed to enhance their storage stability as they are less likely to develop rancid flavour.

Table 1: Proximate composition of wheat, orange peel and orange pulp flours.

Flour			**Composition (%)**			
	Moisture	**Fat**	**Protein**	**Fibre**	**Ash**	**Carbohydrate**
Wheat	$12.32^{b}\pm0.03$	$2.17^{a}\pm0.02$	$13.88^{a}\pm0.03$	$2.21^{c}\pm0.02$	$1.24^{c}\pm0.02$	$68.18^{a}\pm0.07$
Orange peel	$7.91^{c}\pm0.04$	$2.08^{b}\pm0.02$	$8.25^{b}\pm0.01$	$18.24^{b}\pm0.02$	$3.77^{b}\pm0.03$	$59.76^{b}\pm0.06$
Orange pulp	$13.85^{a}\pm0.10$	$0.58^{c}\pm0.04$	$7.96^{c}\pm0.03$	$22.03^{a}\pm0.05$	$4.31^{a}\pm0.01$	$51.27^{c}\pm0.15$

Values are means ± SD of 3 replications. Values within the same column with different superscripts were significantly different (p = 0.05%).

Wheat flour had the highest protein content of 13.88% when compared to those of orange peel flour (8.25%) and orange pulp flour (7.96%). Orange peel and pulp are not known to be good sources of protein. Magda *et al*., (2008) reported a lower protein value of 2.67% for Navel orange pulp flour. This difference may be due to difference in the variety used and geographical location (Ali and Hassan, 2010).Orange peel flour (18.24%) and pulp flour (22.03%) had high crude fibre contents when compared to other fruits such as mango (2.40%) (Fowomola, 2010). The crude fibre content of the pulp was higher than that of the peel. Fibre is the indigestible portion of plant foods. The main action of fibre is to change how other nutrients and chemicals are absorbed in the body (Anderson *et al*., 2009). Fibres bind to bile acids in the small intestine, making them less likely to enter the body and this lowers cholesterol levels in the blood (Anderson *et al*., 2009). Soluble fibre also attenuates the absorption of sugar, reduces sugar response after eating, normalizes blood lipid levels and once fermented in the colon, produces short-chain fatty acids as by products (Weickert and Pfeiffer, 2008).The short chain fatty acids produced are involved in numerous physiological processes such as stabilizing blood glucose levels by acting on pancreatic insulin release and liver control of glycogen breakdown among others (Wong *et al*., 2006).The ash contents of the samples ranged from 1.24% in wheat flour to 4.31% in orange pulp flour. The ash content of the orange peel flour was 3.77%. Ash is a measure of mineral content of a food (Elson, 1992). Orange peel and pulp flours may be considered rich in mineral constituents based on the levels of ash in them. Magda *et al*., (2008) reported a slightly higher level of 4.24% ash for Navel orange powder. Similarly, a higher ash value of 5.02% for orange pulp was reported by Ibrahim *et al*., (2011). Wheat flour was significantly lower ($p = 0.05\%$) in ash content, indicating that orange peel and pulp flours are richer in mineral constituents.

Carbohydrate content of wheat flour was 68.18%, a value which was significantly higher ($p = 0.05\%$) than the 59.76% for orange peel flour and 51.27% for orange pulp flour. Value of 70.19 % for carbohydrate content was previously reported by Magda *et al*., (2008) for Navel orange peel powder. The pulpy part of the orange fruit is a good source of neutral detergent fibre, lignin, fibre e.t.c. (Ibrahim *et al*., 2011).

4.1.2 *Mineral composition of flours*

The mineral composition of orange peel, orange pulp and wheat flours were shown in Table 2. There was no significant difference ($p = 0.05\%$) among the flour samples in their calcium contents. However, wheat flour had the lowest calcium content of 43.67mg/100g when compared with 44.67mg/100g for each of the orange peel and pulp flours. The calcium contents of the orange peel and pulp flours were higher than 23.8mg/100g reported for pomegranate (Dangoggo *et al*.,2012) but lower than 111.3mg/100g for mango seed flour (Fowomola, 2010). Calcium is required for normal development and maintenance of bones and teeth, clotting of blood and normal heart action (Ihekoronye and Ngoddy 1985). Calcium is also essential for conducting nerve impulses and stimulating hormone secretions (Fowomola, 2010).

Table 2: Mineral composition of wheat, orange peel and orange pulp flours.

Flour			**Composition (Mg/100g)**			
	Calcium	**Copper**	**Iron**	**Zinc**	**Sodium**	**Potassium**
Wheat	$43.67^{a}\pm1.53$	$0.70^{a}\pm0.02$	$3.33^{a}\pm0.58$	$4.67^{a}\pm0.58$	$95.67^{b}\pm0.58$	$206.67^{a}\pm6.11$
Orange peel	$44.67^{a}\pm2.08$	$0.18^{b}\pm0.02$	$1.53^{b}\pm0.03$	$1.07^{b}\pm0.02$	$126.67^{a}\pm1.15$	$122.33^{c}\pm4.93$
Orange pulp	$44.67^{a}\pm1.58$	$0.19^{b}\pm0.02$	$1.54^{b}\pm0.02$	$1.10^{b}\pm0.02$	$123.33^{a}\pm4.16$	$135.67^{b}\pm3.51$

Values are means ± SD of 3 replications. Values within the same column with different superscripts were significantly different (p = 0.05%).

Wheat flour had higher contents of copper, iron, zinc and potassium than orange peel and pulp flours. Orange pulp contained higher amounts of copper, iron, zinc and potassium than the orange peel flour. The levels of sodium in the orange peel and pulp flour were high (123.33-126.67mg/100g) when compared to other flours such as cooked beniseed flour (1.24 mg/100g) (Adegunwa *et al.*, 2012) and sorghum (20mg/100g) (Enwere, 1998). A healthy adult should eat less than 2400 mg of sodium per day to reduce the risk of elevated blood pressure (Dangogo *et al.*, 2012). The higher an individual's salt intake, the higher his blood pressure (Dangogo *et al.*, 2012). Keeping blood pressure in the normal range reduces an individual's risk of coronary heart diseases, congested heart failure, stroke and kidney diseases (NRC, 1989). High amount of potassium in the body was reported to increase iron utilization (Adeyeye, 2002) and beneficial to people taking diuretics to control hypertension (Arinathan *et al*., 2003).

4.1.3 *Phytochemical content of flours*

The phytochemical compositions of flours are shown in Table 3. Wheat flour had the highest saponin content of 0.32% while orange pulp had the least saponins content (0.03%). Saponins content of the pulp was much lower than 1.06mg/100 g for Spanish plum and 0.20 mg/100g for black velvet reported by Oladejo, (2009). Saponins are phytochemicals that have been shown to exhibit a wide spectrum of activity as antifungal and antibacterial agents (Sezgin and Artic, 2010). They lower blood cholesterol and inhibit cancer growth (Sezgin and Artic, 2010). Orange peel flour had alkaloid content of 0.63%, which was higher than 0.01mg/100g reported by Fowomola (2010) for mango seed. The alkaloid content of the orange peel flour slightly agreed with the range of 0.82-1.81mg/100g reported for some fresh Nigerian leafy vegetables like utazi, uturukpa, ugu, okazi (Onyeka and Nwambekwe, 2007). Alkaloids are very important in medicine and constitute most of the valuable drugs (Edeoga and Eriata, 2001). Alkaloids are used to treat a range of diseases conditions including malaria and cancer (Shamsa *et al*., 2008).

Flavonoid contents of the orange peel and pulp flours were 1.81% and 1.50% respectively. These values were lower than the range of values (8.0-18.23 g/100g) reported for *Anchomanes difformis,Anisopus manni, Pavetta crassipes and Stachytarpheta angustifolia* plants (Aliyu *et al*., 2008). Onyeka and Nwambekwe (2007) reported low levels of flavonoid in some Nigerian leafy vegetables. Okwu *et al*., (2007) also reported 0.30-0.89 % for crude peel extract of some citrus species. Flavonoids represent the most common and widely distributed group of plant phenolics and are among the most potent antioxidants (Okwu *et al.*, 2007). Flavonoids were detected in citrus fruits at the range of 0.025 to 0.045% (Oluremi *et al*., 2007).

Table 3: Phytochemical composition of wheat, orange peel and orange pulp flours

Flour			Composition (%)		
	Saponins	**Alkaloids**	**Flavonoids**	**Anthocyanins**	**Carotenoids**
Wheat	$0.32^{a}\pm0.04$	$0.04^{c}\pm0.00$	$0.89^{c}\pm0.02$	$1.03^{c}\pm0.03$	$0.90^{c}\pm0.02$
Orange peel	$0.05^{b}\pm0.00$	$0.63^{a}\pm0.03$	$1.81^{a}\pm0.03$	$1.82^{a}\pm0.03$	$1.67^{a}\pm0.04$
Orange pulp	$0.03^{b}\pm0.00$	$0.54^{b}\pm0.02$	$1.50^{b}\pm0.02$	$1.33^{b}\pm0.04$	$1.16^{b}\pm0.05$

Values are means ± SD of 3 replications. Means within the same column with different superscripts were significantly different (P = 0.05%).

Orange peel and pulp flours contained 1.82% and 1.33% anthocyanins, respectively. Anthocyanins are associated with non-green coloured fruits and vegetables (Dewanto *et al.*, 2002). This probably explains their low contents in the peel and pulp. Anthocyanin is a subgroup of flavonoids which are responsible for red, blue and violet colours of a wide variety of fruits such as plums, grapes, black currants etc. (Ihekoronye and Ngoddy, 1985). Carotenoid content of orange peel was 1.67% while that of the pulp was 1.16%. This is expected because of the colour of the peel of the orange fruit. Carotenoids are a large family of yellow, orange and red pigments. They are found along with chlorophyll, in green leaves and are also present in carrots, peaches, apricots, peppers, tomatoes and bananas (Ihekoronye and Ngoddy, 1985).

5. CONCLUSION

This study shows that flours can be produced from orange peel and pulp. These flours can be used in various food systems, such as complementing wheat flour for the production of various snacks. They are rich in bioactive substances, which have the potentials to equip the body and prevent preventable diseases.

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PHYSIO-CHEMICAL AND ORGANOLEPTIC PROPERTIES OF GARRI FROM CASSAVA ROOTS STORED IN MOIST MEDIUM FOR FOUR MONTHS

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ABSTRACT

Twelve months-old cassava roots of TMS 30572, TMS 91934, TMS 419 and TMS 0505 were harvested and stored in moist saw dust for 15 weeks. Ten kilogramme roots of each of the cultivars were harvested, processed manually, without storage into garri, packaged and stored, to serve as control samples. At 3 weeks interval, 15 kg of each cultivar was taken from storage, processed into garri, packaged and stored. This process continued till the end of 15 weeks. The temperature and relative humidity of the saw dust were taken twice daily. At the end of the 15 weeks, the packaged garri samples were analyzed biochemically and physically, using a panel of ten garri consumers who assessed the garri samples. The results showed that there was lower stable temperature and higher relative humidity in the moist saw dust for good storage , when compared with the ambient temperature of the range 27 ± 2.2 ^{o} C up to 12 weeks storage. There was no significant difference in the physical properties of the some of the cultivar garri samples, when compared with the sample of the unstored roots. The biochemical properties of the garri samples of stored and unstored roots did not differ significantly, up to the 15th week of storage. For all the garri samples, the hydrogen cyanide (HCN) content was below the maximum recommended human lethal dose.

Keywords: garri, physio-chemical properties, organoleptic properties, cassava root storage, moist medium

1.0 INTRODUCTION

Garri is a hydrated, granular grit, with creamy white colour or yellow, if palm oil is added. In general, the determinants of a good quality garri are good starch content (drawability) ranging from 81.8 – 90.8 % (g/200g), low ash content, 0.80 – 1.40 (g/100g) (Mani, 1978 and Etejere and Bhat, 1985, Beyene, 2012); low hydrogen cyanide (less than 25 ppm); good flavor, taste, texture, attractive colour and free-flowing, uniform size grains (Anon, 1983). The garri must also swell 1 – 1.53 times its volume, when soaked in water. (Halliday *et al*, 1967). On the other hand, an edible garri should not contain more than 50 mg/kg hydrogen cyanide HCN, which is the safe HCN level for human consumption (FAO, 1972; FAO, 2006).

Currently, garri is one of the most important staple foods in the diet of Nigerian and other West African countries (National Root Crops Research Institute, 2010). It is the most popular product of roots, being consumed by approximately 200 million people in the tropics (Philips, 1978), either by soaking it in cold water with sugar or salt and taken with coconut, peanut, fish, beans porridge or soaked in hot water to form a paste eaten with any kind of soup. It can also be mixed with cooked beans and palm oil and eaten, as in Togo (Igbeka *et al*, 1992).

At present, the scale of garri production in West Africa ranges from a family level average output of less than 5 tons per annum to the large commercial enterprise having over 3000 tons per annum (Ezeilo *et al*, 1975; Ajayi and Olukunle, 2010). According to Ene (1986), the estimated annual output of garri in Nigeria ranges from 3.5 – 5.0 million metric tonnes.

Garri is processed from harvested cassava roots, which must be stored immediately after harvested or poor quality garri will be obtained if the roots are left at ambient condition of 27^{o}C and above for 2 or 3 days (National Root Crops Research Institute, 2010). With the exception of the use of moist saw dust, all other methods such as pit storage, polyethene bag storage and delayed harvesting employed in the storage of cassava roots yielded low dividend.

Adequate scientific knowledge and basic technologies on the storage of cassava roots in moist saw dust have been reported (Igram and Humperies, 1972; Booth, 1977; Marriot *et al*, 1974; Sivan, 1979; Richard and Coursey, 1981; Wickham and Wilson, 1988; Maini, 1978; Balagopal and Padmaja, 1985; and Booth *et al*, 1976). Some of these workers limited their storage evaluations to cassava roots' physical appearance and cooking qualities (Wickham and Wilson, 1988) while others dwelt on biochemical, biophysical and organoleptic tests of the stored roots (Booth *et al*, 1976; Maini, 1978)

Information is scarce on the sensory values (organoleptic properties) and chemical characteristics of garri sample produced from long period stored cassava roots. This is the objective of this work. With this information, the rural farmers, garri processors and consumers can be advised on the optimum and the longest periods that cassava roots should be stored in moist media to get good quality garri.

2.0 MATERIALS AND METHOD

2.1 Cassava Root Storage and Sample Garri Preparation

Twelve months-old improved cassava roots of Tms 30572, Tms 419, Tms 0505 and Tms91934 were carefully harvested without damage from the National Root Crops Research Institute, Umudike, Nigerian germplasm plots, with 15cm stem attached. The healthy roots were stored with moist saw dust (80% (wb) moisture content) in rectangular wooden boxes measuring 100cm x 60cm x40cm. The boxes were covered with lids and kept in a ventilated room. The saw dust was moistened every two weeks with clean water.

To obtain the reference garri samples, 10kg of the freshly harvested cassava roots of the four varieties were manually peeled, washed, grated, de-watered and fermented for 2 days, sieved and fried manually at the temperature of 84 ± 1°C (Okafor and Onyekwere, 1992) until thoroughly dried. On cooling, the garri samples were packed in thick polythene bags. They were mechanically sealed and inserted in the hessian sacks and stored to preserve the moisture content and other qualities of garri (NSPRI, 1983 Halliday *et al*, 1967). Every three weeks, starting from zero day of storage till the 15th week of storage, 15kg of cassava roots were taken from each variety of the stored roots and processed into garri, as done with the control or reference sample (R), and stored,

2.2 Biochemical Tests

Chemically, the garri samples, starting from reference samples, were evaluated. The moisture content was evaluated according to ASAE (1982). Hydrogen cyanide (HCN) was evaluated with the method of Ikediobi *et al* (1980), total titratable acidity (TTA), total ash and swelling capacity, by the methods of AOAC (1975). Each parameter was evaluated with 3 replications and the mean found.

2.3 Organoleptic Evaluation

Evaluation of colour, taste, texture, drawability, flavour and acceptability of all garri samples from stored roots were made with multiple comparisons test (Ihekoronye and Ngoddy, 1985) and compared with garri sample of unstored cassava roots. The garri samples were constituted into doughs for drawability assessment. Each garri sample was assessed separately.

Numerical scores of no difference of R = 5, extremely better than R = 9, extremely worse than R = 1, were used (Ihekoronye, and Ngoddy, 1985). The results were then analyzed statistically.

3.0 RESULTS AND DISCUSSION

3.1 Temperature and Relative Humidity Regime

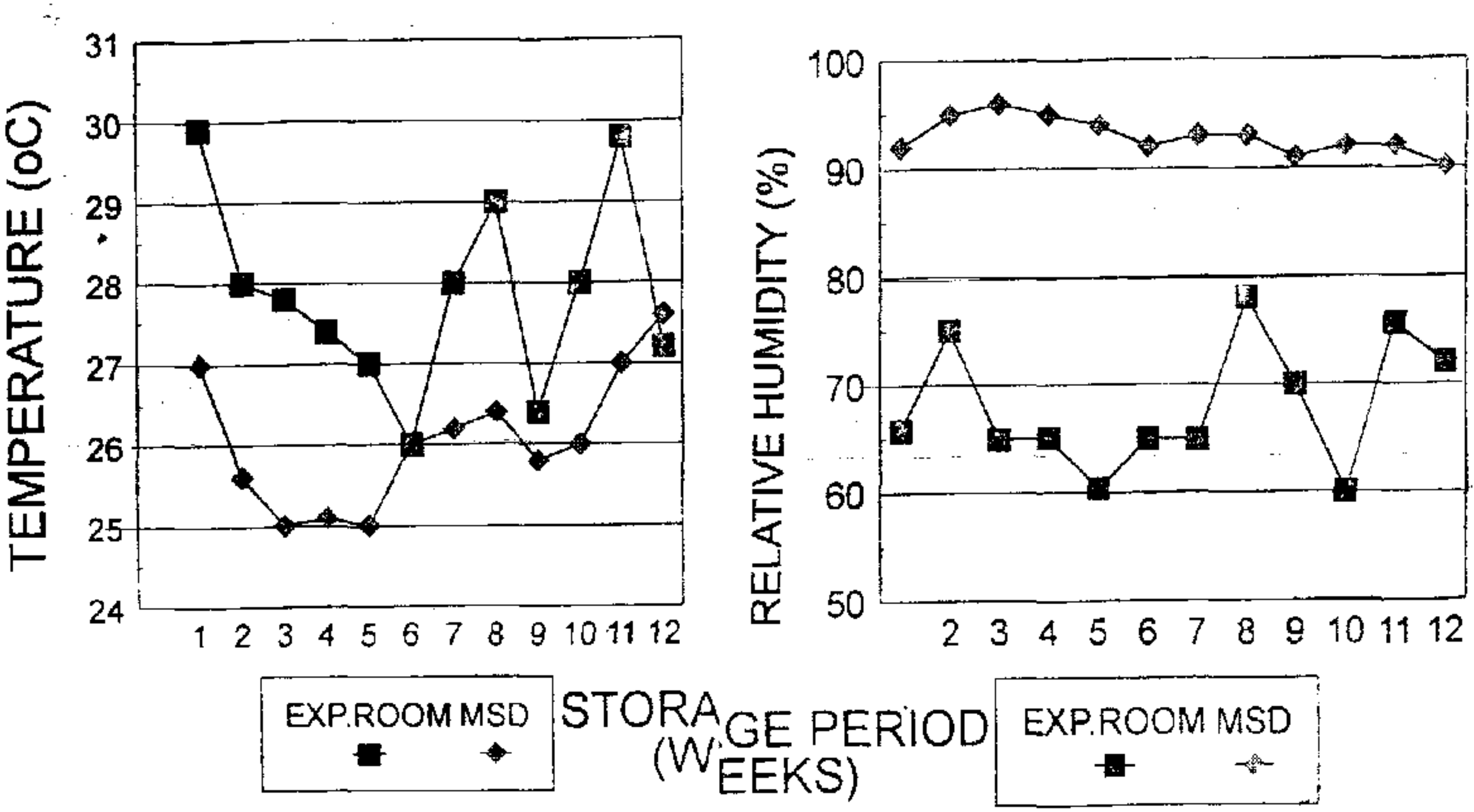
The results of the temperature and relative humidity (Fig. 1a & b) taken throughout this work showed that the moist saw dust served as good temperature stabilization medium for storage of cassava roots for four months.

Table 1: Effect of Storage Period on the Hydrogen Cyanide Content (mg / kg) of Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	30.9a*	33.8a	26.75a	23.63a
3	30.7a	33.7a	26.78a	23.60a
6	30.8a	33.5a	26.50a	23.40a
9	31.1a	33.8a	26.50a	23.10a
12	31.0a	34.0a	26.10a	23.00a
15	31.3a	34.1a	25.81a	22.80a

*Means in the same column with the same letter are not significant at (p = 0.05), Using Duncan's New Multiple Range test.

While the experimental room temperature continued to fluctuate with a mean temperature of 27 ± 2.2°C, the moist saw dust temperature remained at 26 ± 1^0C. This stable temperature helped to maintain the cassava roots in a good condition without shrinkage (Fig. 1b).



(a) (b)

Figure 1: Temperature and Relative Humidity Regimes in Moist Medium and Experimental Room

3.2 Biochemical Evaluation Results

As seen in Table 1, storage of cassava roots in moist sawdust did not increase the Hydrogen Cyanide content of garri obtained in all the cultivars. Table 1 also shows that the level of HCN content in garri samples varied from one cultivar to another. Since the maximum recommended HCN lethal dosage for human consumption of 50mg/kg was not reached by any of the samples during the storage period, it is concluded that all the sample are consumable.

The swelling ability of all the garri samples (Table 2) for the whole period of storage was adequate, since they were within the standard swelling capacity of 1.5 - 3 times the initial volume (Ene, 1986). Garri from Tms 30572 swelled more than that from the other cultivars.

The moisture contents of the garri sample, for the whole storage period were adequate since they were within the range of 8 ± 12%, recommended moisture content for garri samples meant for long storage (Ene, 1986). The little variation observed in some samples may be attributed to the frying situations. At these moisture contents these samples can store for more than one year.

There was little variation in the titratable acidity and fibre content of the garri samples over the storage period. These variations were however not significant and hence it can safely be concluded that storage in moist saw dust did not affect the titratable acidity and fibre content of the garri samples obtained.

Table 2: Effect of Storage Period on the Swelling Ability of the Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	2.00a*	1.90a	2.10a	2.00a
3	2.10a	2.10a	1.90a	2.40a
6	2.40a	1.85a	1.90a	1.90a
9	2.30a	1.85a	2.10a	1.90a
12	2.00a	1.90a	2.00a	1.90a
15	2.30a	1.85a	1.90a	1.90a

*Means in the same column with the same letter are not significant at ($p = 0.05$), Using Duncan's New Multiple Range test.

3.3 Organoleptic Evaluation Result

There were significant variations among the cultivars in the eating qualities of the garri samples as shown in Tables 3-7. The colours of the garri samples remained acceptable up to the 12thweek of root storage (Table 3). Samples of Tms 30572 and Tms 91934 had better colour appearance than the control garri samples, (5.36 and 5.18) in the 6^{m} week of storage. However, at the 12th and 15th weeks of root storage, the colour of the garri samples of Tms 0505 and Tms 419 differed significantly ($p = 0.05$) from the control sample. These colour changes can be attributed to the initiation of physiological changes in cassava roots. Thus the storage, of cassava roots in moist media does not affect garri colour up to the 12th week.

Table 3: Effect of Cassava Root Storage Period on the Colour of Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	5.09a*	5.27a	5.18a	5.00a
3	5.18a	4.45a	5.09a	4.27a
6	5.36a	5.09a	4.82a	5.18a
9	4.64a	5.00a	5.00a	4.55a
12	4.91	3.64b	2.91b	3.81a
15	1.91b	3.55b	1.27c	2.18b

*Means in the same column with the same letter are not significant at ($p = 0.05$), Using Duncan's New Multiple Range test.

Again, for the cultivars Tms 30572, Tms 0505 and Tms 91934, the results showed that the taste were as acceptable as the reference sample (Table 4). It was only the garri sample of Tms 419 that had the taste significantly different at ($p = 0.05$) from the controlled samples in weeks 12 and 15.

Table 4: Effect of Cassava Root Storage Period on the Taste of Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	4.73a*	5.27a	5.73a	4.64a
3	4.27a	4.55a	5.64a	4.45a
6	4.27a	5.00a	4.64ab	4.55a
9	4.00a	4.36a	5.27ab	4.45a
12	3.73a	4.55a	3.55bc	3.82ab
15	3.55b	3.64b	2.18c	2.73c

*Means in the same column with the same letter are not significant at ($p = 0.05$), Using Duncan's New Multiple Range test.

The flavour of the garri samples (Table 5) did not differ significantly ($p=0.05$) with the control sample, up to the 12th week of storage. Differences in flavour appeared in week 15 in the garri samples of Tms 30572, Tms 419 and Tms 91934.

Table 5: Effect of Storage Period of Cassava Roots on the Flavour of Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	5.27a*	4.82a	5.27a	5.00a
3	4.55a	4.18a	6.00a	4.73ab
6	5.18a	5.09a	5.64ab	4.73ab
9	4.36a	4.00a	5.27a	4.00ab

12	5.00a	4.55a	4.18b	2.73b
15	3.18b	3.91a	2.45c	2.55a

*Means in the same column with the same letter are not significant at (p = 0.05), Using Duncan's New Multiple Range test.

Table 6 shows the drawability (starch content) of the garri samples. The results are in agreement with the results of Booth *et al* (1976), in the assessment of cassava roots stored for 80 weeks in moist saw dust.

Table 6: Effect of Storage Period of Cassava Roots on the Drawability of Garri Samples

Storage Period	Cassava Cultivar			
(Weeks)	TMS 30572	TMS 0505	TMS 419	TMS 91934
0	5.27a*	5.09a	4.91a	5.00a
3	4.73a	4.18a	4.36a	4.64a
6	4.27a	4.73a	4.18a	5.00a
9	4.18a	4.45a	4.00a	4.82a
12	5.00a	5.36a	3.27a	5.40a
15	4.00a	6.18a	3.27a	5.36a

*Means in the same column with the same letter are not significant at (p = 0.05), Using Duncan's New Multiple Range test.

Up to the 9th week of root storage, the overall acceptability showed that the samples were acceptable to the garri consumers (Table 7), The garri samples in the 12th and 15thweeks were not accepted to the consumers due to the changes in biochemical and physical qualities.

Table 7: Effect of Storage Period on the Overall Acceptability of Garri Samples

Storage Period	**Cassava Cultivar**			
(Weeks)	**TMS 30572**	**TMS 0505**	**TMS 419**	**TMS 91934**
0	5.27a*	5.00a	5.18a	5.00a
3	4.09a	4.00a	4.55a	4.64a
6	5.00a	4.00ab	4.55a	5.00a
9	4.73ab	3.45b	4.82a	4.36ab
12	3.73b	3.45b	3.36ab	2.45b
15	1.82c	3.45b	2.09b	2.36b

*Means in the same column with the same letter are not significant at (p = 0.05), Using Duncan's New Multiple Range test.

4.0 CONCLUSION

Cassava roots stored for twelve weeks can give garri samples of acceptable physical, organoleptic and biochemical qualities. The hydrogen cyanide content of such garri samples also falls within the consumable dosage. The overall results gave good insight into the qualities of garri from stored cassava roots obtained from the storage structure with the prevailing conditions of this work.

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MOISTURE LOSS FROM SWEET POTATOES IN DIFFERENT STORAGE ENVIRONMENT

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ABSTRACT
This paper reports on the rate and mode of moisture loss from sweet potatoes under different storage environment. The sweet potatoes samples were stored under different conditions of relative humidity (11.1% - 98%) at 26 ± 1°C using saturated chloride salt solutions. The storage lasted for thirteen weeks. The results showed that in storage the sweet potatoes lost more moisture at lower relative humidities than at higher relative humidities. Again, this investigation showed that sweet potatoes has a longer shelf life at the equilibrium moisture content range of 61 -65% wet basis and the relative humidity of 90 - 95%, at 26±1°C. A relevant equation was derived for predicting the cumulative moisture loss from sweet potatoes during storage.
Keywords: Sweet potato, Storage, Moisture loss, Equilibrium moisture content

1.0 INTRODUCTION
Sweet potatoes are domestically roasted, boiled and eaten with oil, or baked or made into porridge or puree. Industrially, it is used to produce starch, alcohol, syrup, glucoseand flour (Onwueme and Sinha, 1991). The tubers and leaves are also used to produce livestock feed. Several attempts made in the storage of sweet potatoes at lower temperature (Mathew and Penny, 1988), in underground pit (Nnodu, 1984), at ambient conditions and rubbing of wood ash, has been reported in literature. Cooley *et al*, (1954) recorded 76% losses after 4 months, storage. The above methods do not ensure the keeping of sweet potatoes in its edible and valuable conditions and as well maintain itsregular supply to agro – processingindustries and domestic consumers, at all seasons. Sweet potatostorage losses result from the natural factor which involves the loss of valuable components due to respiration, and pathological factor which results fromphysiological breakdown, as well asfungi, diseases and bacteria. Sweet potato weight losses due to respiration is smaller than the weight losses caused by evaporation of moisture from the surface (Mathew and Penny, 1988). This moisture loss can lead to 70% loss of the tubers at ambient conditions.

Evaporation of moisture from root and tuber crops stops only at the equilibrium moisture content. Equilibrium moisture content of a crop is the quantity of water in the crop when it is in equilibrium with the surrounding atmosphere.This situation is reached only when the free energy change of the crop is zero. Thus, at equilibrium moisture content, the crop can be stored in a good condition for a long time (Ezike, 1979).

Saturated chloride salt solutions are commonly used to maintain equilibrium environments in research investigations, because they maintain practically the same relative humidity within a small range of temperature variation (Hall, 1980). The saturated solution exerts a certain vapourpressure depending upon their chemical, concentration and temperature.

The attainment of equilibrium moisture content by an agricultural produce depends on the mutual interaction between the moisture content of the product and the ambient relative humidity. An agricultural crop in an environment with relative humidity higher than its equilibrium relative humidity at its current moisture content will absorb more moisture from the environment until its moisture content is in equilibrium with the relative humidity of the environment, On the other hand, an agricultural material in an environment with a lower relative humidity than itself will lose moisture to the environment until anequilibrium is attained.

According to Burton (1963), the rate of moisture evaporation from the tuber surface after curing is in the form.

$$L = (0.2 + 0.1S)VPD \qquad (1)$$

Where

$L = Percentage\ weight\ loss\ per\ week$

$S = Percentage\ weight\ sprout$

$VPD = Water - vapour\ pressure\ deficit\ of\ the\ air\ sorrounding\ the\ tubers,\ mmHg.$

Water-vapour pressure deficit itself can be evaluated from the relationship (Schippers, 1971),

$$VPD = Ps\ (1.00 - RH) \qquad (2)$$

Where

$Ps = absolute\ saturation\ pressure\ at\ average\ dry\ bulb\ temperature, mmHg$

$RH = average\ relative\ humidity, decimal$

Again the percentage weight loss resulting from moisture loss from the tuber is related to the product of vapour pressure deficit of the air surrounding the tuber and the duration of storage (Schippers, 1971). Based on this information, Miseners and Shove (1976) derived an expression for the cumulative moisture loss from the tuberas

$$WT = C_1(VPD)^{C_2}(t)^{C_3}\ (Kg\ Vapour\ t/kg\ tuber) \qquad (3)$$

Where

$WT = Cumulative\ weight\ loss\ per\ unit\ of\ tuber$

$t = time\ (hr)$

$C_1,\ C_2\ and\ C_3 = regression\ coefficients$

Integrating equation (3), the rateof moisture loss from the tuber becomes,

$$\frac{dWT}{dt} = \frac{C_1^1 (VPD)^{C_2^1}}{(t)^{C_3^1}} \qquad (4)$$

The knowledge of the rate of moisture loss and the equilibrium moisture content of fresh and dehydrated sweet potatoes at various environments is very important in the designing of a suitable commercial storage system, as well as in proper handling of the crop at various stages. Since there is paucity of information on this from availableliterature, the objectives of this investigationis to fill this gap.

2.0 MATERIALS AND METHOD

Saturated aqueous solution of chloride salts were used to provide controlled environment of known relative humidity for the storage of sweet potatoes. Glass jars with secured covers were used as humidity salt solution chambers for containing saturated salt solution (Misener and Shove, 1976).

The chloride salts used in the work are shown in table 1 below,

Table 1: Salts and the relative humidities of their saturated solution.

SALT	RELATIVE HUMIDITY
$LiC.H_2O$	11.1
$MgCl.H_2O$	33.0
$SrCl_2.6H_2O$	70.8
NaCl	75.3
KBr	80.7
$BaCl_2.H_2O$	90.1
$K_2Cr_2O_7$	98.0

Sources: Hall, (1980), Wsaxlers and Hasegawa (1954).

In each of the glass jars, 150ml of saturated salt solution was introduced with an excess salt added. Each glass jar contained only one type of chloride solution. The saturated salt solution in the humidity chambers were left undisturbed for 24 hours, to come to equilibrium before the test samples were introduced.

The test samples (sweet potatoes) were weighed separately with a sensitive scale (± 1g) and then attached with a thread toglass jar cover. With this arrangement the samples were suspended above the saturated salt solution in the glass jar and covered tightly. Each jar contained only one sample, (Misener and Shove, 1976).

The glass jarsand their contents were placed in the desiccatorand sealed with silican greaseas reported by Adesuyi, 1973, Ezeike, 1979 and 1988, Kuku, 1980 and Oyeniran, 1979. Each treatment was replicated three times.

Daily readings were taken to determine the moisture loss from the sweet potato samples. The samples were usually covered before removing them from the desiccatorfor weighing to avoid moisture absorption or loss. The salt solutions were stirred daily to ensure concentration. Excess salts were added whennecessary. Samples showing sign of mould damage at high humidity (98%) were discarded.

The samples were weighed daily until a consistency of ± 1 mg was achieved. This experiment lasted for thirteen weeks. Temperature readingswere taken twice daily throughout the period of investigation. The equilibrium moisture content of the samples that reached constant weight were determined by drying at 103°C for 72 hours in air convectional oven (ASAE, 1982).

3.0 RESULTS AND DISCUSSION

At the 5th week, sweet potatoes stored in the environment of 33%, 70.8% and 75.3% relative humidities lost 0.36%, 0.17kg and 0.16kg moisture per kilogramme of tuberrespectively (Fig.l).

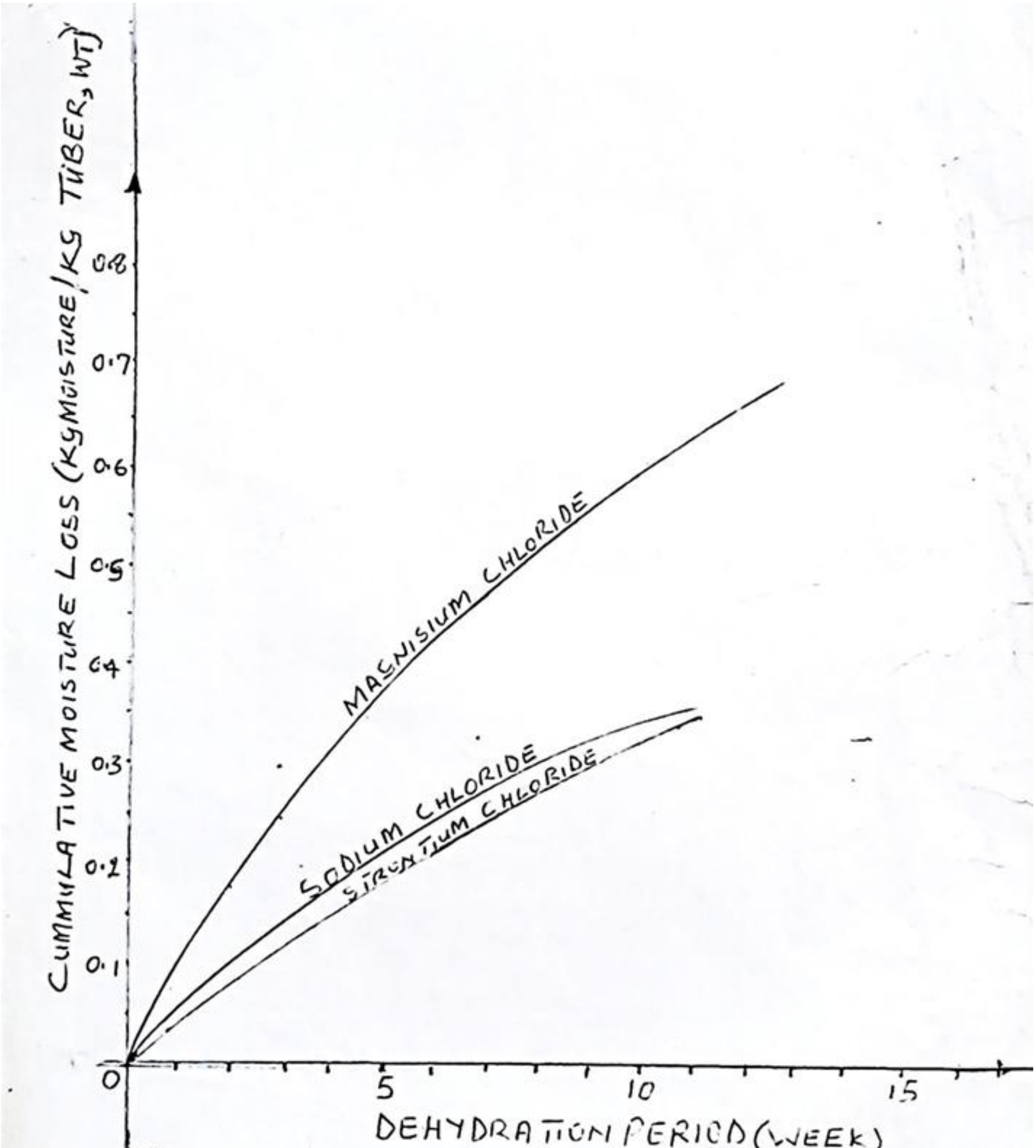

FIG 1. MOISTURE LOSS FROM SWEET POTATOES MAINTAINED AT 26°C AND 33%, 70.8% AND 75.3% RELATIVE HUMIDITY.

In week 10, the samples lost 0.59kg, 0.30kg and 0.28kg moisture per kilogramme tuber in the storage environment of 33%, 70.8% and 75.3% relative humidities, respectively (Fig.l). Thus, there is a higher rate of moisture evaporation from sweet potatoes between 33% and 75% relative humidities, and this accounts for the higher rate of shrinkage and black heart of the crop in the farmers' storage systems.

In the higher relative humidities of 90% and 98%, the stored sweet potato samples lost only 0.20kg and 0.16kg moisture per kilogramme tuber, respectively after 10 days of storage (Fig. 2). Thus, sweet potatoes lost little moisture at higherrelative humidities storage environment.

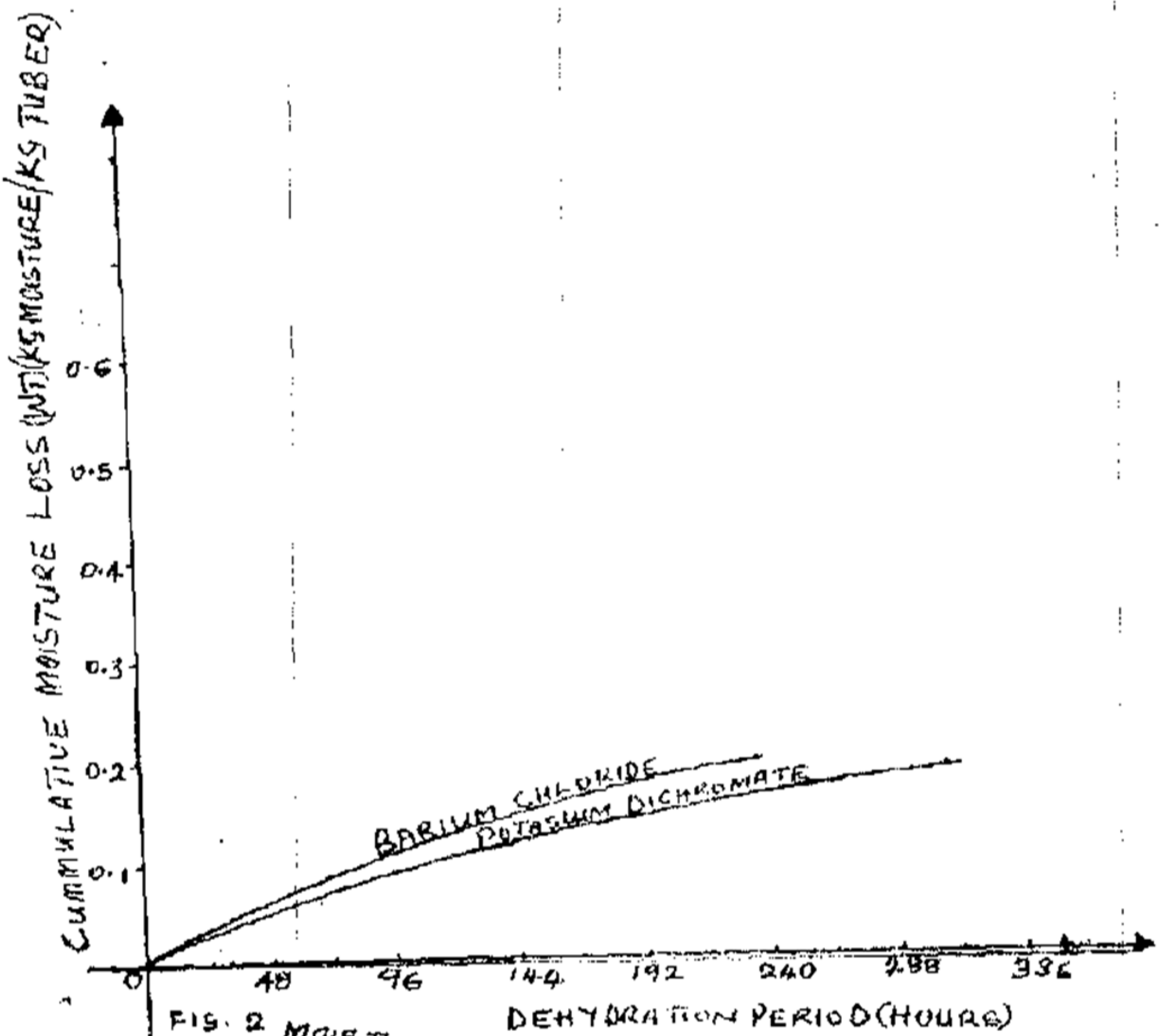

FIG. 2 MOISTURE LOSS FROM SWEET POTATOES MAINTAINED AT 26°C AND 90% & 98% RELATIVE HUMIDITY

The above results showed that therate of moisture loss from the stored sweet potatoes was a function of the vapourpressure deficit andstorage time. Thus, using the values of the vapour pressure deficit got from equation (3) further analysis was performed on the experimental data to determine the relationship between the cumulative weight loss of moisture from sweet potatoes (WT), the vapour pressure deficit (VPD) and the storage period (t). The following equation was obtained:

$$Wt = 0.00047\,(VPD)(t) \qquad (5)$$

The correlation coefficient (R^2) and thestandard deviation were 0.899 and 0.30 respectively. Misener and Shove (1976) got similar relationship in working with potatoes. Differentiating equation (5) the rate of moisture loss becomes

$$\frac{dWT}{dt} = \frac{0.00038^{0.808}}{(t)0.192} \quad (6)$$

Using equation (6) above, the mode and rate of moisture loss in stored sweet potatoes can be monitored between the air relative humidities of 90 and 95% 26± 1°C.

3.1 EQUILIBRIUM MOISTURE CURVES OF SWEET POTATOES

The equilibrium moisture curve, (Fig. 3) showed that the equilibrium moisture content of sweet potatoes increased as the air equilibrium relative humidity increased.

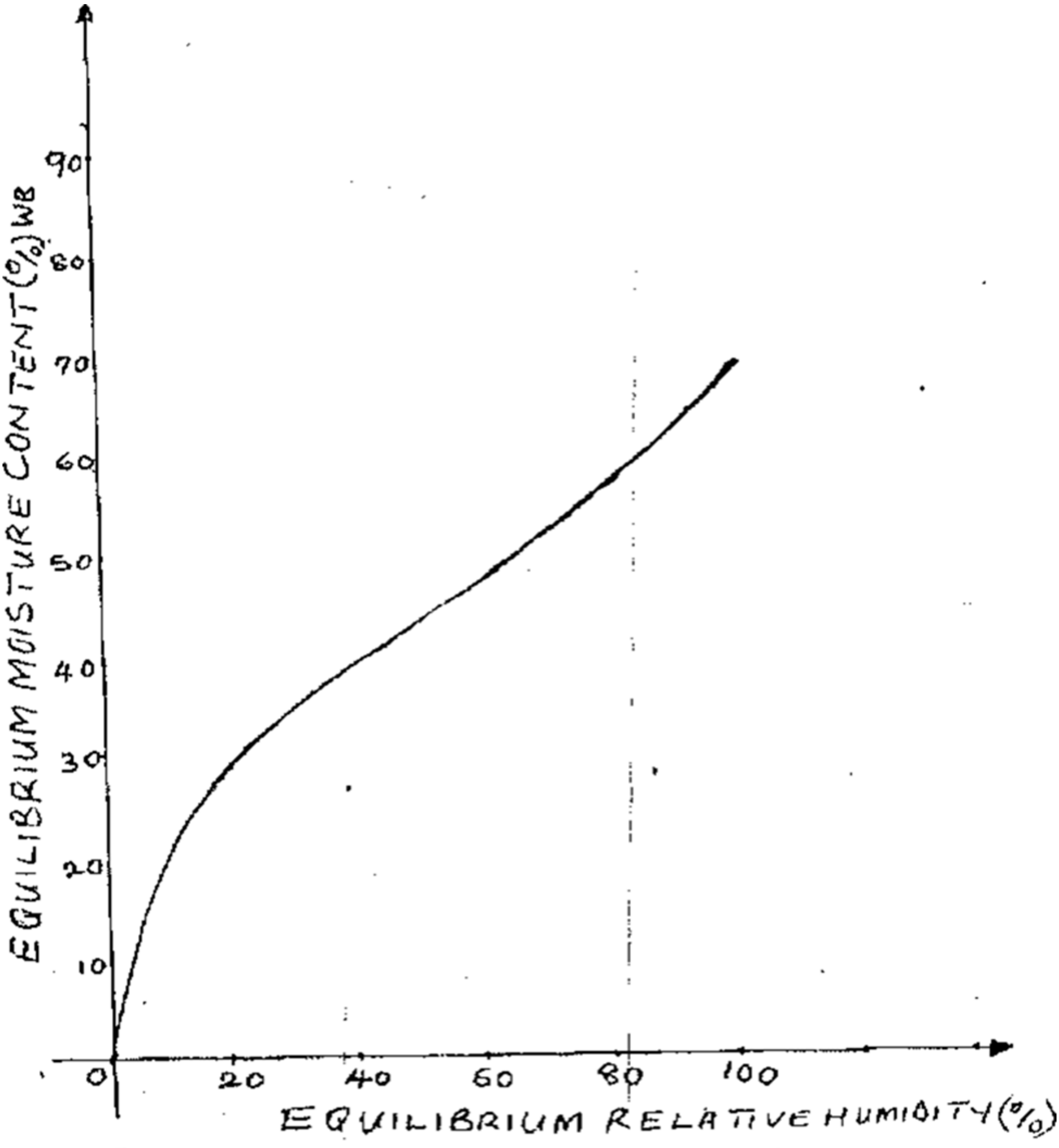

FIG.3 EQUILIBRIUM MOISTURE CURVE OF SWEET POTATOES

This work showed that the storage equilibrium moisture content of sweet potatoes from 90% to 95% relative humidities were 61% to 65% wet basis. Within these equilibrium moisture content range there was no moulding, decay or change of appearance.

4.0 CONCLUSION

The rate of moisture loss from sweet potato was experimentally determined. This work showed that the cumulative moisture loss of sweet potatoes depends on the prevailing vapour pressure difference and the storage time.

Again, the equilibrium moisture content of sweet potatoes has been found to be 61-65% at the air relative humidity range 90-95% and temperature of 26± l ^{o}C.These information will be very useful in designing a storage for the storage of sweet potatoes.

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A REVIEW OF THE PERFORMANCE OF DOUBLE GLAZED SOLAR AIR HEATER

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ABSTRACT

In this study, a review of the thermal performance of double glazed solar air heaters was done. The thermal efficiency of double glazed solar air heater is higher in comparison to single glazed with the concept of doubling the glazing component of the system. Numbers of studies have been carried out on the design of double glazed solar air heaters provided with heat transfer augmentation techniques viz. using extended surfaces, packed bed, v-grooved absorber were reported in the literature. Most of studies were based on the steady state analysis of the systems. In most of the designs, only the active systems were considered. However, there appears to be a lack of agreement among authors on which of these designs is the best. This is due to the fact that most of the studies were independent works with no correlation to previous studies in double glazing designs. Hence, there is then the need for a comparative study of different double glaze solar air heating systems to actually ascertain there performances and to recommend to end users.

Keywords: Double glazed; Air heater; Solar energy; Energy

Nomenclature:

D	depth of air channel (m)
h	heat transfer coefficient ($Wm^{-2}K^{-1}$)
R	recycle ratio
r	fraction of the mass flow rate
S	*absorbed* solar radiation ($W\ m^{-2}$)
T	temperature (k)
U	loss coefficient ($W\ m^{-2}\ k^{-1}$)
Subscript	
a	ambient
b	bottom plate
c	convection
f	fluid (air)
g	cover
w	*wind*
p	absorber plate
r	*radiation*

1. INTRODUCTION

In view of world's depleting fossil fuel reserves and environmental threats associated with it, developments of renewable energy sources have become imperative. Of many alternatives, solar energy conspicuously stands out as a sustainable source for meeting global energy demand. The easiest way to utilize solar energy for heating applications is to convert it into thermal energy by useof solar thermal collectors. Different solar thermal collectors are being used for various applications; these include flat-plate collectors (both active and passive collectors) which are widely applied in low-temperature operations (Wazed et al., 2010; Tyagi et al., 2012). Flat-plate collectors (FPC) are used mostly for heating of water and air respectively. Solar air heater is compact and less complicated in comparison to solar water heater. Solar air heater produces hot air for any agricultural (but mainly drying) applications by using freely available solar energy. The thermal efficiency of solar air heater is less due to excessive heat loss from the top of the collector. Single-glazed solar air heaters have shown appreciable improvement in the efficiency over unglazed solar air heaters (Ong, 1995). However, during off sunshine periods especially in the nights the efficiency of singled-glazed solar air heaters literally drops to zero (Enibe, 2002). To make solar air heater more efficient solar energy utilization system, thermal efficiency needs to be improved by increasing the number of glazing on top of collectors. It is reported in literature that the use of double glazing can increase the efficiency of solar air heaters up to 44% (Ojike, 2011). Further increase of the number of glazing beyond two does not show any significant improvement of the thermal efficiency, hence economically waste of resources, Duffie and Beckman (1991) concludes. Surprisingly, much attention has been paid to single-glazed solar air heater withlots of study and review work on it (Tchinda, 2012; Ekechukwu and Norton, 1999). This is due to the fact that solar air heaters are mainly used as daytime systems. As the need for energy conservation arises due to rising energy demand with increasing shortfalls in energy generation, there is then the need to critically review the performance of double-glazed solar air heaters with a view to substituting the present single-glazed solar air heaters with double-glazed systems. Hence the objective of the study was to carry out a literature review of the double-glazed solar air heaters so as to point out the pros and cons of each design.

2. CLASSIFICATION OF THE DOUBLE-GLAZED SOLAR AIR HEATERS

Double-glazed solar air heaterscan be classified in several ways depending mainly on the design. In all cases, solar radiation passes through the glazing and strikes the absorber plate where they are converted to thermal energy. The various designs and models are as discussed below.

2.1 Single flow Two-cover solar air heater

This collector is made of two covers,absorber plate, and insulation.A single channel air flows between the second cover and absorber plate (Fig. 2.1). As the air flows above the absorber plate, by mainly convection, heat energy is transferred to the air from the absorber plate.

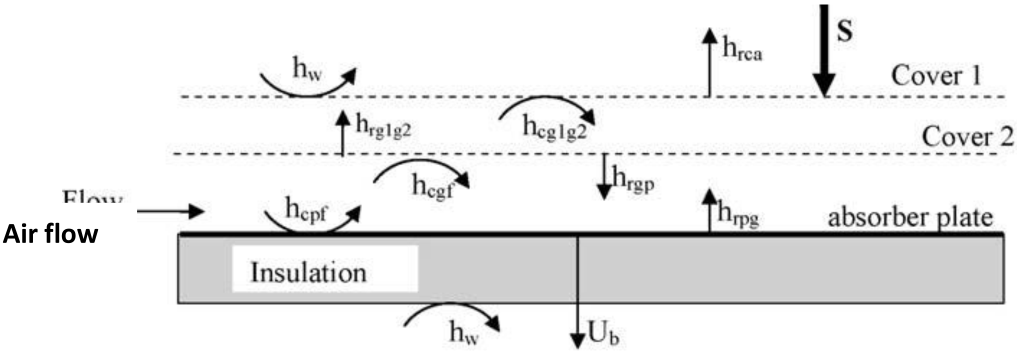

Fig. 2.1: A schematic view of a Single flow Two-cover solar air heater (Njomo and Daguenet, 2006).

Sarma et al. (2014) compared single, double and triple-glazed flat plate collector of this design. The result of the study showed that double-glazed FPC gave a maximum air temperature of 73.34 °C while tripled and single-glazed FPC gave maximum vales of 71.77 °C and 66.36 °C respectively. Equally, Badar et al. (2016) studied the performance of single-glazed and double-glazed solar system of this kind. In the study, it was observed that the absorbed solar radiation increased for the single glazed solar oven compared with the solar oven with double glazing. But because of the lower heat loss coefficient of the double glazed oven than the single glazed one, it resulted in higher air temperature of 81.7^{o}C while singled-glazed gave a maximum temperature of 73.3^{o}C.

Khawale et al. (2017) compared the performance of a single flow double and single glazed air heater where the air flow is between the absorber plate and insulation. From the study, collector efficiency values of 24.70% and 19.0% for double and single glazed air heaters respectively were observed. It shows that the double glazed solar air heater was more efficient than the single glazed system.

2.2 Parallel-pass solar air heater

The solar air heater configuration under consideration is shown in Fig. 2.2. It consists of two covers, double channel design with double air flows between covers and absorber plate and between absorber and bottom plates and with insulation provided.

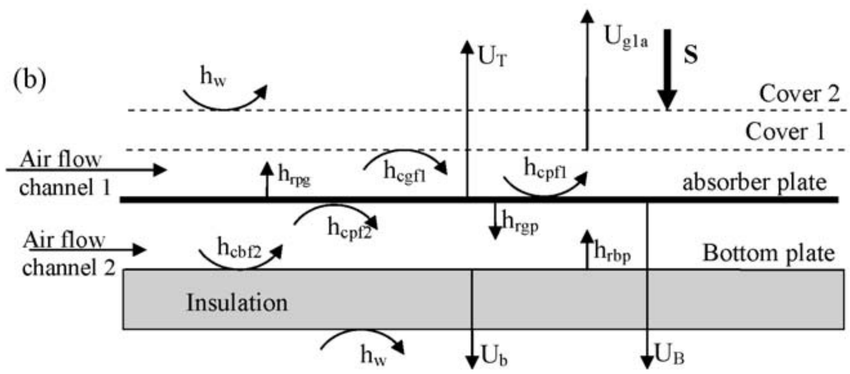

Fig. 2.2: Parallel-pass solar air heater (Ho-Ming, 1999).

As seen in Fig. 2.2, two air streams of different flow rates but with total flow rate fixed, are flowing steadily and simultaneously through two separate channels. Ho-Ming et al. (1999) investigated heat transfer in this design.

The authors in developing the model for the parallel-pass solar air heater considered both steady and unsteady state scenario. However there was no consideration for thermal storage system for off-sunshine periods, thereby limiting the heater to only sunshine periods.

2.3 Solar air heater with slats

Ho-Ming *et al.* (2002) have presented a mathematical model for double flow solar air heaters with fins attached. Fig. 2.3 shows the design of a solar air heater with fins attached in which the absorbing plate divides the air conduit into two parts, channel 1 and 2. The energy flow diagram of solar air heater with slats was also presented. As seen, two air-flows of different mass flow rate but with total rate fixed, flow steadily and simultaneously through two such separated channels of the same size for heating. From their study, it was shown that providing fins attached on the collector, will improve the collector efficiency and that the application of the concept of double flow in the design of a solar air heater with fins attached was technically and economically feasible.

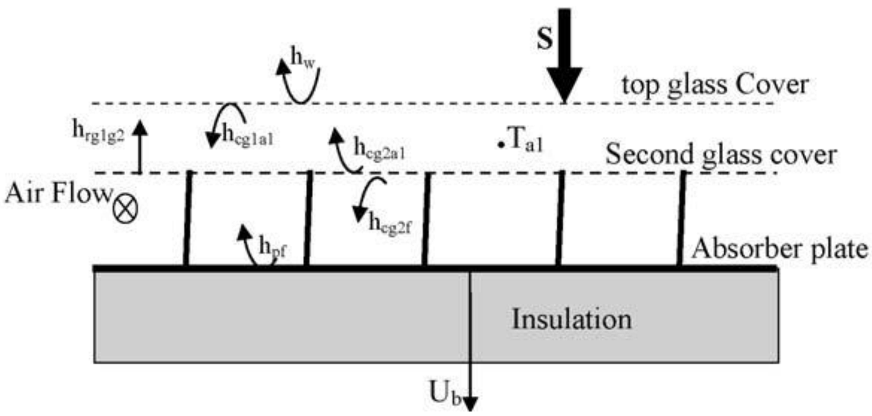

Fig. 2.3: Schematic view of a solar air heater with slats.

The authors in developing the model for the solar air heater with slats considered only steady state scenario and fixed total mass flow rate for air, thereby limiting the heater to only active systems which require fans and electric motors to function properly.

2.4 Two pass solar air heaters

Various authors have studied both analytically and experimentally the concept of two-pass solar air heater (Tchinda, 2009). They developed heat transfer models for two-pass flow arrangements. Fig. 2.4 shows a schematic view of the two-pass flow arrangement under consideration. In Fig. 2.4a, air flows first between the covers and then through the bottom channel. There is a stagnant air gap between the absorber plate and the cover 2. The developed mathematical model was used to study the thermal performance of the two-pass solar air heater design. The results showed that the performance of the two-pass design with air flow above and below the absorber plate in turn is better than the single pass system.

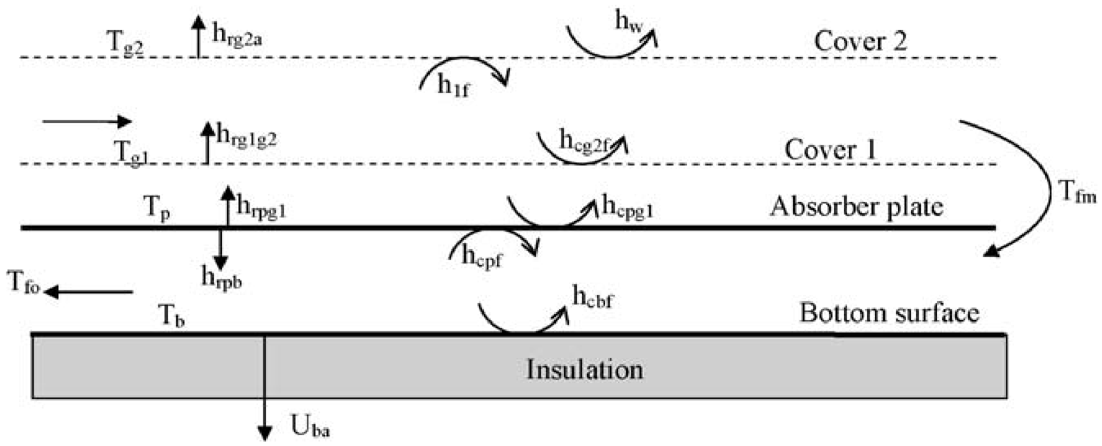

Fig. 2.4a: Schematic view of Two pass solar air heaters – *type a* (Tchinda, 2009).

Another design of this model was studied by Verma*et al.* (1992) and Choudhury et al. (1995[b], Fig. 2.4b). It consists of double glass covers with double air channel flows between inner cover and absorber plate and between absorber and bottom plates and with insulation provided. Choudhury et al. (1995[b]) did not take account of the heat transfer by the radiation from the cover to the sky.

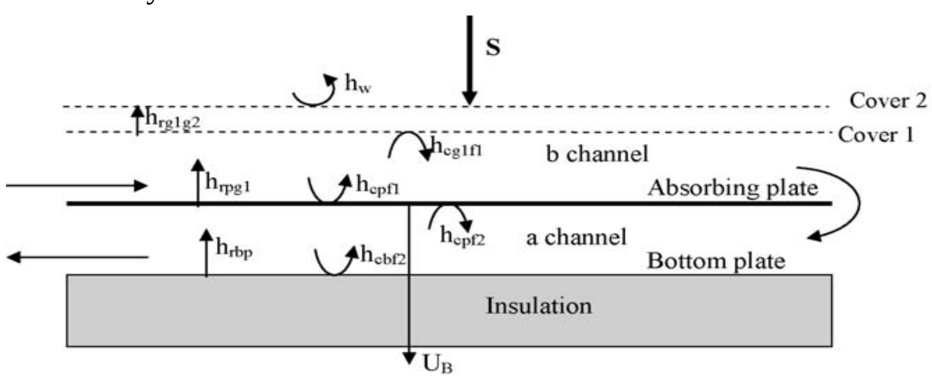

Fig. 2.4b: Schematic view of energy-flow of double-pass type solar air heater

With the aim to reduce losses from the front cover of the collector, Mohamad (1997) modified the two-pass solar air heater with two cover developed by Choudhury *et al.* (1995[b]) and Wijeysundera *et al.* (1982). The schematic view is shown in Fig. 2.4c.

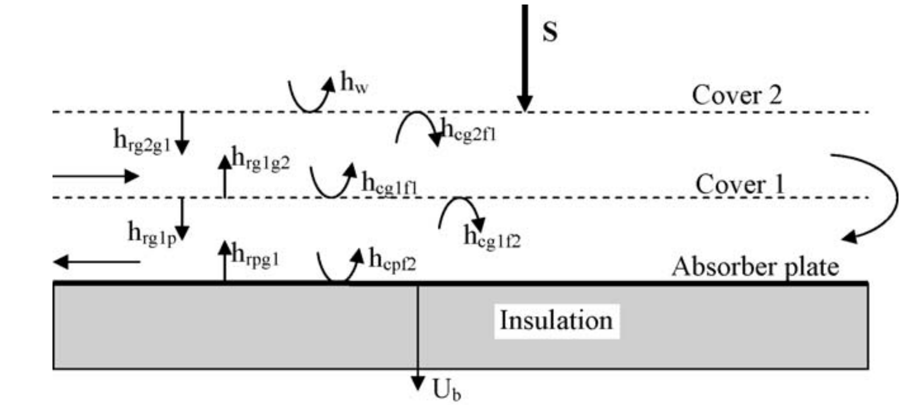

Fig. 2.4c: Schematic view studied by Mohamad (1997).

This model consists of double covers, double channel design with double air flows between upper cover and inner cover and between inner cover and absorber plate, the lower surface of the absorber was in contact of the insulation provided. The results of the study indicated that, under normal operating conditions, the thermal efficiency of the suggested heater was much higher than the efficiency of the conventional air heaters. The authors in developing the model for the two-pass solar air heater limited their study to only active systems which require fans and electric motors to function properly.

2.5 Double-pass flat-plate solar air heater with recycle

It was reported that increasing the fluid velocity by using recycle in double-pass parallel-plate heat exchangers enhances the heat-transfer coefficient, resulting in improved performance (Ho-Ming et al., 2000). The schematic view of the design of the solar heater is shown in Fig. 2.5.

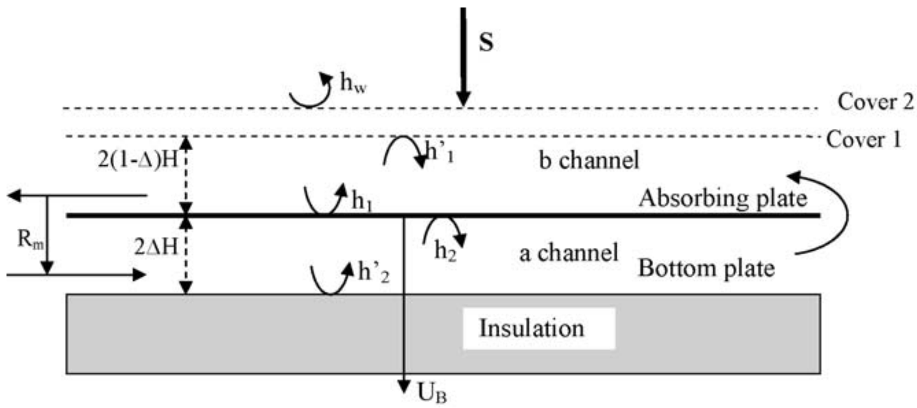

Fig. 2.5: Schematic view of energy-flow of double-pass type solar air heater with recycle.

In addition to increasing the fluid velocity, the recycle operation also produces an effect by remixing the inlet fluid with the hot outgoing fluid Ho *et al.* (2005) in developing the mathematical formulation for this model, made the following assumptions: the temperatures of the absorbing plate, bottom plate and bulk fluid are functions of the flow direction only. Both glass covers and fluids do not absorb radiant energy. The radiant energy absorbed by the outlet cover is assumed to be negligible (Ho *et al.,* 2005). The results showed that the theoretical prediction agree reasonably well with experimental data. It was also confirmed that the collector modules with external recycle are thermo-hydraulically better. The authors in developing the model for the design considered only steady state scenario and limited the heater in design to only active systems.

2.6 Triple-pass solar air heaters

The schematic configuration of a typical triple-pass solar air heater is shown in Fig. 2.6. It consists of two covers, an absorber and a rear plate (Fig. 2.6). The authors made efforts to identify the most superior air heater by comparing the cost effective performance of the air heater with single cover, three pass solar air heater. Choudhury *et al.* (1996) in their analysis have used the heat transfer coefficients predicted by the equations given in Duffie and Beckmann (1991).

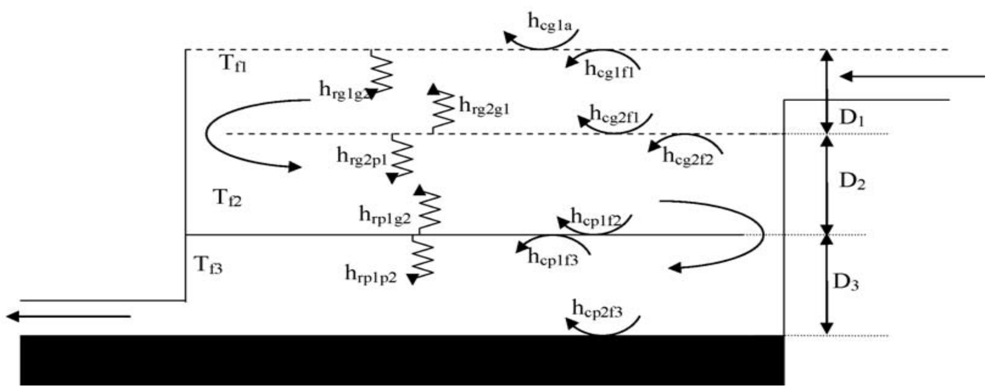

Fig. 2.6: Three pass two covers air heater (Choudhury *et al.*, 1996).

It was shown that the double cover, three- pass solar air heater with air flow from top to bottom is observed to be more cost-effective than the single cover, three pass solar air heater with air flow from bottom to top. The authors who studied the triple-pass solar air heater limited their study to steady state analysis.

2.7 V-groove solar air heater

V-groove solar air heater is made up of v-shaped materials as absorber plate (Fig. 2.7). This design has been studied experimentally and theoretically by Karim and Hawlader (2006).

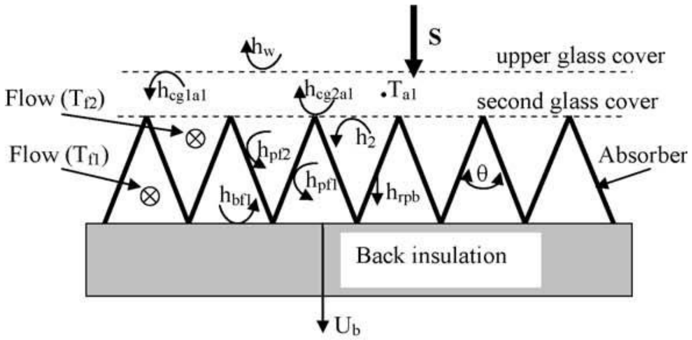

Fig. 2.7: v-Groove air collector (Kabeel and Mecarik, 1998).

The authors conducted series of experiments to determine the performance of the air heater. Experimental and analytical results showed a good thermal performance of the v-groove collector. Satisfactory qualitative and quantitative agreement between experimental and analytical results was achieved.

2.8 Single pass solar air heater with packed sensible thermal storage medium

For solar air heaters to be used during off sunshine periods, they are usually incorporated with thermal storage media. Sensible heat storage is the most widely used and developed technology among the different forms of thermal storage (Zhao and Wu, 2011). The design consists of two sheets of cover and the back plate; the passage between the inner cover and the back plate is provided with black-painted packing of porous solid state sensible heat storage medium, which act as absorbers of solar radiation and transfer the heat to the air flowing through the packed channel (Fig. 2.8). This device has been investigated by Choudhury and Garg (1993) and limited their study to steady state analysis.

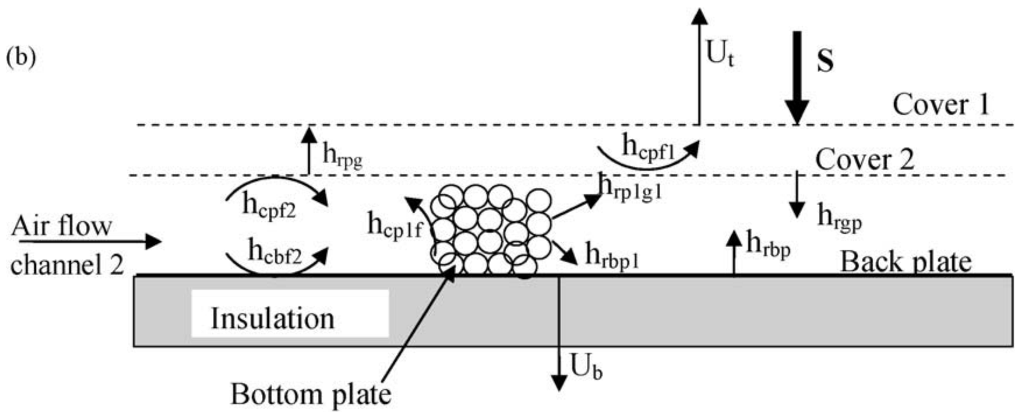

Fig. 2.8: Single pass solar air heater with packedsensible thermal storage medium.

2.9 Double-pass solar air heater with packed porous thermal storage medium

The schematic diagrams of the double-pass solar air heater with packed bed are shown in Fig. 2.9.

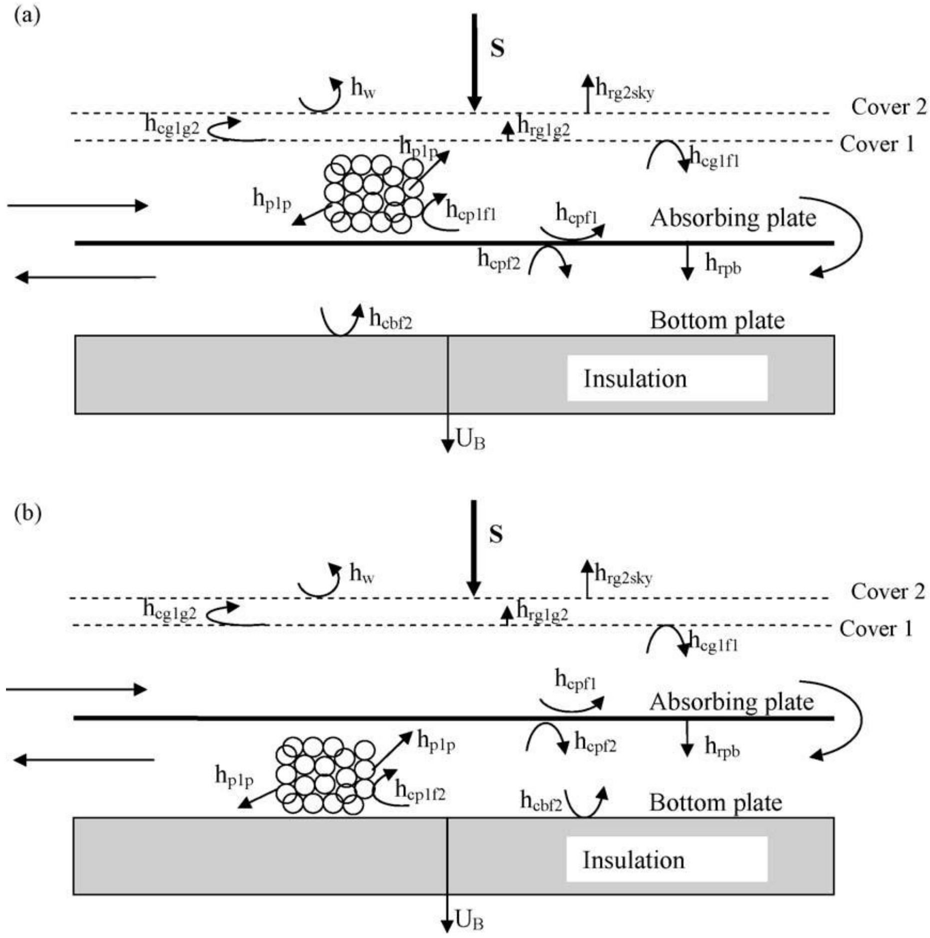

Fig. 2.9: Schematic view of energy-flow of double-pass type solar air heater with packed bed (a) studied by Ramadan *et al.,* 2007. (b) studied by El-Sebaii*et al.,* 2007.

The different heat transfer mechanisms in terms of the various heat transfer coefficients are also shown. Ramadan *et al.* (2007) studied this design with the following assumption that the air heater operates under steady state conditions. It was inferred that for increasing the outlet temperature of the flowing air after sunset, it was advisable to use the packed bed materials with higher masses and with low porosities. It was recommended to operate the system with packed bed materials with values of the mass flow rate equal to 0.05 kg/s or lower.

El-Sebaii*et al.* (2007) investigation heat transfer on a double-pass solar air heater in which the air was first forced through the upper channel, then re-circulated to flow in the opposite direction through a packed bed materials that exists in the lower channel (Fig. 2.9b). The various heat transfer coefficients (Fig. 2.9) were calculated using the correlation given in literature (Sharma *et al.*, 1990). All the authors who studied the double-pass solar air heater with packed sensible thermal storage medium limited their study to steady state analysis. Kareem et al. (2013) evaluated this system with a singled glazed solar air heater. The results of the study showed that doubled glazed recorded upto 70% efficiency single-glazed showed 52%.

2.10 Multi-pass solar air heater with in-built thermal storage

Jain and Jain (2004) and Jain (2005), studied an active solar air heater, investigated the heat transfer in the multi-pass solar air heater with in-build thermal storage. The thermal storage medium could be either sensible or latent heat medium. The schematic diagram is shown in Fig. 2.10. In this model, the solar radiation transmits from the glass covers and is absorbed by the absorber plate. The air flows in between the covers, above the absorber plate and below the storage material. The performance evaluation of the system was carried out for deep-bed drying applications. The study was limited to steady state conditions and only applicable to active mode operation.

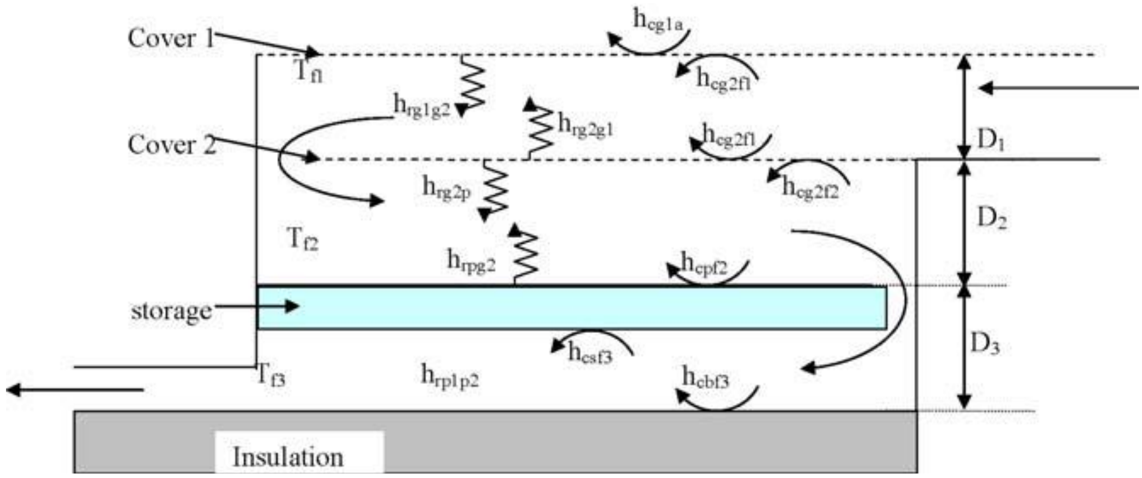

Fig. 2.10: Three-pass two-cover air heater with in-built thermal storage (Jain and Jain, 2004).

3 CONCLUSION/ SUMMARY OF LITERATURE REVIEW

Several works on the solar air heaters with double glazing have been done. There seems to be empathy for steady state analysis of the systems. In this work, a review of the various designs of the air heaters was carried out. In most of the designs, only the active systems were considered. This is due to the fact that, active solar air heating systems are easier to design because of their forced air operation. Passive air heaters which are relatively easy to operate and have low capital costs are generally regarded and used as daytime heater.

However, there appears to be a lack of agreement among authors on which of these designs is the best. This is due to the fact that most of the studies were independent works with no correlation to previous studies in double glazing designs. Hence, there is then the need for a comparative study of different double glaze solar air heating systems to actually ascertain there performances and to appropriately advice end users on the most suitable design for each scenario.

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EFFECTS OF SIEVE APERTURE MODIFICATION IN ACHIEVING HIGH PRODUCTIVITY IN DEWATERED CASSAVA MASH SIEVING PROCESS.

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ABSTRACT

This paper focuses on modifying and establishing dewatered cassava mash (DCM) sieve aperture appropriate for both manual and motorized sieve experimentally as against that established by local craftsmenarbitrarily and by guess work in developing traditional sieve.Threesieves of different apertures namely: 3mm, 5mm and 7mm were used in the experiment. The 3mm sieve served as control and developed by a local craftsman in the accustomed traditional method whereas the 5mm and 7mm served as the experimental sieveand developed using perforation method established by means of drill bits. Sieving was carried out with three replications across each of the test sieves with 2kg DCM.The result show a throughput capacity of 35kg/h, 59kg/h and 84kg/h for the three test sieves respectively.In the analysis of variance (anova), the test statistic at α of 5% significanceshows that there was a statistically significant difference among the population means of the throughput capacity for the three test sieves.Also the effective particle size D_{10} of the garified sample, the fineness modulus and average particle size Dp from the 3mm, 5mm and 7mm sieve were very close. 5mm aperture was recommended for both improved manual and low speed motorized sieve because of its particle size acceptability, high throughput capacity and its effect in reducing sieving stress and time during sieving process.

Keyword: Sieve, Aperture, Dewatered Cassava Mash, Throughput

1. INTRODUCTION

Sieving operation is an important unit operation in garri processing. It is a size reduction and separation process in which the sieve is the active element. The sieve design in terms of mesh count and aperture has a feedback effect on the processors comfort or discomfort especially in traditional method of sieving and also on throughput capacity and machine efficiency in terms of mechanized sieve.

Sieving is done manually using sieves made from palm leaves, bamboo or raffia cane (WilheminaQuaye*et al*., 2009),it is a mechanical process which stratifies particles according to size (James 2012).A sieving media or surface is a sieving medium with predetermined openings used to classify two fractions of a feed material.It consists of forcing the mixture through a screen of a specific size aperture (George, 2012).Mesh represents the sieve size of standard sieve. It is the holes number in 25.4mm which is the mesh count (RMIG 2015). The larger the mesh size, the smaller the aperture (Arthur, 2012). By decreasing the space between holes, webbing or wire diameter, the open area may be increased, increasing capacity (David, 2015).

Ogunsina*et al*. (2008) reported that over 92% of gari producers still use the traditional raffia sieve for pulverizing and sifting operation.On traditional sieving process, where the operator bends forward to apply a repetitive shearing and compressive force on the dewatered mash against the sieve, it might be true to say that the force exerted by the operator to sieve a given mass increases with a decrease in sieve aperture (James, 2012).

The mean sieve aperture currently developed by the local craftsmenfor sieving dewatered cassava mash is 2.86mm(Ahiakwo, 2018).The local processors who are accustomed to the use of this sieve apertureignorantly believe that increasing the sieve aperture beyond the approximately 3mm aperture will make the gari grain extra coarse and hence unacceptable for consumption. The result is that the processors suffer great discomfort in an attempt to squeeze the DCM through the small aperture over a rather longer period of time in an awkward position.

Besides, the primary objective of the sieve as constructed by the local craftsmen is to trap the coarse ungrated particle during sifting of the dewatered lump. With this concept the fixing of sieve aperture, is a decision of the local craftsman who by his imagination and craftsmanship measure out the apertures with his eyes as he knit the individual strip of the raffia together. At the end, an irregular aperture is revealed throughout the sieve. There is no standardization of sieve aperture hence there may be variation depending on who and where it is obtained (Ahiakwo, 2018).

However, to reduce the drudgery inherent in traditional sieving process, a number of mechanized sieves have been developed.Uthman (2011), designed and developed cassava lump breaking and sieving machine.Kudabo*et al*. (2012), developed and evaluated motorized cassava mash sifterwhile Adetunji*et al*. (2013), designed and fabricated an improved gari sifting machine.On the other hand, Abubakar*et al*. (2014) designed a pedal driven pulverizing and sieving machine, and Abiodun*et al.* (2016) developed NCAM reciprocating cassava mash sifter. These machines represent earnest efforts at reducing drudgery in cassava processing and enhance productivity. However these designs are silent on the sieve aperture or mesh used in developing them. This presents a challenge in terms of replacement, reproduction and sieve output capacity. This is true because, all other elements held constant, a change in sieve aperture or mesh might result in irregularity of discharged particle size and machine element malfunction.

Garri grain or particle size distribution is an important factor producers of garri give attention to during processing of cassava into garri. This is because the commercial value, appearance and suitability of garri for various purposes is tied in to this factor (Burubai and Etekpe, 2014). Since particle size distribution of garri which tells of the fineness or coarseness is a function of sieve aperture, analyzing the particle size distribution can provide insight as to the best sieve aperture to adopt (Suryakanta, 2014).

Thisresearch therefore seeks to experimentally modify locally established sieveaperture asconstructed by local developers (Fig.1) and to assess if there is statistically significant difference in the use of the locally fixed sieve aperture and the modified sieve with respect to sieving time, throughput capacity and Gari particle size distribution and acceptability.

Fig1: Raffia sieve development by a local craftsman

It is believed that if processors are aware of the discomfort involved, energy and time wasted in the use of the traditional sieve, they may make a change in order to achieve higher productivity at a shortest possible time. This result also points out the need to give sieve aperture due consideration in the design of an improved manual or motorized sieve.

2. MATERIALS AND METHODS

2.1 Materials

The equipment used for developing the experimental sieves are:

1. A locally developed DCM sieve with 3mm sieve aperture
2. Galvanized metal sheet 1mm thick
3. Drilling machine
4. Drilling bits – 5mm, 7mm
5. Engineers square

6. Scriber
7. Centre punch

2.2 Development of test sieves

Three plates of dimension 450mm x 350 mm each was cut out of the 1mm galvanized metal sheet. Engineers Square was used to square the plate and also guide in scribing horizontal and vertical lines to create inter hole spaces and the square space for drilling the hole. The centre punch was used to make the lines bolder. The drilling machine and bits were used to create round hole squared pitch drill pattern shown in figure 3

2.2.1 Determination of mesh number

The mesh number for each of the sieves was determined by selecting an in-between hole spacing that will give a larger open area. 1mm spacing was selected because it gave the least possible dimension to accommodate the drilling process while producing higher open area. The plates were marked, punched and drilled using round hole square pitch drill pattern shown in Fig 2.

2.2.2 Characteristics of experimental sieve

The two experimental sieves were made of round hole squared pitchdrill pattern and was developed with the characteristics shown in Fig 2.

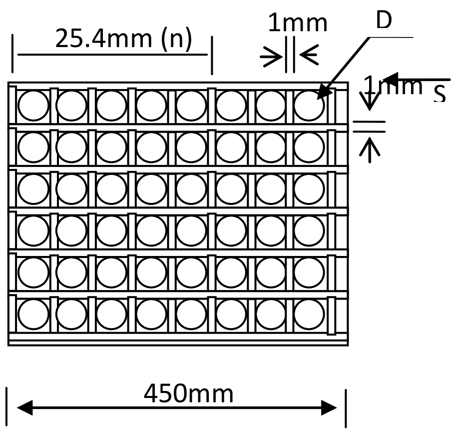

Fig 2: Round hole squared pitch drill pattern of the experimental sieve

Where: D = diameter (experimental sieve apertures)

S = spacing between hole

The mesh number for experimental sieve was obtained from the formula:

$$n = \frac{25.4}{(D+S)} \qquad (1)$$

Where n = mesh number

D = Diameter (sieve aperture)

S = Spacing between aperture

Also, the percentage open area for the experimental sieve was obtained from the formula:

$$A_0 = \frac{0.785d^2}{(s+d)^2} \times 100 \qquad (2)$$

WhereAo = percentage open area,

d= Diameter (sieve aperture)

s = Spacing between aperture

2.2.3Characteristics of the locally developed sieve

The locally made sieve was of the woven wire mesh pattern and was developed with the characteristics shown in Fig 3.

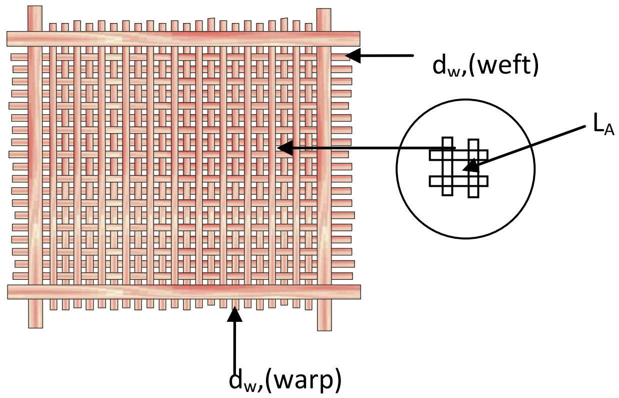

Fig 3: Woven wire mesh pattern of the locally developed sieve

Where:

L_A = sieve aperture = 3mm

dw = Horizontal width of raffia strip = 6mm

Mesh number, $M = \frac{25.4}{(L_A + d_w\ )}$ (3)

And Percentage open area $A_o = (\frac{L_A}{L_A + d_w})^2 \times 100$ (4)

2.3 Experimental design

Randomized complete block design (RCBD) was used for the experimentation. The experiment sought to determine the effect of modifying sieve aperture on sieving time, throughput capacity and particle size distribution. The dependent variable was the sieve size, while the independent variables were sieving time, throughput capacity and particle size distribution. Unit of treatment was 2 kg of DCM. This was used as a treatment for the different apertures of 3mm, 5mm and 7mm which were used in constructingthe locally developed sieve and the experimental respectively. The sieve of 3mm aperture served as control sieve whereas sieves with 5mm, 7mmserved as experimental sieves. The parameters measured were: sieving time, throughput capacity, and particle size distribution.

Table 1: Sieve aperture and sieving process replication in RCBD

Block1	Block 2	Block 3
3mm	5mm	7mm
5mm	7mm	3mm
7mm	3mm	5mm

2.4 Experimental procedure

A processor was asked to load 2kg of DCM on each of the sieves and carry out sieving task manually in a normal and accustomed manner. The sieving process and replication followed the randomized complete block design shown in Table 1. The time to completely sieve the 2kg mash in each case was recorded and replicated 3 times for each of the sieves.The resultant throughput capacity with respect to time was calculated in each case:

$$T_{p\,1\ldots n} = \frac{Q_{1\ldots n}}{t_{1\ldots n}} \quad (5)$$

Where $T_{p\,1\ldots n}$=throughput for the three different sieves

$Q_{1\ldots n}$ = Quantity sieved and

$t_{1\ldots n}$ = Time to sieve the given quantity through the three sieves

To determine the grain size of the sieved particles and its acceptability, sieved samples from the controlled sieve and experimental sieves were subjected to garification. The particle side distribution of garified sample was analysed.

2.5 ANALYSIS*of sieved sample for particle size distribution*

Particle size distribution of the sieved DCM was analyzed using IS 460 Sethi standard test sieve of diameters 1.70mm, 1mm, 0.85mm, 0.35mm, 0.30, 0.20 and pan. The test was carried out to determine particle size variation, fineness or coarseness of sieved particle with respect to control and experimental sieves of 3mm, 5mm and 7mm aperture respectively. The test was also carried out to ascertain the particle size distribution that meets acceptable requirement for local and international consumption.

300g garified sample from each of the researched sieve was loaded on top the test sieve of six stack and pan. This was agitated for 10 minutes after which the weight retained in each of the sieves was recorded for each sample and replicated three times. From the weight retained measured with Pioneer plus analytical electronic balance Cp214, the cumulative weight, cumulative percentage, and fineness modulus were obtain. Also from the distribution curve, the effective sizes of Gari grain, coefficient of uniformity and gradation were obtained.
Percentage retained on any sieve was given as:

Percentage retained $r = \frac{W_r}{W_t}$ x 100% (6)

Where W_r = weight of gari retained
W_t = Total weight of Gari

Uniformity coefficient was calculated from the relation:

$$c_u = \frac{D_{60}}{D_{10}} \quad (7)$$

Where $D_{60}$is diameter corresponding to 60% finer in the particle size distributioncurve.
On the other hand coefficient of gradation was expressed by:

$$c_u = \frac{D_{30}}{D_{10}\times D_{60}} \quad (8)$$

WhereD_{30} is the diameter corresponding to 30% finer in the particle size distribution.
Average particle size D_p was calculated from relation:

$$D_p = 0.135(1.366)^{FM} \quad (9)$$

Where FM = Fineness Modulus

3. RESULTS AND DISCUSSION

Table 2 shows the effect of modifying sieve aperture throughput capacity. Notice from the table that at 3mm, 5mm and 7mm sieve aperture, the throughput capacities are 39kg/hr, 59kg/hr and 84kg/hr.

Table 2: Sieve characteristics and throughput capacity

	Diameter (mm)	Mesh number n	Open area Ao(%)	throughput capacity kg/hr
Control sieve	3	3	11	39
Experimental sieve	5	4.2	55	59
	7	3.2	60	84

From the Table 2, notice also that percentage open area of the locally made sieve is comparatively low whereas that of experimental is comparatively high. This is attributed to the material development pattern. The low percentage open area noticed in the locally made sieve can be attributed to the material and development pattern of the sievewhichwas made by weaving rectangular strips of raffia material. The experimental sieve aperture was established by drilling a round hole with inter-hole spacing of 1mm. This comparatively small inter hole spacing results in a higher percentage open area and by extension a higher throughput capacity of 84kg per hour as oppose to the lower throughput capacity of 39kg/hr obtained by the use of the locally made sieve.

Table 3 shows the effect of modifying sieve aperture on sieving time. The mean time in minutes required to sieve 2kg of DCM across the traditional sieve (control) and that of the modified sieve (experimental) are: 4.1, 2.6 and 1.5 respectively.

Table 3: Mean time required sieving 2kg of DCM in test sieve

	Control	experimental	
Sieve aperture (mm)	3	5	7
	1.5	2.8	1.5
Time 2kg/min	4.4	2.6	1.5
	3.9	2.6	1.5
	3.7	2.5	1.3
Mean time (minute)	4.1	2.6	1.5

This shows that the traditional sieve consumes more time than the experimental sieve for the same quantity of DCM. This time consumption is also connected with the lower percentage open area which permits small quantity of the DCM to pass through the traditional sieve aperture.

The results presented in the tables above actually shows the effect of modifying traditional sieve aperture and to what extent the aperture should be increased to.Increasing traditional sieve aperture from 3mm to 7mm gives a higher throughput capacity (39kg/hr to 84 kg/hr). however the 5mm sieve aperture is recommended though comparatively low in throughput capacity, its particle size proved to be closely related to that obtained using 3mm sieve and hence more acceptable than that from the 7mm sieve. This is in agreement with Ogunsina (2008) who obtained a throughput capacity of 55.46kg/hr, while sieving approximately 1kg of DCM with 3mm raffia sieve. But a throughput capacity of 227.71kg/hr while sieving an average of 1.6kg DCM with 5mm crank sieve at 67 rev/min. The difference in result is attributed to the fact that this research used 2kg and a motorized sieve at 100 revolutions per minute. Also although we use apertures of 3mm and 5mm respectively, the mesh count and percentage open area may not be the same. However the common ground is that the time of sieve using raffia sieve is high while the throughput is low.By increasing the aperture to 5mm the sieving time is reduced with a high throughput capacity.

3.1 Analysis of variance

Table 4 shows the result of sieving 2kg of DCM on three different sieve apertures replicated four times and the throughput capacity presented in anova table

Table 4: DCM throughput Capacity (Kg/hr) in Anova table

Treatment	Replication					
Aperture/2kg	1	2	3	4	Total	Mean
La1(3*mm*)32	33	37	39		141	39
La3(5*mm*)54	55	64	62		235	59
La4(7*mm*)84	87	80	85301		84	

From table 5, the test statistic is the F value of 4.5. Using an α of 0.05, then $F_{.05,2,9}$= 4.

Table 5: Anova of throughput capacity

Source of Variation	Sum of square(SS)	DF	Mean Square(MS)	F
Treatment	3232	2	4471	4.5
Eror	5709	9	993	
Total	8,941	11		

But F > 4.256, hence there is a statistically significant difference among the population means of the throughput capacity.

Particle size distribution of garified sample

Figure 4 show the particle size distribution curve of garified samples from the three researched sieves under consideration, namely: 3mm, 5mm and 7mm. The percentage finer plotted against

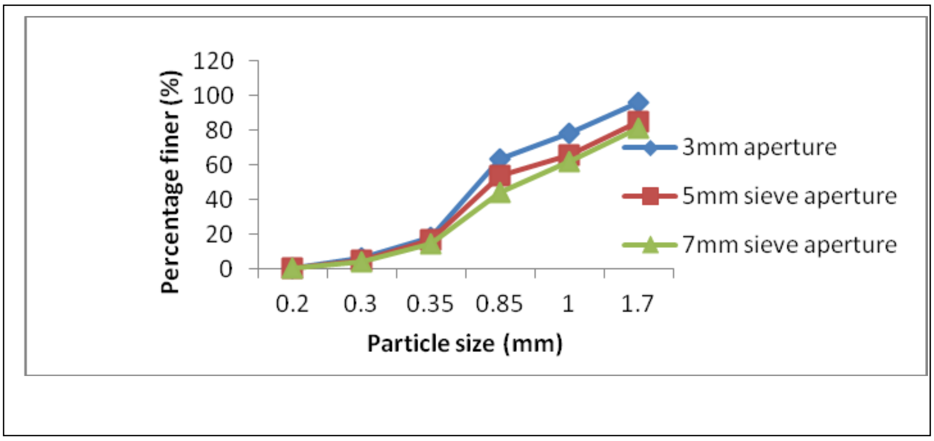

Fig 4: Particle size distribution of garified sample from different sieve aperture

the particle size are 96.37, 78.20, 63.37, 18.54, 6.44 and 0.77 for 3mm, 84.87, 65.54, 53.47, 16.74, 5.07 and 0.34 for 5mm and 81.50, 61.90, 44.13, 14.23, 4.1 and 0.30 for 7mm

Table 6 shows the characteristics of particle size distribution of garified sample from the sieved DCM samples of the three research sieve.

Table 6: Characteristics of particle size distribution for garified sample

Sieve size	D_{10}	D_{30}	D_{60}	FM	Cu	Cc	D_p
3mm	0.31	0.47	0.79	3.37	2.55	0.91	0.39
5mm	0.33	0.54	0.94	3.72	2.85	0.94	0.43
7mm	0.34	0.62	0.99	3.90	2.91	1.14	0.46

From table 6, the effective particle size D_{10} of garified sample, the fineness modulus and average particle size from the 3mm, 5mm and 7mm sieve are 0.31, 0.33 and 0.34; 3.37, 3.72 and 3. 90; 0.39, 0.43, and 0.46 respectively. Notice that the effective sizes D_{10} for the three sieves are very close. It can be observed that there is a progressive decrease in fineness modulus (FM) from 3mm to 7mm sieve size but this did not translate to a large different in their average particle size Dp. For the three research sieve sizes, each have uniformity coefficient (Cu) less than four, and Cc approximately 1 implying that they each contain uniformly graded particles although with 5mm and 7mm sieve having a slightly larger range of particle size. Considering the average particles sizes from the research sieve, a shift from 3mm sieve to 5mm does not make the garii grain extra coarse especially for manual sieve.

CONCLUSION

Through experiment, the locally established sieve aperture of approximately 3mm was modified to 5mm with positive results. Throughput capacity at 5mm aperture was higher by 24kg/hr over the 3mm aperture. This was possible as the use of modified sieve at 5mm aperture reduced sieving time from 4.1min to 2.6min. The test statistics F> 4.256 at $F_{0.5,\ 2,\ 9}$shows there is a statistical significant difference among the population means of the throughput capacities of the test sieves. The effective particle size D10, fineness modulus FM and Coefficient of gradation of the particles from the 3mm aperture differ slightly from that of 5mm but it did not translate to large difference in their average particle sizeDp, hence the particle size distribution of Gari grains from 5mm aperture was within acceptable range of what is obtained locally.

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REVIEW ON COMPARATIVE STUDY OF TWO METHODS OF SESAME SEED OIL EXTRACTION.

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ABSTRACT

Sesame (*Sesamum indicum* L.), otherwise known as sesamum or benniseed, member of the family *Pedaliaceae*, is one of the most ancient oilseeds crop known to mankind. Sesame plays an important role in human nutrition. It was a highly prized oil crop of Babylon and Assyria at least 4000 years ago. This review compared two methods of sesame seed oil extraction, which are the mechanical (Ram press, Ghani process and Screw press) and chemical process using solvent extraction. The solvent extraction process produces higher yield of oil. However the chemicals used often affect both environment and human health, making the mechanical methods more environmental friendly since no chemical residues are produced.

Keywords: Oil Extraction, Mechanical process, Sesame, Chemical process

1.0 INTRODUCTION

Sesame is an important oil seed crop being cultivated in the tropics and the temperate zone of the world (Biabani, and Pakniyat, 2008, Bachmann, 2004).It was a highly prized oil crop of Babylon and Assyria at least 4000 years ago (*Ross, 2005*). Sesame oil, also referred to as gingelly oil, is one of the major sources of edible oil in India and is culturally associated from the Vedic period. The Sanskrit word for oil, taila is derived from the Sanskrit word for sesame tila (Shanthasheela *et al.*, 2007). It is called "sesame" internationally, while it is called "benniseed"in West Africa; "simsim" in East Africa and "Till" in India. Within Nigeria it is called different names in different localities. It is generally called "ridi" in the Northern States (Aboje, 2011). The Igalas, Idomas and Tivs of Benue State call it "Igogo", "Ocha" and "Ishwa"respectively. The Ibos call it "isasa" and Yorubas call it "Ekuku" or "Eeku" in parts of Ogun, Ondo and Oyo states and Ilorin in Kwara State. (Aboje, 2011). Natural sesame oil derived from good quality seed has a very pleasant flavour and can be consumed without further purification (Langham et al., 2008). The natural oil has excellent stability due to the presence of high levels of natural antioxidants. Report has shown the impact of environment on the seed yield .Seed Production Environment and Potential Seed Longevity of Rain-fed Sesame Genotypes were reported by Adebisi, *et al*., (2011).

According to Gokbulut, (2010), sesame oil is used widely in some injectable drug formulations. The lignans such as sesamin, episesamin, sesaminol and sesamolin are major constituents of sesame oil and all have chemically methylene dioxyphenyl group. It ranks ninth among the top thirteen oilseed crops which make up 90% of the world production of edible oil. The oil is also useful in the industrial preparation of perfumes, cosmetics (skin conditioning agents and moisturizers, hair preparations, bath oils, hand products and make-up), pharmaceuticals, insecticides, paints and varnishes (Chemonics International Inc., 2000). Sesame seed has higher oil content (about 50%) than most of the known oil seeds (Hwang, 2005). The seed has 40-60 per cent of oil with almost equal levels of oleic (range 33-50%) and linoleic. Oil can be classified in the oleiclinoleic acid group. The dominant saturated acids were palmitic (up to 8.58%) and stearic (up to 5.44%). The natural oil has excellent stability due to the presence of high levels of natural antioxidants (Lyon, 1972).

2.0 Sesame Seed oil Extraction Methods

The extraction of oil involves mechanical method (Ram press, ghani process and Screw press) and the laboratory method. The mechanical method was an early means of separation which uses physical pressure to “squeeze the oil out”. The most energy efficient, practical embodiment of that method is the modern screw press. More than half of the oil is easily removed in this way, but perhaps 7% or 8% residual oil is left in the cake solid. The process uses considerable horsepower and requires more maintenance. In addition it also requires more machine setups for higher capacity (Elkhaleefa and Shigidi, 2015). Solvent extraction, providing higher yields of 98% to 99%, is nowadays the dominant technique applied in most extraction processes. Solvent extraction becomes the commonly used commercial technique to recover oil from oilseeds, presently n-hexane is the preferred solvent throughout the world due to its extraction efficiency and vailability, (Saxena *et al.*,2011).

2.1 Ram press

The ram press technology (Figure 1) for oil expression has received a lot of attention in the last decade. The technology is based on manually operated mechanical presses. The original machine was designed by Karl Bielenberg in 1985 (ATI, 1985).However, there are other designs either based on the original Bielenberg ram press or using different type of mechanisms, such as that of RAM32 oil expression machine (Uziak et al., 2007). Oil projects that are based on these relatively simple machines have been started in many sub-Saharan African countries such as Tanzania, Kenya, Uganda, Mozambique, Senegal, Zambia, Benin, Zimbabwe and Mali. Although, this technology was originally developed for the expression of oil from sunflower seed, oilseeds such as Jatropha, sesame mustard and rapeseed have been tested on this machine (Uziak and Loukanov 2007).

Figure: 1 Ram press machine. Karl Bielenberg in 1985 (ATI, 1985).

The ram press operates by applying pressure to seeds inside a cylinder and cage by means of apiston and a system of levers. Under the pressure built in the cage the seeds release oil, which flows out through the slots available in the cage. The remaining cake is extruded out through an opening at the end of a conical restrictor.

The operation can be summarized as follows. When the handle is raised, seeds drop down from a hopper through the inlet port into the cylinder, then the piston is moved forward when the handle is lowered, pushing the seeds into the cage under increasing pressure. When the pressure has risen enough, oil is squeezed out of the seeds and drips from the cage through the cage slots. Cake is extruded from the opposite end of the cage provided that sufficient pressure has been built up in the cage. The latter is controlled by means of the adjustable restrictor.

Work in Tanzania has indicated that sesame is suited to processing in the ram press. Pre-grinding is not required but pre-heating the seed by warming in the sun, preferably on metal roofing sheets, is strongly recommended. Craft and Artisan promotion unit (CAPU) press gave an oil extraction efficiency of 57.5% in terms of clarified oil (N.R.I, 1995).

2.2 The Ghani Process

According to Achaya (1994) Ghani operation has been noted in Asia, which had cultural ties with India. The device is widely used in the Sudan to crush sesame seeds. Linguistic evidence suggest that it is from these two crushing systems (mortar and pestle) that presses for both oilseeds and sugar cane developed in the form of a mortar-and-pestle arrangement powered by animals commonly known as ghani.

The ghnai traditional method was described by Kamel-Eldin *et al*. (1992) and Warra (2011). Nag (1982) reported the crushing of 10 kg of sesame seed in a ghani, about three-fourths of the material is placed in the pit and the rest is evenly laid out all around the flat rim. The animal is prodded and allowed to perambulate for a few minutes until pulverized seed is found to climb into the Pit, which is mopped up with a piece of cloth and wrung out by hand into vessels. While the cake is still hot and before it has set really hard, it is pressed out as thick slabs from the chest using a crowbar on the wall of the pit. The animal is halted, and

180 ml of water is sprinkled around the chest and 120 ml poured into the pit. A further 5 minutes of pestle rotation will cause about three-fourths of the seed to be pulverized, after which another 300 ml of water is poured evenly around the pithead. The material built up in the chest is raked using a crowbar, and the pieces are broken up by hand and cast into the pit. After the animal has resumed movement, the rest of the seed is evenly pushed in all around. The operator now tests the solid material by balling it in his or her palm; if it crumbles too easily, more water is needed. The layer of built-up material is again broken up, and brisk ambulation is resumed. After about 45 minutes, a sudden release of frothy oil floods the surface. Another 100 ml of water is sprinkled over the oil, the animal is stopped and the oil is allowed to settle. A final quantity of about 20 ml of water is now brushed over the compacted cake surface using the edge of the palm, after which the animal makes a few more rounds. The operation is stopped, the two curved pieces are detached and the pestle is lifted out and laid aside. If the ghani has a drainpipe, it is unplugged and the oil is drawn into a vessel, otherwise the oil is released.Ghani traditional method was described by Kamel-Eldin *et al.* (1992). The addition of oil to aid the extraction process is of particular interest. Sesame seeds (12 kg, oil content 53.1% Moisture Free Basis (MFB)) were ground in a camel-powered ghani with 0.5 l of water. Oil release was observed after 30 min. when the temperature of the mass was 41°C. After 40 min., 2 l of oil previously extracted (temperature 46°C) were added to assist extraction. Extraction was complete in 55-60 min., giving approximately 5 l of oil (temperature 50°C). (N.R.I., 1995).

2.3 Screw Press

Screw press (Figure 2) can be powered with electric motor, diesel or even be operated manually (Jariene *et al.* 2008). The process begins by putting the oil seed inside the feed hopper. The screw press has a horizontal main shaft that carries the screw composition which is formed integrally with the shaft. The rotation of the screw occurs inside the cage or barrel that is a structure formed by steel bars. Spacers are placed between the lining bars allowing the drainage of oil as the pressure over grains is increased. A movable cone or choke control is installed at the discharged end. This device has the function of operating pressure by changing the width of the annular space through which cake must pass. It is possible to adjust the choke by a hand wheel on the opposite end of the screw (Khan and Hanna 1983). Some machines have a device capable of removing heat generated by friction of grains making use of cold water circulation.

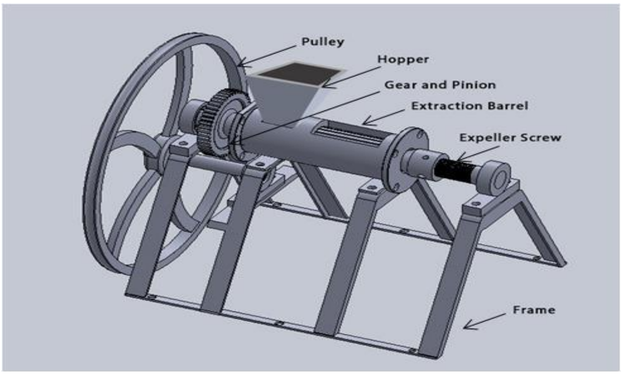

Figure: 2 Screw press (Habib *et al*.,2016).

The working principle of the continuous mechanical pressing is to force the oilseed mass through the barrel by the action of the revolving worms. The volume of the mass is being reduced as the transition takes place through the barrel, causing compression of the cake and the resulting output of oil by the performance of lining bars of the barrel while the deoiled cake is discharged through the annular orifice (Akinoso et al., 2009). Screw press can be operated manually or powered with electric motors and also diesel engine (Jariene et al., 2008). Some researchers mentioned the use of photovoltaic cells to power screw presses (Mpagalile and Hanna 2007). As detailed below, an important parameter related to the pressing efficiency is the determination of residual oil in the cake. High pressure can lead to cakes with less 10% of oil content, which leads to higher crude oil production. A reduction in the speed of rotation of the shaft, for example can reduce the oil yield, increasing the oil content in the cake and solids in the oil (Jariene et al., 2008). In addition to obtaining the oil, mechanical expelling produces a very important by-product named cake or meal. Some oilseed cake are highly rich in nutrient and are use as human food, while some are not suitable as food but serve to complement the diet of Cattles, Pigs and Chickens.

2.4 Advantages and Disadvantages of Mechanical Methods

Mechanical expression results in high quality oil, but has a relatively low yield (Willems *et al*., 2008). Generally it is only used for smaller capacity plants, speciality products or as a prepress operation in a large scale solvent extraction plant (Willems *et al*., 2008). Another important advantage is the possibility of using cake resulting from the pressing as fertilizer or animal feed, since it is free of toxic solvent.

3.0 Chemical Method of Extraction

Modern laboratory methods normally employed in the analysis of oils usually include soxhlet extraction usually using n-hexane and the enzymatic extraction Unal and Yalcsn, (2008). Extraction of crude sesame oil by the use of a soxhlet extractor with n–hexane solvent was reported by Mohammed and Hamza, (2008). Extraction of sesame oil from sesame seeds using supercritical CO_2 was carried out by Doker *et al*., (2010) The solvent extraction process is not a straight forward application as many processes precede the addition of solvent. The overall process is summarized in the process description, each stage addresses particular parameter, Figure: 3

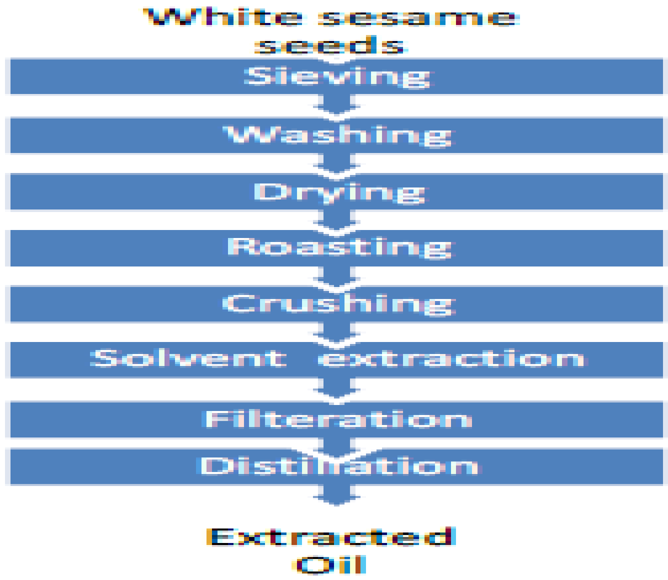

Figure: 3 Solvent Extraction process (Elkhaleefa and shigidi, 2015).

The weighted sesame seeds are first sieved to ensure maintaining particularly specified particle size, this is very important to ease the crushing process, hence obtaining uniformly particle sizes. Seeds are then washed to remove any adhering particulates that may be deposited during harvesting that may contaminate the final product. The seeds are then dried before being roasted.

Durmaz. and Gökmen. (2010) studied the impact of roasting oily seeds and concluded that antioxidant capacity of the roasted seeds and oxidative stability of the extracted oil could be greater than that of the unroasted counterpart. These improvements are attributed to the formation of Maillard reaction products, inactivation of oil degrading enzymes and facilitation of phytochemical extraction as a result of roasting. The seeds were roasted at different temperatures and durations, (Lee *et al* 2010) are then crushed to increase the active surface, thus improve the extraction process. (Döker *et al* 2010) examined the impact of sesame particle size on oil extraction and concluded that the extraction yield increased as the particle size decreased depending on decreasing intraparticle diffusion resistance. The particle size from 45% of the maximum extraction yield obtained was about 300 - 600 µm.

The overall extraction process is summarized in the process description in Figure 3, each stage addresses particular parameter, the solvent extraction is the key unit-operation. Extraction takes place due to the affinity of solvent towards oil. The affinity is mainly chemically based.

3.1 Advantages and Disadvantages of Chemical Methods

Solvent extraction provides higher yield of 98% to 99% (Saxena et al., 2011, Elleuch,et al., 2007). When performed at low temperature the solvent extraction has advantage over screw pressing, as better quality of oil produced. This is because during expelling a sudden heating of the oil can occur changing some parameters of its quality (Williams, 2005). One of the disadvantages of the extraction process is that the solvent extracts some nontriglycerides, which does not occur in the mechanical method of extraction (Williams, 2005). Another serious problem is the presence of volatile organic impurities in the final products which can compromise the quality and go against the new profile of consumers who are seeking for natural products aiming to have a healthier diet (Michulec and Wardenki, 2005).

4.0 Comparison of the Extraction Methods

Chemical extraction and Mechanical Extraction (Ram press, Screw press and Ghani process) can be compared and evaluated in three main parameters: Environmental, economical, and oil yield. Today the process most commonly used commercially is solvent extraction. This process has the advantage of high oil yield (over 98%). However, it has a great disadvantage, which is the chemical solvent. After oil extraction, the remaining solvent should have a proper disposal to prevent environmental damage and avoid addition cost to the process, as well as having investment cost (that is costly equipment). Another serious problem is the removal of the solvent from vegetable oil, ensuring adequate levels that are not harmful to human health. Beside oil, the meal is obtained, a co-product of solvent extraction, which depends on the feedstock source is rich in protein, which could be used for animal feed, if high level of solvent is not present. If necessary one more step could be done, removing the solvent from the meal so it can be used. This process is not recommended for oil seeds with high oil content in its composition. The energy consumed to operate a plant for solvent extraction is high, and requires skilled labour to deal with this complex operation. Mechanical methods are the oldest method of oil extraction. The great advantage of these methods is not using any kind of chemical product, producing a crude oil with high quality and ready for consumption in some cases. Other important advantages are the low cost of acquisition of equipment, low power consumption for the operations and manpower do not need to be skilled. Despite facilities having lower cost than those of the chemical process, the low oil yield and high oil content in the cake make the process unprofitable. (Kurt *et al*., 2012) Compared oil content (%) of soxhlet extracted and cold pressed of 25 different genotypes varieties and the result is shown in Table 1.

Table1. Compared oil content (%) of soxhlet extraction and cold press of 25 different genotypes varieties.

Genotypes	Soxhlet	Cold Press	Differences
Cumhuriyet-99	47.9	36.4	11.6
Tan-99	53.8	38.9	14.8
Kepsut-99	48.3	40.2	8.1
Baydar-2001	49	33.6	15.3
Muganh-57	51.3	38.2	13.1
Orhangazi-99	53.3	39.3	14
Golmarmara	53.4	40.3	13.2
Osmanh-99	52.5	37.1	15.4
Sanhurfa-Siverek	52.4	31.1	21.3
DiyarbakirMerkes	53.1	37.5	15.6
Kahramnmaras	53	38.7	14.3
Diyarbakir-lice	53.9	36.1	17.8
Adana-Kozan-2	52.9	42.8	10.2
Mamisa-Salihli	52	34.9	17
Manias-Alasehir	52.4	39.6	12.9
Adana-Ceyhan	53.7	33.7	20
Antalya-Kumluca	52.8	38.4	14.3
AdanaYumurtahk	50.9	36.5	14.4
Osmaniye-Kadirli	52.4	40.7	11.8
Mugla-Fethiye	51.2	39.3	12
Adana-Karatas	52.7	41.7	11
Adana-Saricam	53.6	40.6	13
Bahkesir-Ayvahk	52.4	34.7	17.7
Aydn-Merkez	54.7	37.2	17.6
Adana- Merkez	51.4	37.7	14

Source: (Kurt *et al.*, 2012).

The oil compositions of sesame varieties were compared in five main dominated sesame fatty acid components namely palmitic, stearic, arachidic, oleic and linoleic acid (Table 2). The content of major fatty acid showed significant variation according to extraction methods. Indeed palmitic and oleic acids were higher in the extraction by cold press. Conversely stearic arachidic and linoleic acids were higher in the extraction by soxhlet (Kurt. *et al.*, 2012).

Table2: Comparison of fatty acid composition (g/kg) of soxhlet extracted and cold press in sesame genotypes.

Genotypes	Palmitic acid		Stearic acid		Arachidic acid		Oleic acid		Linoleic acid	
	Soxhlet	**CP**	**Soxhlet**	**CP**	**Soxhlet**	**CP**	**Soxhlet**	**CP**	**Soxhlet**	**CP**
Cumhuriyet-99	9.816	10.152	4.948	4.885	0.577	0.553	39.0	39.2		
Tan-99	9.633	10.076	4.945	4.847	0.584	0.550	39.2	39.5	43.8	43.2
Kepsut-99	9.399	9.603	5.128	5.073	0.591	0.572	40.1	40.2	43.0	42.8
Bavdar-2001	9.660	10.160	4.816	4.692	0.523	0521	37.8	37.9	45.3	44.8
Mugnah-57	9.722	10.087	4.882	4.805	0.555	0.548	38.4	38.8	44.6	43.9
Orhangazi-99	9.554	9.746	4.755	4.703	0.551	0.538	39.0	39.2	44.2	43.9
Golmarmara	9.493	9.849	5.044	4.949	0.586	0.580	38.8	38.9	44.2	43.9
Osmanh-99	9.554	9.746	4.755	4.703	0.551	0.538	39.0	39.3	44.2	43.9
Sanhurfa-saverek	9.504	9.984	5.044	4.949	0.606	0.594	39.3	39.6	43.6	43.1
Diyarbakir-merkez	9.379	9.726	4.755	4.703	0.584	0.571	39.4	39.3	43.8	43.7
Kahramanmaras	9.589	9.917	5.120	5.042	0.570	0.524	38.2	38.1	44.8	44.7
Diyarbakir- lice	9.622	9.200	4.978	4.843	0.564	0.549	39.4	39.2	43.4	43.0
Adana-kozan-2	9.847	9.980	4.864	4.91	0.573	0.541	41.2	41.7	43.3	43.4
Manias-salihli	9.529	9.109	4.873	4.51	0.580	0.557	37.2	37.5	43.1	42.2
Manias-Alasehir	9.697	10.097	4.990	4.957	0.580	0.571	37.7	38.0	45.1	45.2
Adana-Ceyhan	9.669	10.088	4.926	4.753	0.578	0.563	38.3	38.1	45.2	44.7
Antaya-kumluca	9.713	10.096	4.839	4.876	0.560	0.541	38.2	38.2	44.5	44.5
Adana-Yumurtalik	9.548	9.964	4.822	4.754	0.531	0.554	37.6	37.8	45.1	44.7

Osmaniye-Kadirli	9.910	10.053	4.889	4.088	0.589	0.571	40.8	41.2	45.1	44.9
Mugla-Fethiye	9.670	10.258	4.976	4.858	0.597	0.562	40.2	40.6	42.1	41.9
Adana-Karatas	9.467	9.699	5.078	5.018	0.551	0.583	39.2	39.1	42.8	42.2
Adana-Saricam	9.763	10.010	4.834	4.859	0.601	0.569	38.1	41.3	43.6	43.6
Bahkesir-Ayvahk	9.848	10.189	5.119	4.870	0.590	0.539	37.5	37.5	44.6	44.0
Aydin-Merkez	9.950	10.559	4.806	4.699	0.564	0.535	37.5	37.3	45.3	45.0
Adana-Merkez	9.648	10.021	4.800	4.696	0.567	0.552	37.5	37.3	45.5	45.5

Source: (Kurt *et al.*, 2012).

Conclusion

Extraction of sesame oil can be done through different methods: based on this review using mechanical and chemical methods, although solvent extraction technology has higher yield of oil, it is the best method in industrial production but due to the use of chemicals which affects the environment and human health, it is preferred in the industrial uses, the mechanical methods that is environmental friendly with no chemical residues is healthy for human consumption, but compared to the solvent extraction it oil yield is low.

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AUTOMATION OF MANUAL SPINDLE PRESS FOR PALM OIL EXTRACTION

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ABSTRACT

The processing of the palm fruit locally is crude and tedious for the local and middle class dwellers in palm oil producing communities in Nigeria. The drudgery and time spent in extracting palm oil discourages the youth and affect the productivity of palm oil in our rural community. This study therefore aimed automating the manual spindle press which is commonly used in these community. The existing spindle press was modified to incorporate an electric motor. The major components of the machine were standing frame, threaded shaft, speed reduction gear motor, driving and driven pulley and discharge outlet. The modified machine was tested and was observed to replace the human energy needed in operation and also improved timeliness in operation and production was enhanced. From the quantity of oil produced, it was ascertained that percentage increase of 22.2% was recorded. However, a further research is still recommended a much better increase production.

1. INTRODUCTION

The Palm oil tree (*Elaeis guineensis*), which is the source of edible vegetable, is an important economic tree in Asia, Africa, and South America. About 90 percent of the palm oil produced from this tree ends in food products, while the remaining 10 percent is used for industrial production. Palm oil extract and palm oil manufacturing represent one of the most effective methods of ensuring food security and providing employment opportunities for millions of unskilled, semi-skilled and skilled workers in Nigeria. Its numerous uses and demands increase as the world's population increases and standards of living upsurges. Palm oil accounts for 34 percent of the world's annual production of vegetable oil and 63 percent of the global exports of vegetable oils (Ayodele, 2010; Ekpa, 1995 and Akpanabiatu et al. 2001). Nigeria was once ranked 5th among palm oil producing countries of the world. This lost premier position on the world list of palm oil producers were attributed to neglect of the agricultural sector because of the then oil boom. Study by Ammani (2011) reported that the decline in agricultural production in Nigeria was not statistically attributable to neglect of the agricultural sector during the oil boom period. The reason could be as a manifestation of Dutch Disease, Natural Resource Curse, Rent Seeking phenomenon, or some other reason else. In view of palm oil production, the predominant traditional method of oil processing which is time consuming, laborious, with low production output could be one of the other reasons mentioned.

Lack of appropriate processing technologies constitutes the major obstacle to palm oil production in Nigeria. Over the years attempts have been made to mechanize and automate the various operations involved in palm oil processing. Extraction (pressing) has received the greatest attention for mechanization and automation. Presses developed over the years have included models such as: Manual vertical screw-press, Stork hydraulic hand press, Motor-jack press, Motor-jack/cantilever press, NIFOR hydraulic hand press, combined screw/hydraulic hand press, Mechanical screw-press (Orji and Mbata, 2008; Muthurajah, 2002 and Nwankwojike 2004). The importation of screw press machines for oil palm are very expensive and not readily affordable by small and medium scale processors who form the majority of the processors in Nigeria. Moreover, industries established with imported technology do not function for a long period of time due to lack of spare parts, inadequate maintenance and inability to satisfy some local factors. It is therefore essential to evolve indigenous technology so as to address the issue of palm oil processing in Nigeria.

The manual screw press was a major breakthrough in palm oil production but there need to address some of its shortcomings, like drudgery in extraction of oil, loss of oil in the process of extraction and poor or low quality yield of oil (Poku, 1998, Stephen and Emmanuel, 2009).

This paper therefore aimed reviewing and automating the manual screw/ spindle press so as to achieve optimum efficiency in small - medium scale palm oil production.

2. METHODOLOGY

A survey of the present method of palm oil extraction in some community in Southeastern Nigeria was carried out. Figure 1. Shows the most common traditional and mechanized methods used in the visited community.


(a) Traditional method of extracting palm oil.


(b) A manual screw press operator at work.


(C) A long manual screw press operator at work.


(d) A manual spindle press.

Fig 1: Palm Oil extraction methods in most Nigerian Community

The village traditional method of extracting palm oil involves washing pounded fruit mash in warm water and hand squeezing to separate fiber and nuts from the oil/water mixture. Large quantities of water is used in washing the pulp hence this procedure is called the 'wet' method (FAO, 2002). Oil extraction processes from the palm-nut was a process that span approximately 21 days for the farm family due to the required human efforts, and it involves the cooperation of the man, his wife and children, and in some cases, members of the extended family (FAO, 2002). An improved method was also observed with manual spindle press, hydraulic press and screw press as shown in Fig 1. The manual spindle press was observed to be a good alternative to the traditional manual method of oil extraction in the community. It is relatively cheap and also conserves energy and time with respect to the traditional method of extracting palm oil. However, despite its successes in processing palm oil, setback such as drudgery involved in its operation, and loss of oil due to inadequate pressure application by an operator were observed.

1.1 Modification of the manual spindle press

The manual spindle was modified by adding a round gear to the upward end of the shaft and fixing a thrust bearing to the downward end. A flange bearing, along the shaft was tightened to the frame of the machine for stability. The shaft used was threaded in a trapezoid form to offer high strength during pressing. The circular plate responsible for the compression was designed in such a way that it was attached to the shaft through the hole created on the plate. The plate was designed in such a way that the hole created will be threaded to allow upwards and downwards movement of the plate during the rotation of the shaft. Gears were attached to the rotating spindle of the electric motor and that of the shaft to reduce the speed of the motor and increase the torque. The reduction of the speed of the rotating shaft will give the pressing plate greater torque to be able to compress the palm mash. Finally, the electric motor (electric circuit is presented in Figure 2) was introduced with a gear at the end of it to be able to match the gear on the spindle for proper rotation. Figure 3 and Figure 4 showed the modified manual spindle press and automated spindle press.

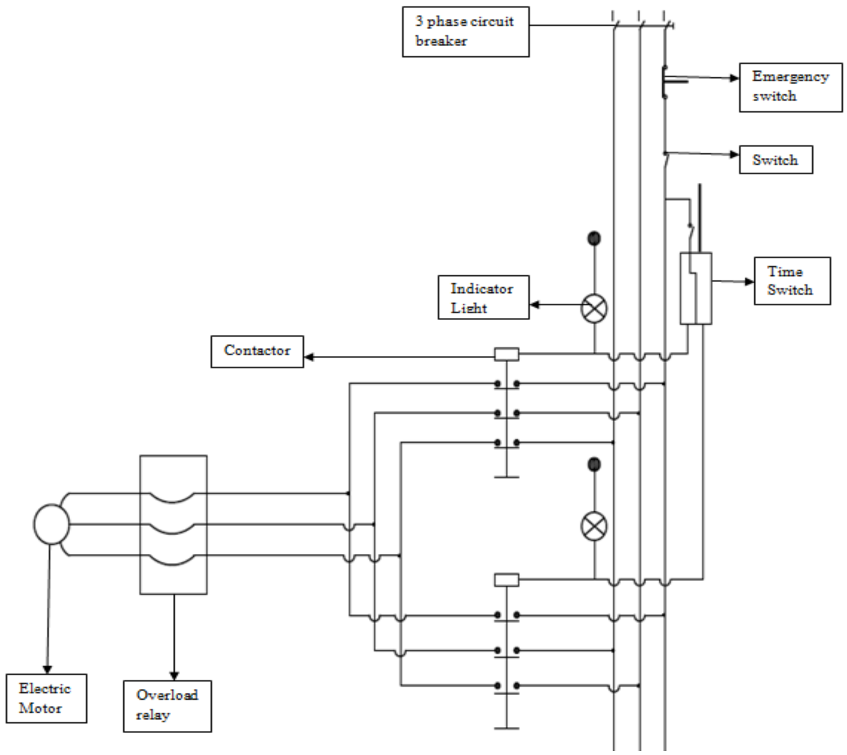

Fig. 2: One Line Diagram of the Electrical Circuit

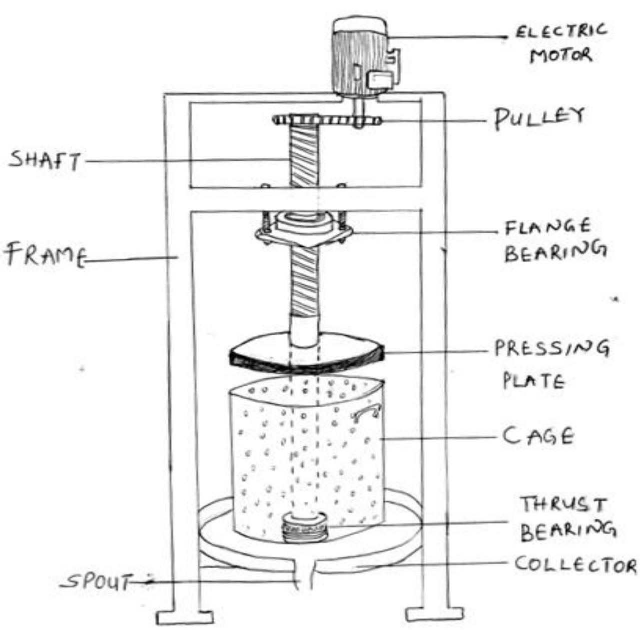

Fig. 3: A diagram of the modified Manual Spindle Press

Fig. 4: Diagram of an Automated Spindle Press

2.2 Design calculations

A 5hp, 750rpm motor was selected and connected to the shaft or spindle.

The shaft speed N_s, was calculated as follows;

$$Speed\ of\ driven\ (Ns) = \frac{Speed\ of\ driver\ (Nm) \times Diameter\ of\ driver\ (Dm)}{Diameter\ of\ driven\ (Ds)} \quad (1)$$

$$Ns = \frac{750 \times 70}{125} = \frac{52500}{125} \quad Ns = 420rpm$$

The motor starts using a star connection. Hence, $V_L = \frac{V_{ph}}{\sqrt{3}}$ (2)

Rated current: $I = \frac{P}{V_L}$ (3)

where I= Current (Amps), P = Power (kW), V_{ph} phase Voltage (Volts), and V_L = Line Voltage

1 hp = 746watts, 5 hp = 3730watts = 3.73kw, 380V_{ph} = 219.39$V_{L,}$ so $I = \frac{5 \times 746}{219.39}$ = 17A

Circuit Breaker Rating:

Since the rated current is equal to 17A, therefore, a circuit breaker of rating 20A was chosen. This prevents too much current entering the electric motor.

Torque transmitted by Motor (T_m): $Tm = \frac{Power\ transmitted\ by\ motor\ (P)}{Angular\ speed\ of\ motor\ (\omega)}$ (4)

Power transmitted by Electric motor (P), $1hp = 0.746KW$, $5hp = 5 \times 0.746 = 3.73KW$

Angular speed of motor (ω), $Angular\ speed(\omega) = \frac{2\pi Nm}{60}$ (5)

(N_m = Speed of electric motor) $\omega = \frac{2\pi \times 750}{60} = 78.54\,rad/s$, therefore, $T_m = \frac{3730}{78.54} = 47.50$N-m

Stress built up in the cage

The cylindrical cage is subjected to two types of tensile stresses, viz: Circumferential stress, and longitudinal stress

Circumferential stress: This is as a result of the internal pressure in the cylinder that has the tendency to split up the cylinder into two troughs. Considering the cylinder specifications; Height of the cage 'H' = 650mm, Diameter of the cage 'D' = 400mm

Thickness of the cage 't' = 10mm.

Total pressure along the diameter of the cage.

We have that stress - $\sigma = intensity\ of\ stress \times area = \sigma dl$ (4)

Circumferential stress in the shell, $\sigma_c = \frac{Total\ pressure}{Resisting\ section} = \frac{\sigma dl}{2tl} = \frac{\sigma d}{2t}$ (5)

$$\text{Hoop stress} = \sigma_h = \frac{Pressure}{Thickness} = \frac{P}{t} \quad (6)$$

Where P = 20psi (137.895KN/m^2), t = 5mm, ram diameter = 250mm

$$\sigma_h = \frac{137.895}{0.005} = 27579\text{KN/m}^2$$

Hoop stress = Tensile stress across the diameter

$$\sigma_c = \frac{\sigma hd}{2t};\ \ d = 400\text{mm} = 0.4\text{m}$$

$$\sigma_c = \frac{27579 \times 0.4}{2 \times 0.005} = \frac{11031.6}{0.1} = 110316KN/m^2 =$$

Volume of the cage: The volume of the cage is given by $V_c = \pi r^2 h$ (7)

Diameter (d) = 400mm, $r = \frac{d}{2} = 200mm = 0.2m,\ \pi = 3.142$

Height of the cage (h) = 650mm = 0.65m, and $V_c = 3.142 \times (0.2)^2 \times 0.65 = 0.082m^3$ X

Area of pressing plates: $A_p = \pi r^2$, $\left[r = \frac{d}{2}\right]$, Diameter of pressing plate = 390mm

r = 390/2 = 195mm = 0.195m, Area = 3.142 × $(0.195)^2$ = 0.12m^2

Pressure on the cage:

Force = Ram pressure × $Area\ of\ pressing\ plate$ (8)

=137.895KN/m^2 × 0.12 = 16.55KN

2.3 Mode of operation

The modified spindle press with flange bearing, electric motor etc., replaced the human energy required in extracting oil from the palm pulp. Its rotational movement, pulls up the pressing plate or pushes it down, which was attached to the shaft in which the electric motor rotates. At clockwise movement, the plate is pushed down to make impact with the plate and on further clockwise movement it applies pressure on it. This pressure extract oil from the palm pulp. During anti-clockwise movement, the electric motor rotates in a reverse direction as a result of the interchange in phases i.e. RYB→RBY. The reversing of the motor comes to a halt immediately after the delay time has elapsed. This is to enable the operator remove the squeezed palm fruit mash. Once this cycle has been completed, the time switch resets and begins another cycle at the command of the operator.

2. RESULTS AND DISCUSSION

The expanded cage of the machine was loaded and an increased oil yield was observed. The incorporated electric motor on top of the frame served replaced the need for human energy required in the extraction of the palm oil. The oil output and timing of operation was observed to be better than the manually operated spindle press. The time taken to extract palm oil dropped from the usual 10 – 15mins used during human operation to 5 – 7mins using the modified automated spindle press. A thorough performance evaluation of the modified automated spindle press is being done to ascertain the efficiency of the machine. Two 25 litres pail filled with palm fruits produces 1 gallon (4.5 litres) of palm oil using the manual method. But using the automated machine for the same two 25 litres pail filled with palm fruits produces up to 5.5 litres of palm oil. The performance efficiency is 22.2 percent

3. CONCLUSION

The manual spindle press which is commonly used in most palm oil producing community in Nigeria was modified by incorporating an electric motor to solve the drudgery involved in oil extraction and also improve the oil yield. The automation was observed to have increased the value of output per person per hour thereby increasing productivity. It also reduces the manufacturing time and minimizes the requirement of more human labour in operating the machine. The automated press system therefore conserves more energy than the manual spindle press. Improving the milling efficiency and the capacity of the processing equipment. Further research on performance evaluation and cost of the modified spindle should be carried.

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COMPUTER-BASED ALGORITHM FOR TEMPERATURE DATA ACQUISITION (TDAq) IN AGRICULTURE AND FORESTRY OPERATIONS

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ABSTRACT
Computer based algorithm for a temperature monitoring using Visual Basic 6.0 (enterprise edition) was developed at the department of Agriculture and Bio-Environmental Engineering technology, Federal College of Agriculture, Ishiagu Nigeria and tested in a temperature device designed to read environmental temperature variations determine their thermal requirements in agroforestry. This system has a comparative advantage of sensing, storing and display of information in unmanned installations unlike other temperature probes that measures momentary instant conditions. The software subsystem consists basically of three parts: The flow chart for initializing commands for the microcontroller; the microcontroller programme and temperature source code programme. The measured temperature value (29.2°C) using a glass thermometer is not synchronous with the material temperature measured using the device. Value changes in temperature reading depends on the condition of the material at a given time. The monitored temperature by the system per minute at the same intervals recorded discrete values of maximum 32°C and minimum 29°C.
Keywords: Algorithm, visual basic, microprocessor, test code, temperature, agroforestry, acquisition

1. INTRODUCTION

The development of climatic profiles for woody materials found in agroforestry is indispensable and without which the description of species would be incomplete and identification of species selections for sites impossible should environmental requirements and tolerances not be included (Bustamante *et al*., 2012). Data acquisition plays an important role in every facets of human endeavour as typically exhibited in agroforest operations, iso-temporal measurements to assess indoor climatic conditions in poultry farms, temperature measurement in poultry house heating (Bello *et al*., 2016; NSW, 2013; Agbakwuru, 2011). Acquisition of a minimum set of climatic data in agroforestry is problematic. Some of these problems ranges from unavailability of the basic data in the field, to the absence or insufficiency of climatic data in relevant literature. Consequently, due consideration has to be given, among other factors, to the collection of climatic data.

One way of achieving this is by Data acquisition (DAQ) process. Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon using a computer. The complete DAQ system consists of sensors, DAQ hardware and a computer with programmable software. The sensor performs a conversation of the physical phenomenon into an electrical signal which is further converted to digital numeric values by DAQ hardware, and controlled by a software program using any of the numerous general purpose programming languages.

In addition to the hardware control, such DAQ software usually also includes data analysis, data visualization, and data storage algorithms. Commercially available DAQ devices range from relatively simple devices up to very sophisticated ones. The latter ones contain analogue-to-digital converters (DAC), digital-to-analogue converters (DAC), digital inputs/outputs, counters, computer bus, circuits for automatic offset and gain calibrations etc. Such large-scale-DAQ devices are very powerful and suitable for applications where functionality has precedence over price, such as within the research area and industrial applications (Agbakwuru, 2011). There are also several applications where such state-of-the-art solutions are sometimes unnecessary. Nowadays, very simple and low cost DAQ devices could be realized using microcontrollers (a small computer on a single integrated circuit containing a processing unit, memory and programmable input/output peripherals) with integrated analogue-to-digital converters (ADC).

Several instruments and methods of measuring temperature have been known and used over the years. However, most of these instruments and methods only measure temperature in analog form and as such does not store the measured temperature data at the various time interval such measurements were taken, thereby making it a little bit difficult in data collection (measurement) and imputation for future purpose for the following reasons;

- The existing instruments available does not accept an intelligent computer program which can monitor, read and store data collected automatically, and
- Most of these instruments' installations are time consuming if there is no existing primary device for measuring flows.

Considering that conventional methods of temperature data acquisition systems lacks the capabilities to store and display information, microcontroller-based data acquisition (DAQ) devices which are controlled by a software program developed using various general purpose programming languages (C++, LabVIEW, Visual Basic, and MATLAB) were developed and have been presented by different authors (Agbakwuru, 2011; Mazidi and Mazidi, 2000; Rejvi *et* *al*., 2011; Rao, 1996). These developed DAQ programme application in agroforestry have remained problematic. Rejvi *et al* (2011) developed a powerful and versatile compact-multichannel-controller DAQ device which has the intelligence of sensing, storing and displaying agroforest temperature data in readable and accessible forms. This device integrates advanced control functions (PID, ON/OFF, time & profiles etc.) and the firmware is stable and the display screen makes the configuration simple and intuitive. The objective of this paper is to present the computer program algorithm for a DAQ device developed at the department of Agricultural & Bioenvironmental Engineering Technology, Federal College of Agriculture, Ishiagu Ebomyi Nigeria.

1. MATERIALS AND METHOD

a. Programming language for data acquisition (DAQ)

There are several software languages used in programming computer data acquisition interface, these include C^{++}, LabVIEW, Visual Basic, MATLAB) among others (Agbakwuru, 2011; Theraja, and Theraja, 2008). Selected software language used in this interface and the device (data acquisition system) is visual basic programming language. The visual basic programming language was used for its ability to serve as a front end application to a data-base system, as well as user interface which collects inputs from the user and displays the formatted output in an attractive format.

b. Visual basic programming

Programming in visual basic is a combination of visually arranging components on a form, specifying attributes and actions of those components. Since the default attributes and actions ought to be defined for the components, it is very simple to write a program without a visual basic programmer. Forms can be created using drag and drop techniques. Visual basic provides many interesting set of tools to help you in building exciting and entertaining applications. It provides a user friendly language which is very effective and efficient (Agbakwuru, 2011). A tool is used to place control such as text box buttons, etc. on the form window. Default value will be provided when a control is created, but it can be changed by the visual basic programmer.

Visual basic is not only a programming language, but it is also a complete graphical development environment. Visual basic has the ability to developed programs that can be used as a front end application to a data-base system, and serving as user interface which collects inputs from the user and displays the formatted output in an attractive format.

c. Experimental device

The experimental device is a box unit comprising of hardware components constructed from locally sourced materials from the open market and assembled together as shown in Figure 1.

The completed unit is to function as temperature acquisition system. The device comprises of a computer system unit, an LCD display unit, digital integrated circuits (ICs) and bus cables.

Figure 1: Experimental device showing building blocks (A) and the screen display (B)

The digital integrated circuits (ICs) used in the design of the system include an LM35 temperature transducer, an AT89C51 microcontroller, MAX232 serial communication interface, DB-9 serial communication connector, ADC0804 analog digital converter, 16 pins liquid crystal display (LCD) and 7805 voltage regulator (Figure 2). The quantity displayed on the LCD is the immediate environmental temperature of the installed system (Jim, 2004).

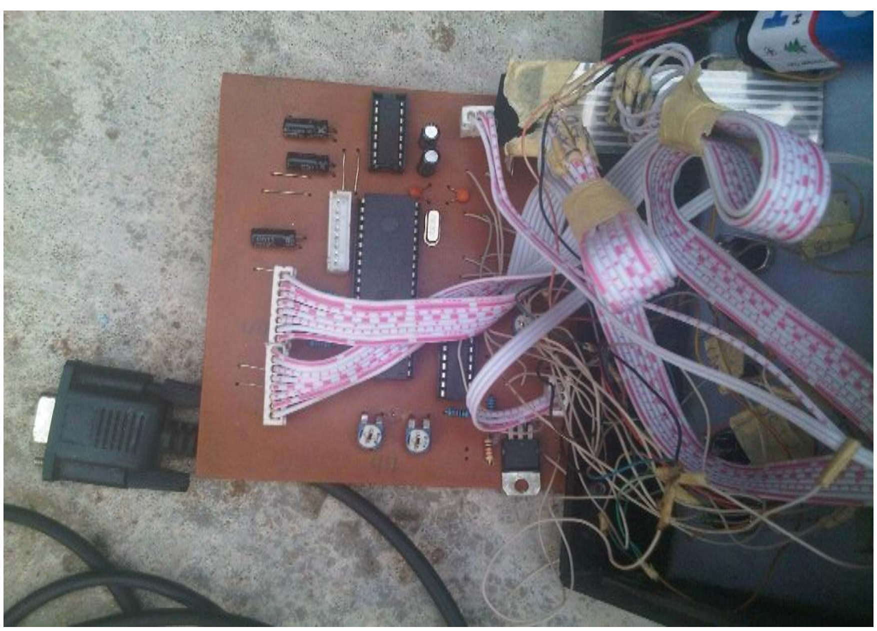

Figure 2: System hardware components

The microcontroller unit supports multi-level programming i.e. its memory has capacity to be mapped into various sections. A microcontroller integrates a number of components of a microprocessor system (i.e. CPU core (microprocessor), memory (RAM and ROM) and parallel digital 1/0) onto a single microchip (Jim, 2004).Also, microcontrollers are cheap and support serial data communication because it supports a set of back rates which are compatible with most computers (Valvano, 2000).

d. Software design selection

The software subsystem consists basically of three parts: The flow chart for initializing commands for the microcontroller; Programming of the microcontroller and temperature source code programme.

i. **Flow chart for initializing the command**

Before the programming of the microcontroller, a flow chart representing the sequence of operations to be performed in order to find solution to the problem as illustrated in Figure 2 was produced. The flow chart helps to facilitate communication between the microcontroller and the units interfaced to it. It also plays a vital role in programming of the problem and helpful in understanding the logic as well as the complication and lengthiness of the problem. Each sub-routine of the system flow chart is assigned to a particular section of the memory of the microcontroller, with one central programming calling each sub-routine when necessary (Young, 2001).

From the flow chart, when the power button is pressed, the LCD is initialized and the system default message is displayed. Pressing the start button causes the system to be in operation and the ADC and transducer perform their respective functions and the result is processed and stored in the microcontroller. If the stop button is pressed, the system displays the first recorded temperature.

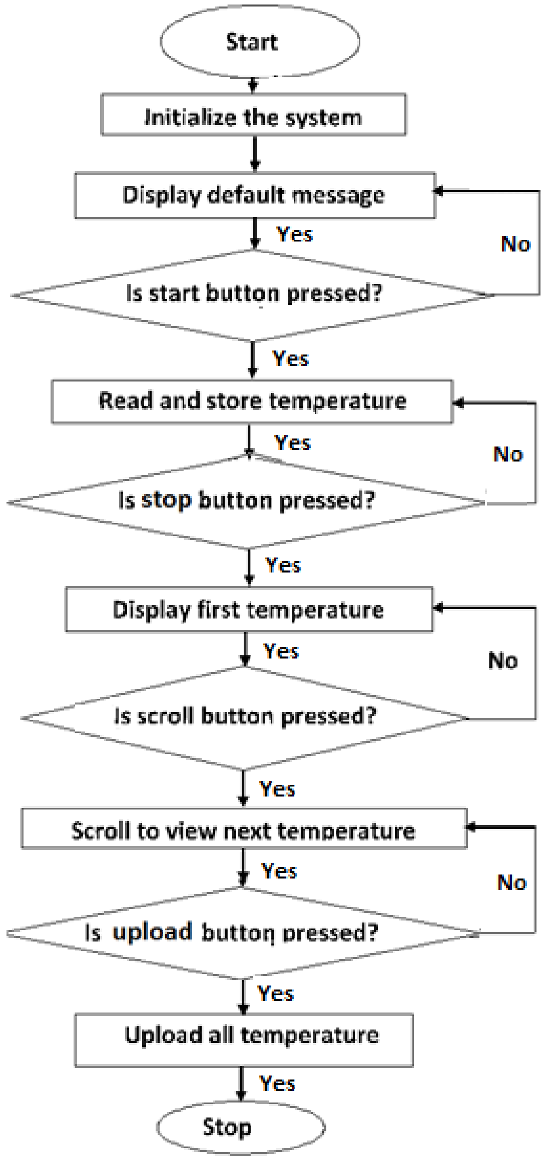

Figure 3: Flow diagram of the software subsystem

To obtain readings of the stored temperature recorded, the up or down button is scrolled. To upload all the recorded temperature data to a computer system, the serial communication port of the acquisition system is connected to the computer system and a program software written using low or high-level programming language (visual basic) creates a Graphical User Interface (GUI) that can then interact with the acquisition system and thus upload the recorded temperature data into the computer system.

ii. **Programming of the microcontroller**

The microcontroller is a high level integrated computer that executes any program burn into it. The microcontroller circuit is shown in Figure 5 which was programmed using an assembly language.

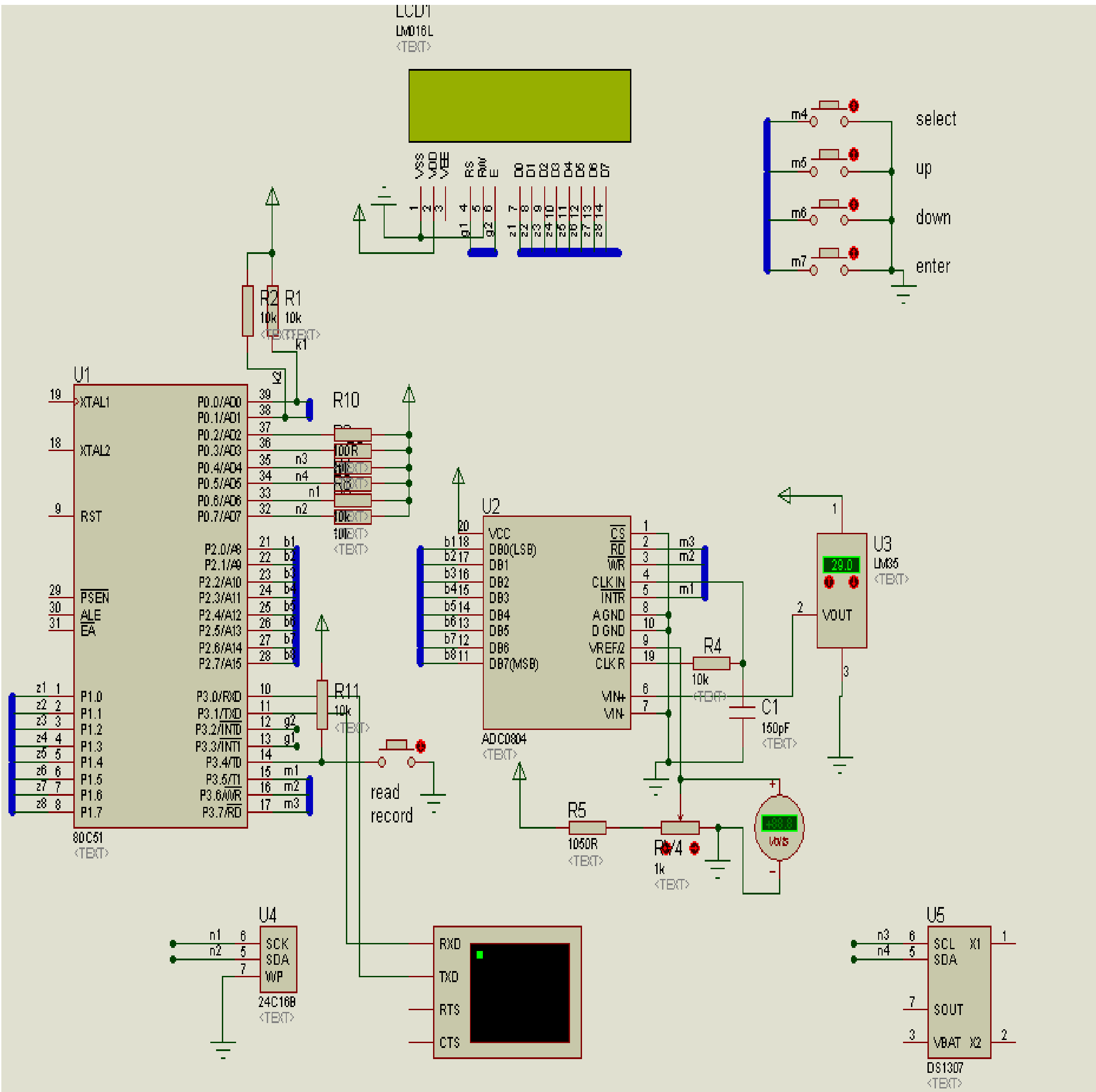

Figure 5: The full circuit diagram of the microcontroller

iii. **Temperature source code programme**

The computer interface programme written in visual basic for temperature source code and illustrated in pseudo code presented in Appendix 1.

iv. Performance test

The experimental temperature control device is shown in Figure 3. Performance test was carried out on the experimental device by installing the sensor in a lumber shed to monitor the temperature change. The required specified temperature of the environment was entered into the system and left for ten minute after which the monitored temperature was uploaded at a fixed intervals of 1 minute into the personal computer via the serial communication port.

Figure 3: Experimental setup with installed programme running

2. RESULTS AND DISCUSSION

a. ***Results***

The computer display results generated is shown in figure 4 and the temperature data measured at regular time intervals within the lumber shed was tracked recorded and stored by the system. Table 1 below indicate temperature measured manually using a thermometer under same test condition. Each measurement was taken at intervals of 1min after a\the initial 10 minute test trials at three different locations, 10m apart within the shed.

Table 1. Atmospheric temperatures measured during the experiment

S/No	**Temperature** (° C)			
	T_1 (° C)	**T_2** (° C)	**T_3** (° C)	**T_{Ave}**(° C)
	28.9	29.0	29.5	29.2
	29.0	30.0	28.9	29.3
	29.0	29.3	28.7	29.0
	29.0	29.9	30.0	29.3
	28.9	29.0	29.3	29.4
	30.0	28.9	28.9	29.3
	29.3	28.7	30.0	29.3
	29.0	30.0	28.9	29.3
	28.9	29.0	29.3	29.1
.	30.0	29.0	29.5	29.5
.	29.0	29.3	29.0	29.1
.	28.9	29.0	30.0	29.3
.	29.0	29.0	29.3	29.1
.	29.0	28.9	30.0	29.3
.	28.9	29.0	29.0	29.0
.	30.7	29.9	30.0	30.3
Mean temp	**29.1**	**29.1**	**29.3**	

An average of temperatures T_1, T_2, and T_3 measured using the thermometer was compared to the monitored temperatures on the device.

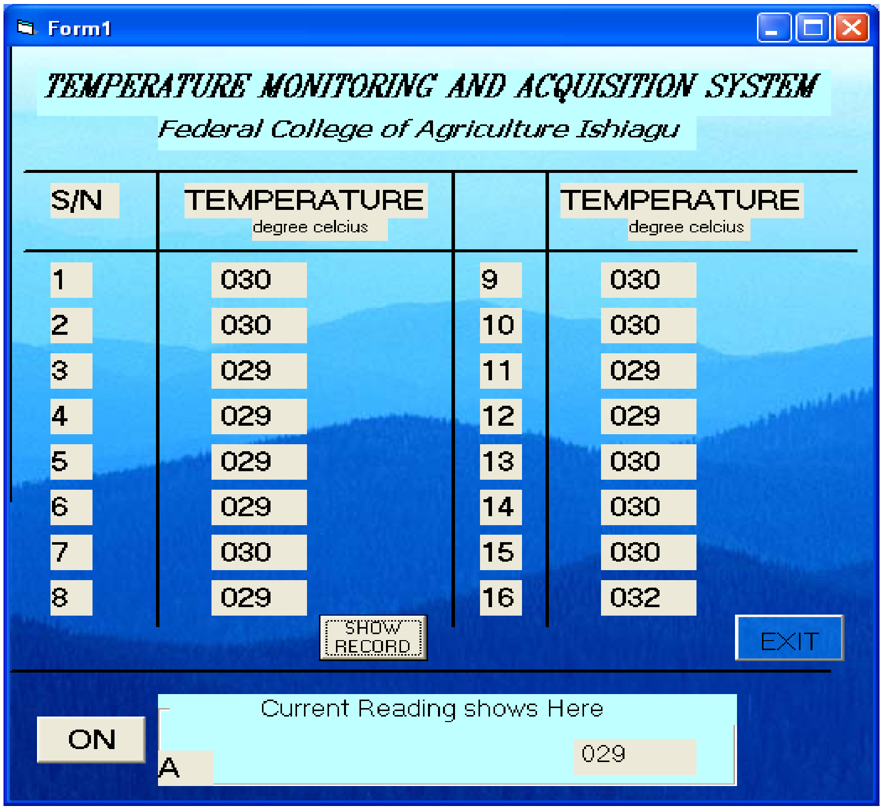

Figure 4: Result of temperature monitored on computer screen

b. ***Discussions***

From Table 1, the mean atmospheric temperatures measured (29.2°C) using a glass thermometer is below the material temperature of 30.0 °C. The measured temperature value is not synchronous with the atmospheric since its value changes depending on the condition of the material at a given time. The monitored temperature by the data acquisition system per minute at the same intervals recorded discrete temperature measurements of maximum temperature of 32°C and minimum of 29°C. Fluctuations in material temperature over time intervals could be attributed to noticeable defects in the stored wood products, especially under the open atmospheric conditions where temperature conditions are not controlled. The increased temperatures observed in wood material favours moisture movement from the wood to air, and subsequent drying.

This system has a comparative advantage of sensing, storing and display of information in unmanned installations unlike other temperature probes that measures momentary instant conditions. However, the instrument has low buffer capacity and could not store long time temperature data especially during power outage for more than 30 minutes as such requires constant power supply to function. The programming language is user friendly and interactive, easy to debug and coded to be used in other applications in agriculture.

3. CONCLUSIONS AND RECOMMENDATIONS

a. Conclusions

Visual basic programming language has been used to drive a temperature monitoring and measuring device in agroforest environment. Though, this programme was coded to measure temperature variation in stored wood in a timber shed in Ishiagu as a case study. The monitored temperature regime between the woods and the environment indicate a ≈2 °C difference which accounts for drying dynamics and moisture movement. The temperature device system has flexibility for modification to measure other physical quantities like atmospheric pressure, relative humidity, light intensity, material density etc. Also the programme can be modified to monitor parametric physical quantities in agriculture, such as farm system heating, animal thermal environment, poultry house temperature requirements etc.

b. Recommendations

To improve the performance of the temperature acquisition system, the following recommendations were made;

1. The serial communication bus could be replaced with a universal serial bus (USB) which is becoming universal port connector.
2. The device should be tested under controlled atmospheric storage condition and its application in other fields of human endeavours are possibilities that could be explored
3. The system should be upgraded to improve on data storage time during power outage.

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Appendix 1

Source code for temperature monitoring

```
Option Explicit
Dim count1 As Integer
Dim cnt As Byte
Dim rnt As Byte
Dim sData As String ' Holds our incoming data

Private Sub Command1_Click ()
'k = 1
Timer1.Enabled = True
End Sub

Private Sub Command2_Click ()
End
End Sub

Private Sub Command3_Click ()
cnt = 1
rnt = 1
```

```
End Sub

Private Sub Form Load ()

Timer1.Enabled = False
‘Fire Rx Event Every Two Bytes
MSComm1.RThreshold = 1

‘When Inputting Data, Input 2 Bytes at a time
MSComm1.InputLen = 1    ' 2

‘9600 Baud, No Parity, 8 Data Bits, 1 Stop Bit
MSComm1.Settings = "9600, N, 8, 1"

‘Disable DTR
MSComm1.DTREnable = False

‘Open COM1
MSComm1.CommPort = 15
MSComm1.PortOpen = True
                        'Label4.Caption = 0
End Sub

Private Sub Form Unload (Cancel as Integer)
MSComm1.PortOpen = False
End Sub

Private Sub MSComm1_OnComm ()

Dim lHighByte As Long   ' Holds HighByte value
Dim lLowByte As Long    ' Holds LowByte value
Dim lWord As Long       ' Holds the Word result

'cnt = 0
count1 = 1
```

```
'
' If comEvReceive Event then get data and display
If MSComm1.CommEvent = comEvReceive Then

        sData = MSComm1.Input ' Get data (2 bytes)
       'Label22.Caption = Label22.Caption & sData
        count1 = 1
        lHighByte = Asc (Mid$(sData, 1, 1)) ' get 1st byte
    If cnt = 1 Then

            cnt = cnt + 1
            Label22.Caption = " " 'Label22.Caption & Val (sData) 'cnt

    Else If cnt = 2 Then
            If rnt <= 3 Then
                rnt = rnt + 1
                Label22.Caption = Label22.Caption & Val (sData)
            Else
                rnt = 1
                cnt = 1
            End If
 '############### 1 ##########
    Else If cnt = 10 Then
            cnt = cnt + 1
            Label4.Caption = " " ' Label4.Caption & Val (sData)
End Sub

Private Sub Timer1_Timer ()

MSComm1.Output = "A"
Label21.Caption = "A"
cnt = 10
rnt = 1
Timer1.Enabled = False
End Sub.
```

DEVELOPMENT, CONSTRUCTION AND PERFORMANCE EVALUATION OF ADAPTIVE TECHNOLOGIES FOR SPLITTING COCONUT

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ABSTRACT

Two adaptive technologies (punch-split and impact-split mechanisms) were employed in the development of a coconut splitter and its performance evaluated with existing machines. The essential features of the splitter include dual splitting mechanisms (punch and impact split), handle, screw shaft, constrictor cup and pressure plate. Performance evaluation results indicated that the impact-split mechanism has higher machine capacity (≈ 625 nuts/hr), higher splitting efficiency (93.14%), linger splitting time (≈ 6 sec) and safer operation compare to the punch-split capacity of (≈ 360 nuts/hr), 88.17% splitting efficiency and reduced splitting time of 4.28sec. In comparison with existing splitters, the machine has comparative advantage in output capacity, lower machine cost and maintenance cost unit operation. The estimated cost of fabricating the machine was N20, 300.00 ($55.62). The level of technology adoption of the technologies among the end users in Ivo LGA favours the impact split mechanism (87.8%) than the punch split mechanism (60.0%).

Keywords: Coconut, splitter, efficiency, splitting, mechanism, constrictor, and capacity.

1.0 INTRODUCTION

Coconut also known as “tree of heaven”, is mainly cultivated for its nuts, oil, oil cake, fiber and provides many necessities of life including food and shelter. The white fleshy interior is tasty and can be eaten when grated, chopped, cooked or used to flavor foods. The husk or fiber, is used to make coir which in turn has multiple applications. The water is a refreshing drink which has many healing properties and as a substitute for blood. Coconut oil and milk, which have additional applications, can also be extracted from the flesh. The hard shell is fashioned into ladles, cups and other household and decorative objects. The nutritional content of coconut contains traces of proteins, fats, and minerals like Na, K, Ca, Fe, Cu, P, S, Cl, and vitamins of the C and B group like nicotinic acid, pantothenic acid, riboflavin and biotin (Mownesh and

Mehatha, 2015, Rajanikanth and Reddy, 2015). People, especially living in tropical countries and island communities have used and continued to use it in many facets of daily life as food and health, and in some instances as currency.

As coconut enters into agro-processing world, with homes as well as restaurants deriving benefits from using fresh and matured coconuts in everyday cooking, the difficulty experienced in dehusking and breaking them open is an impediment deterring housewives, chefs or restaurant operators from using them in their cooking more often. A review of existing coconut dehusking techniques by studying commercially available machine and other developed concept had been carried out and some design have also been proposed by Indika, (2015). Cutting open the tender coconut and separating the kernel from shell after dehusking is not an easy task. There had been in existence different devices and mechanisms for splitting coconut, but involves direct human effort and aids. Conventional manual breaking methods of coconut that has been widely practiced include: 1) By using a sharp chef's knife or a meat cleaver (Vinay *et al.*, 2016) and 2) hitting on a hard surface. The present trends and tools in use are ergonomically unsafe, unsustainable, and messy and often require skills and training (Roshni, *et al.*, 2009).

Throughout the history of mechanization of coconut, this task had been made easy by the introduction of coconut punching and splitting machines. In 1926, Carter invented a splitter to split open coconut, so that the kernel can be removed easily from the shell after sun drying. Rey in 1956 developed another a rather too bulky apparatus to split open coconuts of which very few models are available in the market today. Anitha and Shamsudeen (1997) developed a tender punch splitter in which the punch was pivotally attached to a hand-lever, which was hinged along a horizontal pin mounted on a stand. The up and down swinging of the hand-lever made the punch reciprocate up and down in a sleeve. Jippu (1998) equally developed a tender coconut punch, activated by a slider crank mechanism. A limitation of this equipment is the difficulty experienced in punching more matured tender coconuts due to increased hardness of the shell. Shamsudeen *et al.* (1999) developed a tender coconut cutter. But it was experienced that the mechanical work was not adequate to split open the overripe nuts easily. A coconut splitting device developed by Beloin in 2008 has a lowering device which lowers coconut onto the cutting blades to split it open (Roshni, *et al.*, 2009).

An innovative research and development paved way for 400% increase in coconut output through the development of the 1st ever coconut cutting machine that is able to crack 450 coconuts per hour (FIRC, 2016). This machine increased productivity significantly by 435%. In 2009, Foale developed a cocosplit nutcracker that splits with firm blow from a large 1350 gram (3 pound) hammer. The mechanism consists of a base plate for saving the juice, a circular cap, chisel point and spring. Locate the nut carefully on the cushion of the base-plate. Direct contact between shell and the metal base-plate may cause a jagged break in the shell.

In 2010, Unnikrishnan (2010) reported the development of a coconut punch and cutter having a cutting blade mounted on a stand and then operated with a lever pivoted to the other end of the blade through a horizontal axis. The cutter can be used to cut the shell and separate the kernel with ease. Pattenden in 2011 obtained a US patent for his invention; a tool to pierce and slit a coconut (Pattenden, 2011). The equipment is one embodiment of a tool designed to pierce and split a coconut to facilitate removal of water and meat from the nut.

2.0 MATERIALS AND METHOD

2.1 Conceptual machine development

The machine was developed from the concepts of manually splitting coconut with pressure application either from a punch or an impact from a heavy object (Bello and Emmanuel, 2014).

2.2 Material selection

Materials of construction: The materials of construction were sourced locally from the open market as well as from metal junk houses around. Three major materials of construction used are mild steel rods and plates, as well as hard wood.

Coconut samples: Coconut samples (Figure 1) were sourced from the local market ad their geometrical dimensions measured and recorded in a table.

Figure 1: Coconut samples

2.3 Machine description and operation

The machine comprises of dual cracking mechanisms, a punch-split mechanism and an impact-split mechanism (Figure 2). The machine can be used simultaneously to crack open coconuts and can be used as single unit.

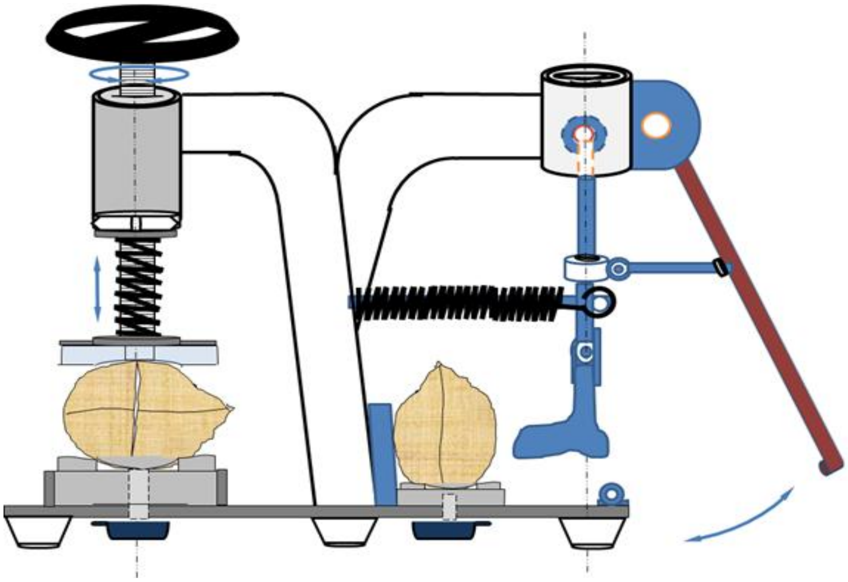

Figure 2: Schematic drawing of device

The punch-split mechanism: The punch-split mechanism comprises of a G-frame, a screw shaft with chisel/punch head, a spring loaded wooden block guide and a constrictor cup. The machine was developed from the concept of cocosplit developed by Foale (2009). The nutcracker (cocosplit) is mechanically used to split coconut with a firm blow from a large 1350 gram (3 pound) hammer. However, the hammer was replaced with a screw shaft with a punch head.

In operation, the coconut is placed on the constrictor cup, while the spring loaded wooden block is used to stabilize the coconut in place. As the screw shaft is wheeled down, the punch end of the shaft touches the coconut and exert a compressive force until the force exceed the yield strength of coconut and splits. The water drains through the drilled hole in the constrictor cup, through the baseplate into the receptacle below the plate.

Figure 3: Punch-splitting by the machine

The impact-split mechanism: The impact-split mechanism unit comprise of a handle, hinge (pivot pin), 13mm bolt and nut and a pressure bearing attached to the handle. The lever is a 1½ inches diameter stainless pipe, 1200mm long attached to the G-frame though the pivot pin, 13mm bolt and nut. The hammer is suspended by a 17mm bolt and nut on the G-frame and spring loaded for impact when operated. The extension spring has a bulk length of 150mm and a free length of 250mm on extension guided by a 6.5mm rod to prevent buckling in compression. Coconut constrictor formed from a half-hollow wooden material centrally positioned in alignment with the screw shaft restricts the coconut during impact. G-frame is a tubular rectangular G-shaped metal permanently welded to the base plate support and houses all other components attached.

In operation, the coconut to be split is contained in the constrictor cup on the base platform while the spring loaded hammer suspended on the G-frame and running on a sliding pressure bearing made impact on the coconut when the lever is pulled. The hammer displaced through an angle of 45° produces a force as the lever is released. The impact action of the hammer exceeds the yielding strength of the coconut and it splits open in a neat track (crack) round the coconut. The water drains through the drilled hole in the constrictor cup, through the platform into the receptacle below the plate.

Figure 4: Impact-splitting action of the machine

2.4 Machine performance indicators

Machine performance indicators investigated include:

a. Splitting efficiency: Splitting efficiency is expressed as the effectiveness of splitting open a coconut compare to known machine performance:

$$Splitting\ efficiency = \frac{Length\ of\ obervable\ crack}{Diameter\ of\ cocnut\ along\ the\ axis} X\ 100\% \qquad (1)$$

b. **Machine capacity:** Machine capacity expressed as the quantity of coconut split per unit time of measurement:

$$Machine\ capacity = \frac{Total\ weight\ of\ cocnut\ split}{Time\ taken}\ (\frac{kg}{hr}) \qquad (2)$$

c. **Machine rate:** Total number of coconut split per unit time is evaluated from:

$$Total\ no\ of\ coconuts\ split = \frac{Machine\ capacity}{Mean\ unit\ weight\ of\ cocnut\ split} \qquad (3)$$

d. **Crack patterns on coconut samples split**: The visible split patterns noticed on each coconut under load is described as follows:

Hair pin: Superficial cracks measuring ≈1mm gap in the coconut shell and not affecting the flesh

Minor: Cracks measuring approx. 2-3mm gaps revealing the flesh. The shell and flesh experienced near visible cracks

Major: Openings greater than 3mm revealing the inner flesh

Shatter: Complete breaking of coconut into several parts

3.0 RESULTS AND DISCUSSION

3.1 Physical properties of coconut samples

The physical properties of selected coconut samples for the test is shown in Table 1 below. The measured average weight, mean diametric width and length of coconut samples is 2.12kg, 168.06 mm and 177.09mm respectively.

Samples	**Mean of measured parameters**		
	Axial length (L)	**Diametric width (W)**	**Weight (Kg)**
A	190.20	170.80	2.56
B	180.40	180.20	1.83
C	170.34	160.74	1.50
D	167.40	160.50	1.68

Table 1: Mean of measured physical properties of coconut samples

3.2 Machine performance under load

The machine typically showed desirable performance under load (Figure 5). For the impact split mechanism, at the first impact, a hair pin/minor cracks appeared in most of the coconut samples, on the second impact, the cracks developed into major cracks and subsequently shattered cracks (Figure 6).

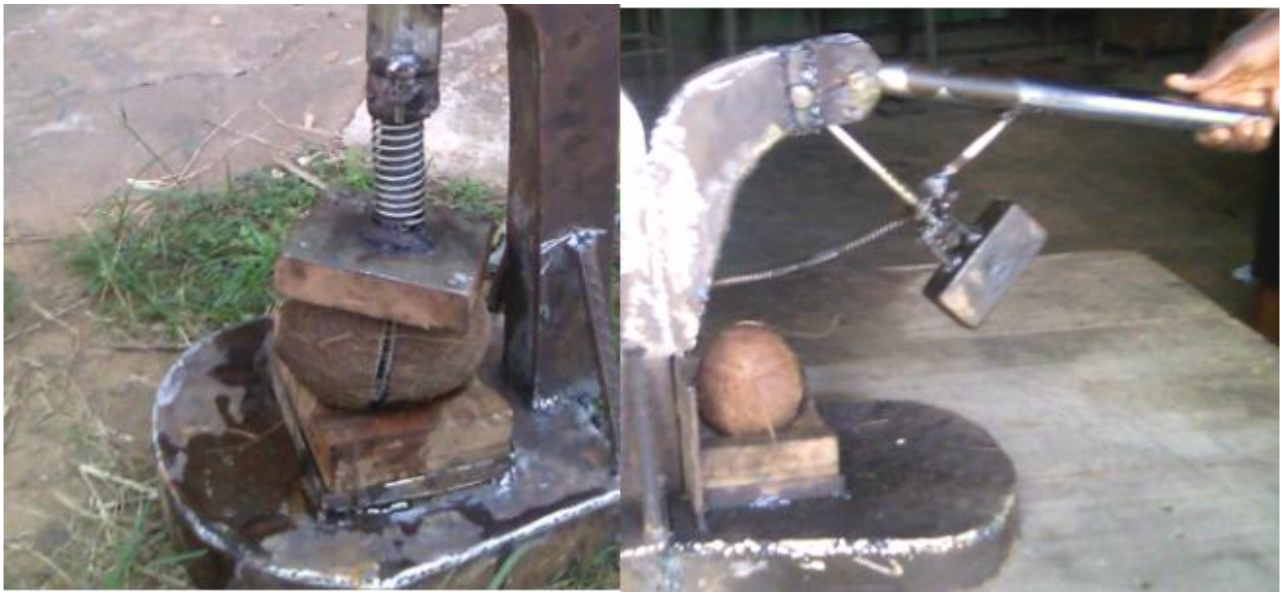

Figure 5: Punch and impact-split mechanisms under load test

However, the punch split mechanism required much effort to overcome the initial resistance offered by the shell to crack the nut, and subsequently, the nut rapidly yielded under the applied force. Table 2 shows the pattern of cracks in coconut samples and Figure 15 shows the pictorial representations.

Table 2: Description of crack patterns on coconut samples split

Samples	Pattern of crack at impact		
	1st	2nd	3rd
A	-	Minor	Major
B	Hair pin	Major	Shatter
C	Major	Major	Shatter
D	Hair pin	Major	Shatter

Figure 6: Pattern of cracks on coconut samples

Mean of measured length of cracks in coconut samples and the average time taken in cracking each nut is shown in the Table 3.

Table 3: Measured lengths of cracks and time taken to crack coconut samples

Samples	Length of crack at each impact			Time taken (sec)	
	1st	2nd	3rd	Impact -splitter	Punch -splitter
A	-	7.80	150.60	6.50	5.50
B	5.70	13.60	170.20	5.80	4.50
C	14.30	15.20	152.70	5.10	3.50
D	8.30	14.40	152.40	5.20	3.60
Mean				**5.65**	**4.28**

Comparing the mechanisms' performance characteristics, the impact-split mechanism has higher capacity in terms of total nuts cracked per hour (≈ 625 nuts/hr) than the punch split (≈ 360 nuts/hr), the impact-split mechanism has high splitting efficiency (93.14%), splitting time (≈ 6 sec), ease of operation and safer comparable to the punch-split with an efficiency of 88.17% and reduced splitting time of 4.28sec (Table 4.The impact split mechanism is easier and more convenient in operation than the punch-split mechanism. The estimated cost of the fabricated dual mechanism machine was N20, 300.00 ($55.62). An estimated unit cost of individual mechanism are; punch split unit is N8, 500.00 ($23.29) while the impact split unit costs N11, 800.00 ($32.33).

Table 4: Comparison between the dual-splitter mechanisms

Performance	Punch-splitter	Impact-splitter
Splitting time	Reduced splitting time ≈4.28 sec	Longer splitting time ≈ 6 sec
Machine capacity	Low capacity ≈ 360 nuts/hr	High capacity ≈ 625 nuts/hr
Splitting efficiency	88.17%	93.14%

3.3 Performance comparison with existing splitters

Performance characteristics shown in Table 5 indicate the comparison between the developed machine and some existing splitters. The dual splitter has better performance judging from the available literatures.

Table 5: Comparison between the dual-splitter with existing splitters

Machines	Time (sec)	Machine capacity (kg/hr)	No. of nut/hr	Cracking efficiency (%)
Punch-splitter	4.28	1315.28	≈ 360	88.17
Impact-splitter	6.00	1,417.85	625	93.14
FIRC, 2016	7.00	-	450	-
Ranganath *et al.*, 2016	7.50	-	480	-
CPCRI 2016	7.00	5,000.00	400	92.16
Tonpe *et al.*, 2010	-	-	195	90.00
Beloin, 2009	-	-	200	92.00

3.4 Performance comparison with traditional (manual) method

Comparing the dual-splitter machine performance with the traditional methods of heating on hard surfaces and knives, a survey was conducted among coconut sellers in Ivo LGA on the acceptance of the technology as well as on some ergonomic factors. The outcome is presented in Table 6.

Table 6: Comparison between the dual-splitter mechanisms and traditional method

Performance	Traditional method	Punch-splitter	Impact-splitter
Handling	Stressful and hazardous	More effort is required in screwing and unscrewing	Little effort required in operating lever
Loading and unloading	Loading time not required	Longer loading & unloading time	Requires lesser time
Cleanliness	Unclean splitting operation with high soiling tendency	Possibility of coconut puncture	Clean split operation
Risk factors	High (82.4%)	Less (41.4%)	Much less (18.6%)
Ease of use	Difficult (73.4%)	Easy (45.2%)	Quite easy (90.3%)
Effort required	Very high (84.7%)	Less (68.4%)	Much less 89.6%)
Wastage	High (50.5%)	Low (78.1%)	Low (88.4%)
Cost valuation	Low (95.8%)	Moderate (64.7%)	Moderate (70.8%)
Technology adoption	High level (20.2%)	Moderate (60.0%)	High level (87.8%)

From the table, the technology is more acceptable and preferred to the traditional manual methods. The machine was generally preferred to the conventional traditional methods and the time required to break the coconut shell using this machine is less comparable to traditional method.

4.0 CONCLUSION AND FUTURE WORKS

4.1 Conclusions

Based on the overall objectives the following conclusions are evident;

- A dual coconut splitter was developed and constructed and its performance evaluated.
- The test results indicate a desirable, easy and hazard free operation, short splitting times (approx. 4.8-6 secs), increased machine capacity (625 nuts/hr) and high splitting efficiency (93.14%).
- The developed machine compares favourably with existing machines in cost and improved mechanical advantage and high level of technology adoption among end users.

4.2 Future works

Future works in the development of machine operation considers continuous rather than batch operation. Furthermore, improvement in the design of coconut holding device (constrictor cup) during operation is under consideration.

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COMPUTER VISION AND INTERNET OF THINGS FOR FOOD SAFETY AND QUALITY INSPECTION

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ABSTRACT

The importance of food quality and safety in a society cannot be over-stated since food security impacts national security. In general, food inspection is a manual, time-consuming, error prone, and expensive process. Computer vision (CV) systems, which enable a computer to replicate human vision and decision-based outcomes, have been applied to automate, speed up and streamline the inspection process. Nigeria as a developing country has many food quality and safety inspection challenges that could be solved using such existing technology. In this paper we look at the computer vision techniques applied to food quality inspection and then discuss how it can be tailored to fit the Nigerian environment.

Keywords: Computer Vision, Food safety and quality, Meat inspection, IoT, Machine Learning

I. INTRODUCTION

Food safety and quality monitoring involves inspection and analysis at every stage of the food production chain from the farm to consumers' plate to prevent potentially dangerous health risks (Maksimović 2015). Individuals in developed and developing economies are now more conscious of what they consume especially those that require strict diets to avoid health complications. For example, diabetics have to constantly monitor their sugar intake as a spike or drop in their blood sugar level can have grave consequences. Also, food processing companies must ensure that their products meet consumer demands and remain competitive while abiding by strict laws stipulated by national and international food safety regulators. Thus, is it imperative that the process of food quality inspection is made to be cost-effective, efficient, faster and safer.

Computer vision (CV) systems have been used successfully for so many years as a tool for cost-effectiveness and accuracy in food quality inspection. It is used in monitoring conditions in a bakery; checking for defects and stage of ripening in fruits; classification of grains into varieties; checking for meat tenderness, packaging and logistics (Sun 2000; Tillet 1990; Timmermans

1998; Gunaserkaran 1996). According to Ballard and Brown (1982), "*Computer Vision can be defined as the construction of explicit and meaningful descriptions of physical objects from images*". Computer vision, also known as machine vision, is an easier and automated way of obtaining data that would have been difficult to obtain via manual methods. A basic computer vision system consists of the following process.

- Acquiring the image of a physical object using a suitable image sensor
- Analyzing the image with specialized computing software and hardware

The image sensor can be an X-ray, ultrasound, near infrared spectroscopy, displacement device, documents scanners etc. The major aim of computer vision is to mimic and automate the human visual decision making process on color, texture, shape and content (Du and Sun 2006). This information is stored as pixels that comprise the acquired image. Intensity defines the scalar value of the pixel. Color describes the intensity vector value of the pixel. The size is defined by the group of pixels, while shape denotes the objects boundary or interior region. The texture defines the dependency between a pixel and its neighboring pixels. The color, shape, texture and most times the contents of a food product are attributes that a consumer checks prior to purchasing or consuming a food item.

Over the years, computer vision has been applied to various foods for inspection and quality assurance. For baked goods, Scott (1994) analyzed the height and slope of the top of bread loaves while Sapirstein (1995) analyzed the crumb grain as metrics to determine and measure defects in bread and cake for corrective action. Images of beef were used to determine tenderness and also differentiate between fat and lean by extracting and analyzing color and textural features (McDonald and Chen 1990; Li et al. 1997). Basset et.al (2000) showed that the age, muscle type and breed can be determined from images of slices of bovine meat. Vegetable, fruit and grain are not excluded from the narrative as computer vision techniques have been applied to them for several purposes.

Image processing is the core technique of computer vision and can be categorized into low level, intermediate level and high level processing. The low level deals with image acquisition and pre-processing. The intermediate level involves image segmentation, representation and description. The high level uses neural networks and statistical classifiers for image feature recognition and interpretation (Sun 2000; Gunasekaran and Ding 1993; Swami and Swami 2010).

A computer vision system acquires and analyzes an image, just like a human eye, then makes informed decision based on the analysis. The outcome of the analysis is heavily dependent on the quality of image acquired. Thus, the image acquisition process is the primary step in ensuring accurate results. Image acquisition involves the capture of optical signals from real images and storage as analog or digital electronic data using an analog or digital image sensor or camera. These camera sensors can be webcams, embedded cameras, digital compact camera, Digital Single-Lens Reflex (DSLR) camera, three dimensional cameras, laser range finders and other devices used in capturing images. The next step is the pre-processing which involves enhancement or noise removal using appropriate filters to improve image quality.

The image segmentation step facilitates the division of the image into regions of interest. Based on the segmentation, the image can be represented as a boundary or as a region. Quantitative information can now be extracted from the image as a way of describing it. There are various methods of carrying out segmentation, representation and description based on the specific aim of the computer vision system being designed.

Image recognition and interpretation can be carried out using various methods like neural networks, classifiers, fuzzy logic etc. on the region of interest. This is arguably one of the most important steps in the computer vision system. It is of absolute importance to accurately interpret the acquired data and apply it in the decision making process. A knowledge database is required for data storage, which facilitates accurate and intelligent decision-making. Some machine learning techniques can be applied to this database for premium analysis of data.

The science of computer vision is interdisciplinary, thus requiring cross-functional and systems expertise in a number of technologies. For some time now, computer vision has been a closed loop of data acquisition and analytics but recently, with the introduction of internet connectivity, advanced sensor technology and advanced analytics, has created a doorway for machine learning and the internet of things (IoT). This has revolutionized the way computer vision systems work.

2. REVIEW OF RELATED WORK

Farmers, food processors and consumers have several properties they apply in meat quality inspection. These include lean meat content, animal welfare and ecology, meat color, nutritional value and safety (presence/absence or quantity of toxic compounds, drugs, and other contaminants). These properties determine the acceptance or rejection of the meat. The meat industry, as a part of the food industry also requires inspection and quality control of meat. The tenderness, spoilage detection and meat shelf life are some of the characteristics used in asserting its quality. The age, sex, muscle shape, fat color, fat texture, meat color, meat texture and meat marbling are also important meat characteristics used to determine its grade and quality with the use of computer vision.

2.1 Internet of Things Enabled Computer Vision

The Internet of Things (IoT) is a paradigm that works on the concept that every single device or "thing" is connected to the internet. “Things” are everyday objects, which can be read, recognized, located, addressed and controlled through the Internet enabled with either Radio Frequency Identification (RFID), Wireless Local Area Network (WLAN) or Wide Area Network (WAN). “Things” are able to “speak” for themselves without much intervention from human beings; therefore, we could monitor anything (Niewolny 2013). With respect to computer vision systems, “Things” can be any gadget used for image acquisition and dedicated hardware for image processing. Looking at computer vision from the IoT perspective, it introduces the advantage of remotely monitoring food inspection processes in real-time. It also enables the initiation of relevant action based on data gathered from the sensors. Such action could include increasing or reducing the temperature of a freezer/cold room if the sensor records a temperature lower/higher than a preset threshold.

The application of IoT in various industries has shown great promise. It is currently used most commonly in the food and agricultural industry to track and trace the status of products through the production, processing and supply chain. IoT is just a few steps ahead of the technology that used radio frequency identification (RFID) and bar codes to track food items from farm to table. The IoT can be applied to the meat industry through the following ways;

- Leveraging available data generated from constantly monitoring the cattle/fish/poultry from their farms to determine how their diet affected growth and how they reacted to different medicinal treatments that may have been administered.
- Using appropriate sensors to monitor livestock by tracking their location and monitoring vital signs.
- Infusing IoT technology with the transportation of slaughtered animals from farm to retail shops to table.
- Improve food shopping experience for consumers by taking advantage of data collected from sensors used in meat inspection (by tracking temperature and humidity from farm to table).

The Food and Agricultural Organization (FAO) predicts a 70% rise in global food production to meet expected demand by 2050 (Connecting the IoT: The Road to Success 2018). Therefore, systems that can handle the increase in workload are important. An IoT system consists of data acquisition layer and a data analysis and storage layer, quite similar to the Computer Vision System. The data acquisition is normally executed with the use of sensors that have internet capabilities or sensors that connect to devices like smartphones with internet connectivity. The data analysis layer can be carried out via cloud computing or edge computing. The IoT provides the ability to remotely monitor things in real-time and initiate relevant action using sensors and computers with little or no human intervention. Containers used to transport meat from the slaughter house to the market can be fitted with sensors that constantly monitor temperature, and the recorded temperature delivered in real-time to an inspector. Therefore, if the temperature is about to rise above unacceptable values, appropriate action is taken to avoid health risks. Sensors are used to monitor safety factors like food dust particles, temperature or humidity during processing in manufacturing plants and logistics of containers.

Smart cameras with internet connectivity can be connected to the cloud for real-time analysis of captured images of meat or any food product. The cloud gives it the capabilities to handle large amount of data, run complex algorithms for analysis and adequate data storage. This reduces the amount of hardware required thus making the system cheaper and easier to deploy.

Market analysts from International Data Corporation (IEEE Transmitter 2018) predicts that by 2020 there will be about 30 billion connected things. This means that there will be an increase in amount of generated data thereby making decision-making process easier since more data would contain more relevant information. The IoT produces a large amount of data that was not previously available, thus the new question is how to effectively harness the information contained in the data to improve the way our industries work. This is where Machine Learning as part of Big Data analytics comes into play.

2.2 Machine Learning-enabled Computer Vision

As a result of the growth associated with computer vision, there is a data deluge, thus, a greater need for higher processing speed and accuracy in data analysis. Machine Learning (ML) allows prediction of new behavior through learning past behaviors and rules from old data. It can be applied to diverse industries such as education, medicine, veterinary, banking, telecommunication, security, etc. It can be used for various data processing tasks such as classification, regression, estimation, clustering, prediction and decision-making (Qiu 2016). The

ML requires a broad choice of features and large datasets provided by computer vision to train the intelligent machine.

Thus, ML would enable food and health officials to easily detect anomalies or presence of harmful contaminants in food samples. It would provide a better understanding of what causes contamination and spread of food-borne diseases. The ML can also be used to build up a database for future use. For example, Mars and IBM (Consortium for Sequencing the Food Supply Chain 2018) are building up a genetic index of bacteria that can occur in food by sequencing their DNA and RNA of the bacteria.

There are several machine learning techniques that can be applied for food data analysis. These include Naïve Bayes, C4.5, Decision trees, Genetic Algorithm (GA), Support Vector Machine (SVM), k-Nearest Neighbour and Artificial Neural Networks (ANN). These have different strengths and weaknesses, therefore more than one technique can be combined for better analysis and classification.

Machine learning can also be used to extract features from images (Lin 2011). Cortez and Portelinha (2006) employed a Support Vector Machine for feature selection based on sensitivity analysis. This model was used to predict the tenderness of lamb meat. Color is also an important feature for the classification of various meat properties. Gerrard et al. (1996) effectively predicted the lean color and marbling scores in 60 steaks using image processing techniques. Hu et al. (2012) used SVM in conjunction with computer vision to classify fish species by color and texture. Quinn et al. (2011) used k-nearest neighbour for classification of images of cassava leaves based on color and shape information in other to detect crop diseases.

Neural networks have also been applied to evaluating color in meat and Lu et al. (2006) applied this technique to pork meat with a very low prediction error. Neural network classifiers have also been used to classify chicken carcass as bruised, torn or tumorous (Park et al. 1996) or to detect anomalies/defects in chicken carcass at a high processing speed using a color histogram (Daley et al. 1994). A neural network was also applied to fish species classification by measuring the number of features of different fish species moving on a conveyor belt at the speed of 0.21 m/s, then classifying the specie from input data (Storbeck and Daan 2001). Furthermore, Prevolnik et al. (2011) did an extensive review on the application of ANN to meat production. They highlighted the novel technologies for meat quality evaluation and control.

Deep Learning (DL), which is a complex and advanced ML is used when presented with even more data. According to Nvidia, advancements in deep learning have reduced classification inaccuracy of machine learning to less than 5%. Convolutional Neural Network (CNN), which is a DL technique, was applied to the cleanliness classification of live cattle from an extensive image database of dirty and clean cattle (RMIT University 2018)

3. DISCUSSION

In Nigeria, the process of slaughtering farm animals for sale and consumption rarely follows any hygienic practices. Any external contaminants these animal might have on their hide prior to slaughtering is mostly ignored. This can be seen in a study done by Byrne et al (2000) which showed that slaughtering an animal with dirty hide contaminated with bacteria from various sources can be transferred to the carcass of the animal and washing for a short period of time might not remove it especially in the case of the Escherichia coli (E. coli) bacteria. A computer vision technique can be implemented to automatically check and identify such contaminant especially in a large-scale slaughter house. Also, over the years there have been food safety incidents that have led to disease breakout, for example Lassa fever and Ebola which led to loss of lives and economic losses. Food items can be monitored with the help of computer vision to help detect and contain these outbreaks.

For the past few years in Nigeria, there has been a security issue activated by the Fulani herdsmen from the Northern part of Nigeria. The scarcity of grazing land in the North caused by climate change has forced these herdsmen to move South and encroach into the lands of sedentary farmers without permission. They have been infiltrating villages and towns causing havoc and death as a result of the resistance to allow their cattle to graze on private farmlands. This is a major security issue in the country and requires immediate attention before it escalates.

There has been some talk on boycotting the cattle sold by these herdsmen as a way to solve this problem. If this had any chance of working, computer vision and the IoT would have been perfect tools to track the source and history of the meat we purchase.

Computer vision techniques albeit its advantages are more effective in large scale production/processing plants which are not widespread especially in the Nigerian meat industry. Production is owned by small clusters of individuals working mostly with limited means and resources, thus it is too small for automated techniques.

One way this problem can be solved is by the use of co-operatives to provide food safety services to the meat sellers in bulk. Also, the use of smart phones in Nigeria is becoming widespread. A vast majority of individuals are connected to internet for various purposes, most commonly for social media platforms or to have access to daily news. With the growth of IoT, smartphones (Rateni et al 2017) could be employed in developing personalized food inspection systems, not unlike the personalized healthcare that is currently in vogue. With the advancement in technology, smartphone cameras are now able to take high resolution pictures. These phones also have powerful processing systems and could be connected to a cloud computing (Doukas and Maglogiannis 2012) platform for more processing power. The decision made from the analysis of the image has to be fed back in order to take an action. The output could be an alarm indicating the presence of harmful contaminants in the meat. Additionally, for situations where the internet connectivity is poor causing the transfer of data to the cloud to be slow and congested, we could leverage edge computing (Madukwe et al 2017) or local analysis of data. Quinn et al. (2011) showed the use of a camera phone for image acquisition of cassava leaves for the diagnosis of plant diseases. This would equip survey workers and food safety officials with easily accessible tools without complex training.

The adoption and acceptance of computer vision technology for meat inspection and safety would require a high initial cost and expertise. There is also the increased risk, delays and cost if the computer vision automatic system fails. Production levels in the Nigerian meat industry is currently low and thus may make the deployment of computer vision techniques uneconomically viable. Consequently, there is a great need for large scale agricultural and food processing industries in Nigeria to adopt the computer vision technology in their operation due to its flexibility and non- destructive information retrieval nature of its techniques. Computer vision system can be used to create a database of collected data for future research purposes. If food safety techniques are adopted by everyone involved in a supply chain, from the farmers to the logistics company, to the retailers and consumers, then it would be easier to trace and identify the point of origin of outbreaks. Therefore, making it easier to combat or contain.

3 CONCLUSION

Computer vision technology is present in our everyday lives, from smartphone cameras that can focus automatically on people and faces to self-driving cars that can read traffic signs and detect pedestrians. It is not alien and it is applied in many other areas of our lives. The mere act of capturing, storing and transforming images into information that can trigger an action has revolutionized many industries and has driven research in other technologies.

In this paper, we presented the application of computer vision technology to food quality inspection with emphasis on meat inspection. Difficulties and hurdles are still present especially in the Nigeria food industry but the prospects of public acceptance, adoption and commercialization are good. There are several IoT startups and computer vision research groups all over the continent of Africa, this means that the revolution is not far behind.

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LIVELIHOOD ENHANCEMENT THROUGH MECHANIZATION OF TURMERIC PRODUCTION IN NIGERIA

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ABSTRACT

Production of turmeric and awareness of its usefulness in medical and food industry has been on the increase in the recent years. Its production has become a source of income to farmers in Nigeria. This paper seeks to review the livelihood enhancement of famers through mechanization of turmeric (*Curcuma longa Linn*) production in Nigeria. Production of turmeric has been a challenge to farmers in Nigeria due to the absence of planting and harvesting machines. Farmers are left to the traditional method of planting with hoes and cutlasses. This method is time consuming, costly, labour intensive, associated with human drudgery and a high demand for human energy. Recent discovery on the potentials of turmeric in medical and food industries holds a great future for Nigerian farmers to boost their income. Increased cultivation of turmeric in Nigeria will help not only empower the farmers financially but will also help the country to boost its export. Various uses of turmeric as well as gain of mechanization of its production as highlighted in this paper have the potential of making a significant impact on the Nigerian economy.

Keywords: Turmeric, livelihood, enhancement, mechanization, planting, harvesting.

1. Introduction

Turmeric (*Curcuma Longa Linn*) is a stem tuber crop. It belongs to the same family as ginger (*Zingiberaceae*) and grows in the same hot and humid tropical climates. In Nigeria, turmeric is cultivated mostly on subsistent bases in about 19 states and given different local names depending on the area.It is called *atale pupa* in Yoruba language; *gangamau*in Hausa; *nwandumo*in Ebonyi; *ohubobochi*in Enugu (Nkanu East); *gigir*in Tiv; *magina*in Kaduna; *turi*in Niger State; *onjonigho*in Cross River (Meo tribe). (Nwaekpe, *et al*., 2015). It is native to India and Southeast Asia. India is the largest producer, consumer and exporter of turmeric. Indian turmeric has been known to the world since ancient times. It has been used as a dye, medicine and flavouring since 600 BC (Srinivasan and Dhandapani 2013).To most people in India, from housewives to Himalayan hermits, turmeric affectionately called the 'KITCHEN QUEEN', the main spice of kitchen (Lal, 2012). The major constituent in turmeric called curcumin is a free radical scavenger and hydrogen donor, and exhibits both pro-and antioxidant activity (Hatcher *et al*., 2008). Modern medicine has begun to recognize its importance, as indicated by the over 3000 publications dealing with turmeric that came out within the last 25 years (Sahdeo and Bharat, 2011).

2. Nigeria Contribution to the World Production of Turmeric

Though Nigeria contribute about 3% to the global production of turmeric (Table 1), cultivation practices have not been adequately researched. Due to the drudgery associated with the manual production of turmeric, most farmers are showing little or no interest in engaging into large scale production. As a result of the absence of implements for mechanization of turmeric in Nigeria, productivity has been low. Awareness creation of the economic importance of turmeric in medical and food industries should be encouraged in Nigeria. As this wonder spice now gets global recognition for its tremendous medicinal value, better cultivation methods need to be adopted.

Table 1: Percentage contribution to the world production of turmeric

Entry	Country	Percentage contribution
1	India	78%
2	China	8%
3	Myanmar	4%
4	Nigeria	3%
5	Bangladesh	3%
6	Others	4%

Source: http://www.indianspices.com/pdf/state_prd.pdf

3. Challenges of Turmeric Production in Nigeria

In Nigeria, turmeric has not gained the desired popularity among other root and tuber crops. There is need therefore, to create awareness and increase the production of turmeric through mechanization. Turmeric is mostly cultivated by peasant farmers in small portion of land less than one hectare. This is as a result of drudgery associated with turmeric production. As an emerging crop in Nigeria, the need to develop efficient implements aimed at increasing turmeric production is paramount. There is an increase in the demand for processed products of turmeric in Nigeria which makes its large scale production attractive. In Nigeria, turmeric has not received the desired attention that will boost its large scale production. From the research carried out, turmeric has little or no mechanization in its production processes from planting to harvesting in Nigeria. The only mechanization of turmeric production in Nigeria is the land preparation (ploughing and harrowing). Turmeric, if fully mechanized will create more job, boost the income of farmers and the country at large.

3.1 Planting of Turmeric Rhizomes

Planting of turmeric has been a challenge to the farmers in Nigeria due to absence of planting machine. The farmers are left with the traditional method of planting with hoes and cutlasses (Figure 1). This method is time consuming, costly, labour intensive, associated with human drudgery and a high demand for human energy. The rhizomes (figure 2) are the planting materials and are planted 50cm inter row and 30cm intra row spacing.

It was noted that "time is the essence of farming", in other words, farming operations are timely, and whatever help shorten the time required for planting will help overcome the effect of adverse weather (Ajit *et al*., 2006). To achieve food security through large scale production (Mechanization) of crops with high potentials/prospects such as turmeric, there is much need to provide a planting aid to Nigerian farmers to alleviate their suffering.

Figure 1: Land preparation and planting of turmeric
Source: NRCRI Nyanya farm, Abuja Nigeria.

Figure 2: Planting material (Rhizomes)

Source: National Root Crops Research Institute, Nyanya Sub Station farm, Abuja, Nigeria

Figure 3: Established Turmeric Farm

Source: National Root Crops Research Institute, Nyanya Sub Station, Abuja, Nigeria

3.2 Mulching

Mulching of the bed is very important in turmeric production. Two mulching are required, first immediately after planting and the second mulching is done 8 weeks after planting. The mulching help to: conserve moisture, promote germination, suppress weed, regulate soil temperature, supply nutrients to the soil and improve soil physical fertility for maximum yield. The mulching is done with elephant grass at the rate of 12t/ha (Nwakor *et al.*, 2014)

3.3 Harvesting of Turmeric

The crops are ready for harvesting seven to nine months depending upon the time of sowing. The harvest is carried out during January to March. It matures in about 9 months. The marketing season is from February to May. The leaves of crop turns dry and are light brown and yellowish in colour on maturity, height of crop around 1.5 feet after the complete growth with maximum 8-10 branches with cracks development on the soil signifies good yields of turmeric. The land is ploughed and the rhizomes are carefully lifted with a spade. Harvested rhizomes are cleaned of mud and other extraneous matter adhering to them (Lal, 2012).

Usually the land is ploughed and the rhizomes are gathered by hand picking or the clumps are carefully lifted with a spade. Harvested rhizomes are cleaned of mud and other extraneous matter adhering to them. The average yield per acre is 8 -10 tonnes of green turmeric.

For baby turmeric, harvest the rhizomesby loosening the soil approximately 12 inches from the base of the plant with a shovel orgarden fork, then grasp the stems near the ground and pull the entire plant from the ground or container by the stalks. Harvest yields depend on fertility, water, competition with weeds, and temperatures.

3.4 Processing and Utilization

The processing stages of turmeric starts from boiling which convert it into a stable commodity through a number of post-harvest processing operations like boiling, drying and polishing. Boiling of turmeric is taken up within 3 or 4 days after harvest. The fingers and bulbs (or mother rhizomes) are separated and are cured separately, since the latter take a little longer to cook. The dry recovery of the different turmeric varieties vary widely ranging from 19 to 23% (Jayashree *et al*., 2015). The processing of turmeric in Nigeria is hampered by unavailability of machines and equipment to carry out various processing tasks. The engineering properties of turmeric rhizomes are yet to be properly evaluated, and as such there is no empirical data to develop required processing equipment. The physical properties of some turmeric varieties were determined by Athmaselvi and Varadharaj, 2002; Balasubramanian, *et al.*, 2012; Dhinesh and Ananda, 2016. The data obtained can be used to design a turmeric chipping machine, turmeric planting machine, as well as turmeric harvesting machine. It has been observed that the need to determine the engineering properties to enhance postharvest operations of turmeric is important and it cannot be over emphasized (Athmaselvi and Varadharaj, 2002). The turmeric promotion and awareness program under National Root Crops Research Institute, Nyanya Sub-station, Abuja has identified various value added products of turmeric to include: turmeric oleoresin, volatile oils, and curcumin pigments with high commercial value. The value addition will increase consumption by different categories of people, increase production and empower farmers. The processing of turmeric involve: cleaning, slicing, curing, drying, polishing, colouring, grading, milling and packaging.

3.5 Storage

Turmeric can be stored in different ways. Cured turmeric bags are stored in a pit made on a raised ground with sides and the bottom padded with a thick layer of paddy straw. The stores should be clean and free from infestation of pests and harborage of rodents. It is not recommended to apply pesticides on the dried/polished turmeric to prevent storage pests (Jayashree *et al.*, 2015).Turmeric pigment is highly unstable as compared to the yellow synthetic colorant, tartrazine. However, if protected from light and humidity, the curcuminoid pigments in turmeric powder and oleoresin are stable. Therefore, turmeric rhizomes and powder should be stored away from light and in a very dry environment. Additionally, all water or ethanol solvent should be removed from the oleoresin to assure pigment stability (FAO 2004).

4. Soil and Climatic Requirements

Turmeric is known to grow well on a well-drained, sandy or clay-loam soil (Rema and Madan, 2001). Improvement of crop cultivation technology for local climatic and edaphic factors is important for successful production (Amzad, *et al.*, 2005). Turmeric can be cultivated in diverse tropical conditions up to 1,600 meters from the sea level, with temperatures varying from 20-40 ºC (Table 2), and rainfall above 1500 mm (Lal, 2012). It grows in irrigated and rain fed conditions, black, clayey looms and red soils having natural drainage. Crops cannot withstand water logging or alkalinity (Srinivasan and Dhandapani, 2013) Turmeric thrives in tropics and subtropics where it requires hot, moist climates as shown in figure 3. Turmeric is a sterile plant and does not produce seed. It is produced through vegetative propagation (Nwakor *et al.*, 2014). Adequate soil moisture is the most significant factor affecting rhizome yield. Turmeric needs plenty of moisture, but does not like to sit in wet soil.

Table 2: Temperature requirements for turmeric production

S/N	Required temperature (^{o}C)	Stage of growth
1	High temperature 30 to 35	Sprouting
2	25 to 30	Tillering
3	20 to 25	Rhizome development
4	18 to 20	Enlargement

5. Consumption and nutritional values

More than 100 components have been isolated from turmeric. The main component of the root is a volatile oil, containing turmerone, and there are other coloring agents called curcuminoids in turmeric (Sahdeo and Bharat, 2011). Nutritional analysis (Table 3) shows that 100 g of turmeric contains 390 kcal, 10 g total fat, 3 g saturated fat, 0 mg cholesterol, 0.2 g calcium, 0.26 g phosphorous, 10 mg sodium, 2500 mg potassium, 47.5 mg iron, 0.9 mg thiamine, 0.19 mg riboflavin, 4.8 mg niacin, 50 mg ascorbic acid, 69.9 g total carbohydrates, 21 g dietary fiber, 3 g sugars, and 8 g protein (Balakrishnan, 2007; Sahdeo and Bharat, 2011). Proximate analysis of turmeric rhizomes indicate that it contains: moisture (8.6%), crude protein (14%), crude fibre (8.63%), fat (3.82%), total ash (6.97%) and starch (57%) (Nwakor *et al.*, 2014). The reported consumption of turmeric in Asian countries in humans is in the range of 200–1000 mg/day or 160–440 g/person/year. Intake in urban areas is lower (200 mg/day) than in rural areas (600 mg/day/person (Sahdeo and Bharat, 2011).

Table 3: Nutritional composition of turmeric.

Entry	Constituents	Quantity per 100g
1	Ascorbic acid (g)	50.0
2	Ash (g)	6.8
3	Calcium (g)	0.2
4	Carbohydrate (g)	---
5	Fat (g)	8.9
6	Food energy (K Cal)	390.0
7	Iron (g)	47.5
8	Niacin (mg)	4.8
9	Potassium (mg)	200.0
10	Phosphorus (mg)	260.0
11	Protein (g)	8.5
12	Riboflavin (mg)	0.19
13	Sodium (mg)	30.0
14	Thiamine (mg)	0.09
15	Water (g)	6.0

Source: Lal 2012

6. Economic Importance of Turmeric

Turmeric can be best described as a wonder tuber crop owing to its great potential both in food industries and in the prevention/treatment of various health disorders. Curcumin has a surprisingly wide range of beneficial properties, including anti-inflammatory, anti-oxidant, chemo-preventive and chemotherapeutic activities. Turmeric is produced for both local use and for export.

6.1 Food industry

Turmeric is widely used as food additive for products that are specially packaged to protect from sunlight. It is also used in mustard, pickles for compensating fading colour (Nepal Value Chain, 2011; Dhinesh and Ananda, 2016). As a result of Indian influence, turmeric has made its way into Ethiopian cuisine. In South Africa, turmeric is traditionally used to give boiled white rice a golden color. Turmeric is also used in manufactured food products such as canned beverages, dairy products, baked products, ice cream, yellow cakes, yogurt, orange juice, biscuits, popcorn, sweets, cake icings, cereals, sauces, and gelatins. It is a significant ingredient in most commercial curry powders (Sahdeo and Bharat, 2011). It is also used as a natural colouring agent in foods (Nepal Value Chain, 2011). Recently the powder has also been used as a colorant in cereals (FAO 2004).

6.2 Natural dye and cosmetics

Turmeric is used to manufacture various sunscreen, fairness creams and lotions. The anti-oxidant properties help to lighten the skin. It is a natural dye of cloth, leather, silk, palm fibre, wool and other fabrics. Turmeric rhizomes yield 2-6 per cent orange-yellow essential oil (curcumin, upon oxidation becomes vanillin), which is used in perfumery (Nepal Value Chain, 2011).

6.3 Medicinal and industrial uses

Traditionally, turmeric has been used for curing a number of diseases. It is popular for its anti-bacterial, anti-fungal, anti-ulcer and anti-tumoral effects. Its use is reputed to alleviate asthma, cough, jaundice, and also used for treating skin inflammations (Nepal Value Chain, 2011). Constituents of turmeric block the replication of HIV, enhances wound healing, protects against cataract formation in lenses, exert several protective effects on the gastrointestinal tract. It also used for prevention/cure for Chronic Inflammation, Rheumatoid Arthritis and Pain, Depression and Diabetes, cancer, Turmeric is extremely healing for the brain and for increasing memory function. Turmeric is also used for both traditional and modern medicine (Lal, 2012). It is also used for digestive disorders; to reduce flatus, jaundice, menstrual difficulties, and colic; for abdominal pain and distension (Bundy *et al.*, 2004); and for dyspeptic conditions including loss of appetite, postprandial feelings of fullness, and liver and gallbladder complaints. It has anti-inflammatory, choleretic, antimicrobial, and carminative actions (Mills and Bone, 2000).

Ayurvedic doctors prescribe it for boils, biliousness, bruises, dyspepsia, dysuria, elephantiasis, inflammations, leucoderma, scabies, smallpox, snakebite and swellings. Boiled with milk and sugar, it is used as a remedy for colds. As the global scenario is now changing towards the use of non-toxic plant products, development of modern drugs from turmeric should be emphasized for the control of various diseases (Hamid *et al*., 2014). Many industries in Nigeria depend on agricultural produce for their raw materials. Mechanization of turmeric in Nigeria holds a great future for the pharmaceutical and food industries in the production of drugs, food supplements and spices.

7. Poverty Alleviation through Mechanization of Turmeric in Nigeria

There are high potentials in the modern techniques being used in agricultural production. Turmeric, as an emerging crop with many usefulness holds a great prospect. Its full mechanization will increase the production output and income generation of the farmers. Mechanization of the production processes of turmeric will help to reduce associated drudgery. Development of farm tools and implements for planting, weed control and harvesting will lead to great increase in the production of turmeric. Low level of mechanization of agriculture in Nigeria has led to the decrease in farm produce. This has discouraged many youths from taking agriculture as an occupation.

The increasing demand for natural products as food additives makes turmeric an ideal candidate as a food colorant, thus increasing its demand. Additionally, recent medical research demonstrating the anti-cancer and anti-viral activities of turmeric may also increase its demand in Western countries (FAO, 2004). Increased cultivation of turmeric in Nigeria will help not only to meet its own turmeric requirements but also help the country to boost its export. To achieve food security through large scale production (mechanization) of crops with high potentials and prospects such as turmeric, there is much need to provide a planting aid to Nigerian farmers to alleviate their suffering.

Curcumin as a spice, exhibits great promise as a therapeutic agent. As the global scenario is now changing towards the use of non-toxic plant products, development of modern drugs from turmeric should be emphasized for the control of various diseases (Hamid *et al*., 2014). However, the increasing demand for natural products as food additives makes turmeric an ideal candidate as a food colorant, thus increasing demand for it.

Turmeric can be best described as a wonder tuber crop owing to its great potential both in food industries and in the prevention/treatment of various health disorders. Curcumin has a surprisingly wide range of beneficial properties, including anti-inflammatory, anti-oxidant, chemo preventive and chemotherapeutic activity. Turmeric is produced for both local use and for export.

8. Conclusion

All activities in the production of turmeric are done manually with cutlasses, hoes and spade. The little aspect of mechanization in few areas where tractor is available is land preparation (land clearing and ploughing). Turmeric production is costly, associated with drudgery and high requirement for human energy. Turmeric, being a crop with high potentials and prospects both in food industries and medicine requires mechanization in its production processes for increased production for domestic uses and export. It is therefore recommended that the Federal Ministry of Agriculture and National Root Crops Research Institute, Umudike which has the National mandate to research into the crop should intensify effort in developing machines and other equipment for mechanization of turmeric production in Nigeria.

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EFFECT OF SOIL AND STEM MOISTURE CONTENT ON SOME PERFORMANCE PARAMETERS OF A PUSH-TYPE CASSAVA HARVESTER

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ABSTRACT

Cassava harvesting is regarded as the most laborious operation in its production, involving three main sequential operations from stem cutting (coppicing), soil loosening and then uprooting of the tubers. A precise knowledge of the relevant properties and factors affecting all operations in cassava harvesting, plays a vital role in any attempt to overcome the existing challenges associated with cassava harvesting. One of such relevant property being moisture content was investigated for the soil and stem of cassava in determining the harvesters cutting efficiency, soil loosening and uprooting efficiencies. Moisture in the soil was investigated from nine randomly selected samples, for three treatment classes (A, B and C) at varying depths and locations in the cassava field. Class A and B were conditioned by adding 10 and 5 litres of water respectively to three different cassava stands each, while Class C was used as a scientific control, having no water added. Three replicates of soil samples were collected and subjected to moisture content determination test for each treatment class. Mean soil moisture content on d.b was evaluated for Class A, B and C treatments as 18.7%, 10.8% and 1.94% respectively. Soil moisture tests revealed that at harvest, 10 MAP (months after planting), unconditioned (class-C) soil moisture was between 1.5 and 3%, while on conditioning with specific quantities of water, under class A and B treatments, revealed the soils moisture to between 17 – 20% and 10 – 12% respectively. Moisture in the stem was also determined from fifty randomly selected stalk samples and found to be between 45.84 – 81.02%. ANOVA test results from the experimental research revealed that the effect of moisture content on the cutting efficiency, soil loosening efficiency and uprooting efficiency of cassava were significant ($p<0.05$). A useful information necessary in the development of cassava stem cutting and harvesting equipment.

Keywords: Moisture content, Performance Parameters, Push-Type, Cassava Harvester

1. INTRODUCTION

Cassava, *(Manihot esculenta)* a staple food for millions of people globally especially in Africa, is regarded as the second largest crop after rice (Akinwonmi and Andoh, 2013). It is a herbaceous perennial woody shrub, with a tuberous starchy root and belongs to the class of Carbohydrates, a major source of calories that is processed into flour, starch, snacks (baked foods). It consists of 6% leaves, 44% stem and 50% roots, and contains 60 – 66% moisture and 32 – 35% carbohydrates (Felber *et al.*, 2016). The plant was believed to be first discovered in Southern American, after which was then introduced into Africa in the 17th century (Howeler, 2012).Cassava as a food crop plays a vital role in the food security of the world because of its ability to grow well under marginal soil conditions and tolerance to drought (Kolawole *et al.*, 2010). In the past, rice and maize were Africa's most important food crops. However, maize production in Africa has drastically declined lately, due to unpredictable rainfall, and high financial implication were irrigation system is adopted. Cassava is an essential source of food and income and classed as one of the three world's most important food crops, amongst rice and maize. It is virtually produced in about 24 of the 36 states in Nigeria (IFAD *et al.,* 2008). Cassava is ranked as the fourth supplier of dietary energy in the tropics (after rice, sugar and maize) and the ninth globally (Ennin *et al.*, 2009).

Harvesting of cassava for food can be done, 6 – 8 months after planting (MAP) for early varieties, or at least 10 MAP and even as late as 24 months for late varieties (Addy *et al.*, 2004). Cassava can be harvested at any time depending on the need of the farmers. For small scale farming, roots can be harvested without cutting the stems, but on industrial scale, the crop is harvested all at once between 10 – 12 MAP, by first cutting the stems at a distance 20 – 40 cm above the ground and preserving it for the next planting season, after which an available or preferred method of uprooting the tubers off the ground is employed; either by direct human labour, using manual harvesting tools, semi-mechanised or the use of mechanised equipment (Ennin *et al.,* 2009).

Cassava can either be harvested manually or mechanically. Manual cassava harvesting is usually done by hand; cutting the lower part of stem (coppicing) and pulling the roots out of the ground, then detaching them from the base of the plant by hand after the upper parts of the stem with the leaves are removed. Manual harvesting may also employ harvesting tools such as hoe, cutlass, mattock, and earth chisel. Levers and ropes can be used to assist harvesting (semi-mechanised). Studies by Amponsah *et al.,* (2014a) revealed that harvesting with an improved manual harvesting tool saves about half the time required as compared to uprooting with bare hands. Mechanical harvesting of cassava involves the use of a harvesting implement integrally hitched to a tractor to dig up cassava roots. Mechanical harvesting, though most preferable is often unavailable or unaffordable to over 70 percent of farmers (Amponsah, 2011).

According to Agbetoye (2003), the most difficult operation in cassava production is harvesting. Especially were manual labour is the most affordable and available method, and if harvesting must be done as recommended by Ekanayake *et al.*, (1997) when the soil is dry; this could result to poor timeliness of operation and low efficiency. Studies by Addy *et al.*, (2004) further opined that cassava harvesting constitutes the highest production cost, involving a sequence of operations from stem cutting/coppicing, soil loosening were necessary and then uprooting. Amponsah *et al.*, (2017) studied the physical properties of the soil relevant to cassava harvesting and opined that, soil moisture content at harvest depletes down the soil profile with in an increase in penetration resistance and soil bulk soil, therefore making uprooting more difficult and prone to greater likelihood of tuber damage. Alternatively, studies have also proved that an increase in moisture content of the soil aids manoeuvrability, and to a great extent reduces harvesting force requirement (Agbetoye, *et al.*, 1994). Researches by Agbetoye (1998) and Kolawole *et al.*, (2010) propounded that direct average uprooting force of cassava is a function of the soils moisture content at the time of harvest.

Ekanayake *et al.*, (1997) stated that the most appropriate time to harvest cassava is when the soil is dry (dry season). Harvesting right after a heavy rain or when the soil is too wet is not recommended. This is mostly applicable for mechanized harvesters, equipped with soil engaging components cuts through the soil to a minimum depth of 30 – 40 cm, handling about 50kg of soil to harvest a single plant (Agbetoye *et al.*, 2000). For such equipment, harvesting on relatively wet soils may not be advantageous. This can be attributed to the high water content in the soil and due to its wet nature, particles stick easily to the roots and harvesting implements, especially if the soil is clayey, thus making the roots hard to clean and implement more difficult to use. Also, the high water content in the tubers makes them difficult to store after harvesting, and prone to speedy deterioration (PRCIS, 2005; International Starch Institute, 2002). According to Philippine Root Crops Information Service – PRCIS (2005), harvesting cassava during relatively dry weather is the best since the soil does not stick to the harvesting implement or roots easily.

Studies by Amponsah *et al.*, (2014); Amponsah *et al.*, (2017) and Udensi *et al.*, (2011) on the engineering and agronomic properties for major adopted varieties of cassava grown in Nigeria with sample sizes between 30 – 100 plants revealed the relationship between cassava tuber properties, and the force requirement for harvesting.

Research by Xue *et al.*, (2015) on the mechanical properties of cassava stalks was necessitated for the design of a cassava stalk cutting and recycling machine. Axial, radial compression and cutting strength tests of this research revealed that, moisture content and sampling position are relatively significant in stem cutting (Table 1). Table 1 shows that increase in stem moisture content is inversely proportional to the shear force and strength, required to cut the stem and vice versa. Kaewwinud *et al.*, (2017) asserted that the average length, mass and diameter of cassava stalk decreases with decreasing moisture content and vice versa. Further analysis indicated that shear stress increased with decreasing moisture in the stem and increased with a change in the region of cut from upper section, having a smaller diameter, to a lower section, close to the root zone with a larger diameter. Thus implying that, moisture content and region of cut had significant effects on the shear stress and cutting force required. Therefore recommending that, cassava stalks be cut timely enough at relatively higher moisture contents to minimize cutting force requirement.

This study attempts to explore and analyse the effects of cassava stem moisture to the cutting efficiency and soil moisture content, to the soil loosening and uprooting efficiencies of a developed push-type cassava stem cutter and tuber uprooting machine. This was aided by the determination of the moisture content in the stem and in the soil of the field where the cassava was grown.

Table 1: Mechanical Properties of Cassava Stalk at varying Moisture contents

Sample	Moisture Content (%)	Min. Shear Force (N)	Max. Shear Force (N)	Min. Shear Strength (MPa)	Max. Shear Strength (MPa)
1	68.85	241.22	1053.23	0.78	2.43
2	67.15	326.56	900.25	1.32	2.65
3	64.65	305.97	1141.49	1.26	3.26
4	62.14	397.17	1023.81	1.54	3.22
5	60.44	329.50	1150.32	1.46	3.75

(Source: Xue *et al.*, 2015)

2. METHODOLOGY

Preliminary investigation of some relevant physical properties of the soil and cassava stem and tuber, essential and necessary in the design of the component parts of the harvester and evaluation of the machines performance were carried out.

Moisture Content

Moisture content was determined for both the soil and the cassava stem. The soils moisture content was investigated in order to design an experiment to evaluate the machines performance for soil loosening and tuber uprooting, on varying moisture levels and recommend the soils moisture content in which the machine will perform optimally during harvesting. The soils moisture content was determined and classified by randomly collecting nine (9) different soil samples from the cassava field. The classification was based on three treatments; Class A – Ten litres of water applied to the soil, Class B – Application of five litres of water and Class C – No water added.

In order to minimise the possibility of errors, three replicates of soil sample were randomly collected for all three treatments at depths of 0 – 10, 10 – 20 and 20 – 30 cm using a soil sampler and a mallet (Smith *et al.*, 1994). Samples were collected for treatments A and B about 15 minutes after the water was added and stored in labelled polythene bags. This was to allow for better absorption of the water by the soil and for easy identification respectively. Treatment C was used as a control system, were no water was added to the soil. Collected soil samples were oven dried at a temperature of 150^0 for 8 hours, after which were re-weighed and recorded. The soil moisture content was determined for all three treatments using equation 1 (Smith *et al.*, 1994).

Moisture content in the stem was determined as a variable to investigate the effects of varying moisture levels in the stem to its cutting efficiency. Moisture content in the stem was determined by randomly collecting stem samples of length 15cm from fifty (50) cassava stands from the demonstration farm, cultivated from the TME 419 variety. Each stalk sample was numbered and weighed on a digital lab scale before oven dried at a temperature of 150^o for 18hrs. Dry stalk samples were then carefully collected, re-weighed and recorded and the moisture determined. Equation 2 was used to determine the moisture content in the stem. On successful determination of the moisture content in the stems, samples were then classified into three moisture content categories of 40 – 55% (stalks affected by fire from indiscriminate bush burning), 55 – 70% and 70 – 85%.

$$MC_{(d.b)}\ \% = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \tag{1}$$

$$MC_{(d.b)}\ \% = \frac{W_w - W_d}{W_w} \times 100 \tag{2}$$

Where,

$MC_{(d.b)}$ % = Percentage Moisture content in dry basis

W_1 = weight of sampling bag

W_2 = weight of sampling bag and soil

W_3 = weight of sampling bag and oven dried soil

W_w = weight of wet stalk

W_d = weight of oven dried stalk

Diameter/Girth of stem (cm)

Fifty stem samples were randomly selected from the field. Their diameters were measured and recorded at a recommended coppicing height of 30 – 40 cm above ground level, using an analogue Vernier calliper. The mean stem diameter was also calculated and recorded.

Experimental Design

A completely randomized design (CRD) was used to simplify the experimental procedure and to provide better understanding of the effects of varying moisture levels in the stem and soil on the individual performance of each mechanism of the machine.

Evaluation of the Machines Performance

All three mechanisms of the machine; Stem cutting, Soil loosening and Uprooting mechanism were evaluated individually, reflecting the effects of cassava stem and soil moisture contents on the machines efficiency, in order to recommend for its best performance using the following parameters:

1. Cutting efficiency (P_{ε}):

Equation 3 was used to determine the stem cutting efficiency of the machine.

$$P_{\varepsilon} = \frac{P_r}{P_r + U_{pr}} \times 100\% \tag{3}$$

Where; P_r = Number of stalks cut

U_{pr} = Number of Un-cut stalks

2. Soil Loosening Efficiency (L_{ε}):

The soil loosening efficiency was determined for depth of soil loosed (LED) and for unbroken tuber uprooted after loosening (LET). Data was collected for actual depth of soil loosened against predicted loosening depth and for number of whole or broken tubers harvested as a result of loosening operation. Equation 4 and 5 were used to determine the efficiency of the soil loosening component.

$$L_{\varepsilon_D} = \frac{D_{Act}}{D_{Prd}} \times 100\% \tag{4}$$

$$L_{\varepsilon_T} = \frac{W_H}{W_H + W_B} \times 100\% \tag{5}$$

Where:

D_{Act} = Actual depth loosed (cm)

D_{Prd} = Predicted loosening depth (cm)

W_H= Mass of harvested tuber (kg)

W_B= Mass of Broken/damaged tuber (kg)

$W_H + W_B$ = Total tuber yield (kg)

3. Uprooting Efficiency ($U\varepsilon$):

The uprooting efficiency of the machine was evaluated on the basis of soil moisture content levels and length of the uprooting lever arm from the fulcrum, with respect to the whole and broken tuber harvested. Equation 6 aided evaluation of the uprooting efficiency of the machine.

$$U_{\varepsilon} = \frac{W_{up}}{w_{up} + W_{bk}} \times 100\% \qquad (6)$$

Where,

W_{up} = Mass of Uprooted Cassava tubers (kg)

W_{bk} = Mass of broken tubers dug out of the soil (kg)

3.0 RESULTS AND DISCUSSION

Soil Moisture Determination

Table 2 shows the results of soil moisture content for the three treatments used for the experiment. This informed the choice for the moisture content range used for in evaluating the machines soil loosening and uprooting efficiencies. Class A soil sample, conditioned by addition of 10 litres of water was observed to have increasing moisture levels from 16.9% to 19.2% and a mean moisture content of 18.17%. Class B, conditioned by the addition of 5 litres of water had a mean moisture of 10.80%, with moisture levels from 10.1 to 11.8 and Class 'C' was unconditioned (no water added) had a mean moisture of 1.94%. This informed the choice of the three treatment range for soil moisture to be 1.5 – 3.0%, 10 – 12% and 17 – 20%.

Table 2: Summary of Results for Soil Moisture Content

Class	Replicates			Mean
	Sample 1(%)	Sample 2 (%)	Sample 3 (%)	
A	16.9	18.4	19.2	18.17
B	10.5	11.8	10.1	10.80
C	1.5	1.87	2.45	1.94

Stem Moisture Determination

The results of stem moisture content (d.b) and girth, for fifty (50) randomly selected cassava stalk samples are presented in Table 3. The result shows that, stem girth was proportional to the moisture contained in the stem for the TME 419 cassava variety of 10 months after planting (MAP). Stalk girth was found to range between 2.08 cm and 4.31 cm and moisture content of between 45.84% and 81.02%, similar to assertions by Kaewwinud *et al.,* (2017). This further informed the choice of the range for moisture content in evaluating the machines stem cutting efficiency.

Table 3: Summary of Results for Preliminary Investigation of Cassava Physical Properties

Properties	Sample Size	Minimum	Maximum	Mean
Stem Girth (mm)	50	2.08	4.31	2.82
Moisture Content (%)	50	45.84	81.02	68.97

Stem Cutting Efficiency

Analysis of the study for all three selected performance parameters is shown in Table 4. From the three levels of moisture content of 40 – 55%, 55 – 70% and 70 – 85%; mean stem cutting efficiencies were 29.412%, 41.176% and 76.471% respectively with standard deviation 28.584, 34.419 and 28.298 respectively. High standard deviation values for cutting efficiency in the experiments can be attributed due to human errors from the operation of the machine in the field and other constrains in the coppicing operation, which can be negligible, owing to the fact that the operation is not a laboratory experiment, but a field work.

From table 5, Analysis of Variance (ANOVA) deduced that, at moisture level three (70 – 85%), there is significant different in the cutting efficiency from levels one and two (40 – 55% and 55 – 70%) at $p<0.05$. This is because, the greater the moisture in the stem, the less shear stress required to cut and vice versa, therefore making coppicing more easier and faster as asserted by Kaewwinud *et al.,* (2017) and Xue *et al.,* (2015). Figure 1 depicts a graphical representation of the analysis, with a constant increase in cutting efficiency, characterised by higher moisture in the stem.

Soil Loosening Efficiency

The soil loosening efficiency was evaluated for actual depth of soil loosed (LED) and for unbroken tuber uprooted (LET), with respect to depth loosed. This was carried out to ascertain the effect of moisture in the soil to the efficiency of the diggers to lose the soil to a predetermined depth and also the combined effect of the soils moisture and loosening operation on the tuber uprooted. Table 4 further shows results obtained from evaluating the soil loosening efficiency on three soil moisture levels 1.5 – 3%, 10 – 12% and 17 – 20%. Soil moisture was found to be insignificant on all three moisture levels for Soil Loosening Efficiency with respect to depth (LED) with mean loosening efficiency of 80.208%, 87.431%, and 86.387% and a standard deviation of 21.890, 12.436 and 12.052 respectively. Analysis of Variance results in Table 5 further illustrates that, varying soil moisture levels had minimal (insignificant) effect on the depth of soil displaced in attempt to loosen the soil prior to uprooting. This is because, the configuration of the soil engaging component, designed with small pointed surface area and its mass, had minimal resistance overcoming the soil forces, disintegrating it irrespective of the amount of moisture contained in the soil. But on the other hand, the soil engaging component had a damaging effect on the tubers in the soil, which adversely, affected the loosening efficiency for tuber (LET), thus the decrease in standard deviation and error, characterised by minimal soil loosening requirement with increase in the soil moisture content.

Furthermore from Table 4, Soil Loosening Efficiency with respect to whole tuber (LET) and on all three moisture levels showed that, mean loosening efficiency increased steadily with increase in the soils moisture from 70.116%, 80.275% and to 90.568% standard deviation of 7.032, 10.837 and 11.074 respectively. Higher soil moisture levels was found to increase the effect of loosening efficiency on the tuber (LET) but had limited or no effect on the loosening efficiency with respect to depth loosed (LED).

ANOVA results for LET in table 5 revealed moisture content to be significant from the second and third moisture treatments. Higher mean soil loosening efficiency was observed on LET because, increase in soil moisture reduces the soils cohesion and strength, requiring a minimal uprooting force and conversely, reduces the likelihood of tuber breakage. This is in accordance with assertions by Smith *et al.*, (1994); Agbetoye *et al.*, (2000) and Amponsah *et al.*, (2017).

Uprooting Efficiency

Result for uprooting efficiency as depicted in Table 4 shows that, at a soil moisture content of 1.5 – 3.0 %, 10 – 12% and 17 – 20%, mean uprooting efficiency was 67.006%, 74.26% and 91.312% respectively. This clearly shows a significant increase in the performance of the uprooting mechanism with increase in soil moisture content (Figure 4). Low uprooting efficiencies resulting from tuber damage, were as a result of difficulty in uprooting due to the compact nature and high cohesive nature of the soil, significantly characterised by low soil moisture as asserted by Agbetoye *et al.,* (2000); Kolawole *et al.,* (2010) and Udensi *et al.*, (2011). Higher uprooting efficiencies was observed with minimal or no damage to tubers and were notably observed on soils with higher moisture levels as depicted in the results presented in table 5

Table 4: Effect of Soil Moisture on Selected Performance Parameters of a Cassava Harvester

Moisture Content	Mean (%)	Std. Deviation	Std. Error
Cutting Efficiency			
45 - 55%	29.412a	28.584	6.932
50 - 70%	41.176a	34.419	8.347
70 - 85%	76.471b	28.296	6.862
LED			

1.5 - 3%	80.208a	21.890	7.739
10 - 12%	87.431a	12.436	4.396
17 - 20%	86.387a	12.052	4.261
LET			
1.5 -3%	70.116a	7.032	2.486
10 - 12%	80.275ab	10.837	3.831
17 - 20%	90.568b	11.074	3.915
Uprooting Efficiency			
1.5 -3%	67.006a	3.564	1.594
10 - 12%	74.26a	6.105	2.730
17 - 20%	91.312b	6.237	2.789

Different letters within the same column indicate significant differences according to Tukey HSD Test (p<0.05).

Table 5: Analysis of Variance for Stem Cutting, Soil Loosening for Depth (LED), Soil Loosening for Tuber (LET) and Uprooting Efficiency

Source of Variation		Sum of Squares	df	Mean Square	F	Sig.
Cutting Efficiency	Between Groups	20392.156	2	10196.078	10.914	1.2×10^{-4}*
	Within Groups	44839.712	48	934.160		
	Total	**65231.869**	**50**			
LED	Between Groups	243.815	2	121.907	.469	6.3×10^{-1}NS
	Within Groups	5453.684	21	259.699		
	Total	**5697.500**	**23**			
LET	Between Groups	1673.243	2	836.621	8.668	1.8×10^{-3}*
	Within Groups	2026.844	21	96.516		
	Total	**3700.088**	**23**			
Uprooting Efficiency	Between Groups	1556.954	2	778.477	26.275	4.12×10^{-5}*
	Within Groups	355.533	12	29.627		
	Total	**1912.488**	**14**			

*Significant at $p < 0.05$: NS – Not Significant

Figure 1: Effect of Stem Moisture on Cutting Efficiency

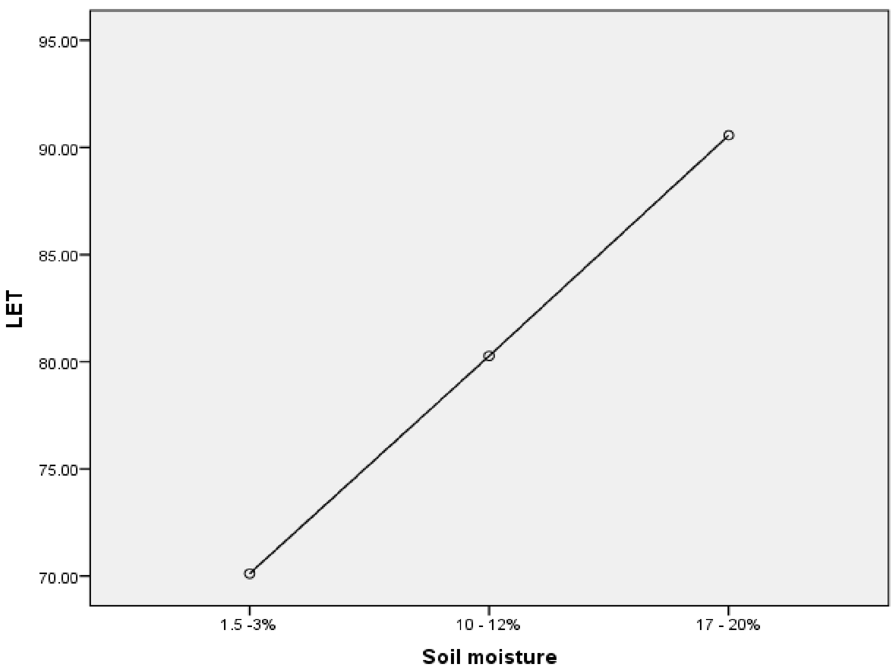

Figure 2: Soil Loosening Efficiency for Whole Tuber

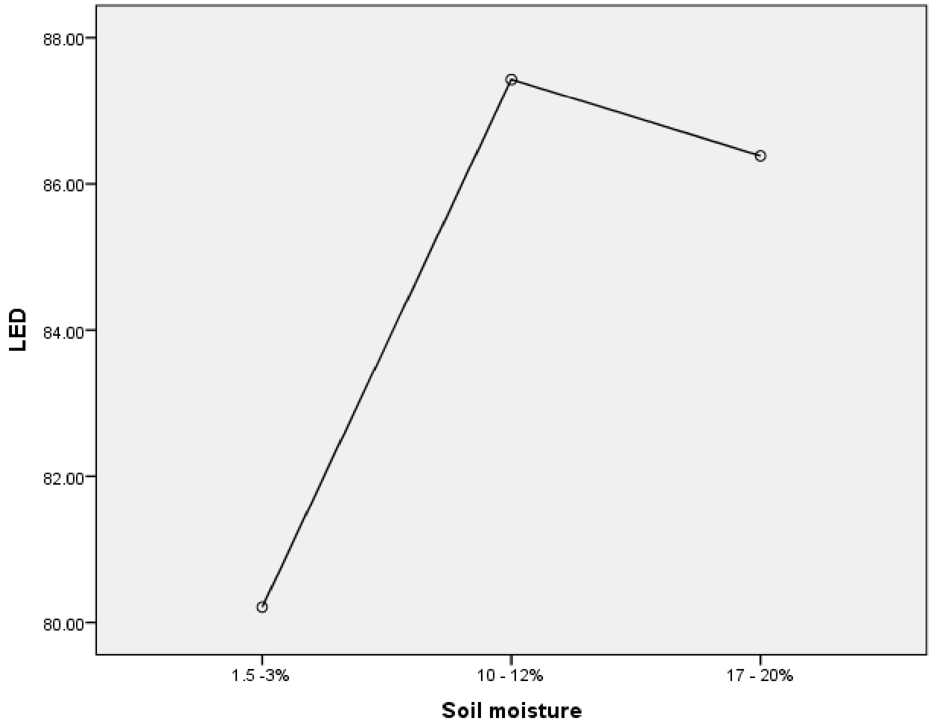

Figure 3: Soil Loosening Efficiency for Loosened Depth

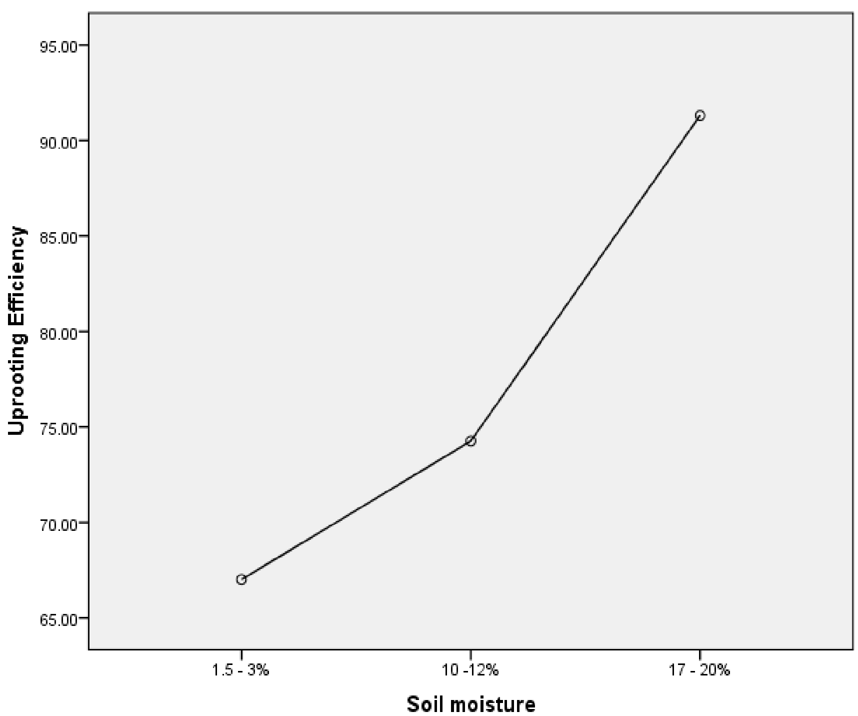

Figure 4: Uprooting Efficiency

4.0 SUMMARY AND CONCLUSION

Moisture in the stem was determined to range from 45.84 – 81.02% with a mean of 68.97%. Soil moisture tests revealed that at harvest, 10 MAP (months after planting), soil moisture was between 1.5 and 3%, while on conditioning with specific quantities of water for experimental analysis, from 5 litres per stand to 10 litres per stand, increased the soils moisture to between 10 – 12% and 17 – 20% respectively.

Mean percentage stem cutting efficiency increased significantly from 29.412%, 41.1765 to 76.471%, with increase in stem moisture content at a moisture range of 45 – 55%, 55 – 70% and 70 – 85% respectively. There was no significant effect resulting from variations in the soil moisture content range of 1.5 – 3.0%, 10 – 12% and 17 – 20% in evaluating the performance of the loosening component to lose the soil to a required depth. This produced mean loosening efficiency for depth (LED) of 82.208%, 87.431% and 86.387% respectively. Whereas, soil moisture content was found to have significant effect on the Soil loosening efficiency, investigated to determine the effect of loosening operation in uprooting tubers (LET). LET produced mean loosening efficiency of 70.11%, 80.275% and 90.568% with increasing soil moistures of 1.5 – 3.0%, 10 – 12% and 17 – 20% respectively. Uprooting efficiency of the machine, being a function of whole tuber uprooted had increasing mean results of 67.006%, 74.26% and 91.312% proportional to a rise in soil moisture content.

The significant effect of soil moisture on the loosening and uprooting efficiency can be attributed to the effect of moisture content on some physical properties (strength, cohesion, and compaction) of the soil as opined by Agbetoye (1995). Therefore, soils with high moisture levels will result to decrease in the soils strength and penetration resistance, further leading to ease of soil loosening and uprooting tubers with less breakage, as opined from soil sampling analysis by Agbetoye *et al.,* (2000) and Amponsah *et al.,* (2017).

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DEVELOPMENT AND COMPARATIVE EVALUATION OF CUTTING DEVICES EMPLOYING SCOTCH-YOKE MECHANISM FOR PALM FRUIT HARVESTER

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ABSTRACT

In this study, a scotch-yoke mechanism for a motorized palm fruit bunch harvester was designed and fabricated and tested. A comparative evaluation was performed using sickle and saw cutting devices to determine the best cutting device for harvesting palm fruits bunch with the developed mechanism. The two cutting devices were tested on eight (8) palm trees of uniform age, average height of about 6.5 ft, and two bunches harvested per palm tree. The harvesting parameters used are harvesting time (HT) and fuel consumption (FC) for the two cutting devices. Regression analysis was carried out on the data collected at 5% level of significance using Minitab 17.0 software package. The average harvesting time (HT) per bunch, for the sickle and saw cutting devices are 56.5 and 39.75 seconds respectively, while the average fuel consumed (FC) per unit time to harvest for sickle and saw cutting devices are 2.15 and 1.48 ml/s respectively. The total harvesting time for sickle device is over 10% more than the harvesting time for saw cutting devices. Statistical analysis shows that harvesting time (HT) and fuel consumption (FC) per unit time is significantly affected by the harvesting devices ($p < 0.05$). From the comparison of means of the two cutting devices, it is deduced that the saw cutting device is faster, more economical and will harvest more fresh fruit bunch (FFB) than the sickle cutting device. Regression equation relating the various parameters was derived. The study concluded that the saw is a better cutting device for harvesting fresh palm fruit bunches using the motorized palm fruit harvester employing scotch-yoke mechanism.

Keywords: Cutting device, palm fruit bunch, Scotch-yoke mechanism, Reciprocating cutting, harvesting time, fuel consumption.

1.1 INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the most important sources of oil for domestic and industrial purpose, and its fruit is a major export product for most countries of West Africa. Palm tree is a versatile plant of great economic importance in Nigeria, Malaysia, Brazil and several West African countries. The oil palm tree is indigenous to West Africa where it grows in the wild and is cultivated as an agricultural crop. The palm trunk is sawn into timber and used in constructing fences, roofing houses and reinforcing buildings and as raw material in some paper industries. The palm bunch contains the fruits. The fibrous residue from oil extraction and the shells of the palm kernel serves as fuel for rural homes. The crude palm oil processed from the fruit is reddish because it contains a high amount of β-carotene. It is used in cooking oil for various cuisines and contains vitamin A which is essential for good nutrition (Edem, 2002). It is also used in the edible oil refining industry. The palm kernel oil is used in confectionary, cosmetics, and pharmaceutical industries (Rozman *et al.*, 2001).

Harvesting is the most important activity in oil palm cultivation. It was estimated that the operation requires about 60% of the total labor for the crop and about 50% of the total cost (Abdulrazak *et al.*, 2007). Oil palm harvesting involves four interrelated activities, like cutting the fronds and fruit bunches, stacking for fronds, collecting the lose fruits and carrying the harvested fruit to the collection point (Abdulrazak *et al.*, 1998). Nowadays, there is about 25% of FFB collected through mini tractor and 75% is really done on manual labor (Carter *et al.*, 2007). Indeed, a lot of time and energy have gone into palm oil harvesting. Such an enormous amount of energy is required for harvesting oil palm by cutting a single frond alone, using the sickle cutter (the Malaysian knife), could require the exertion of force as much as 18,048 N for the most matured frond (Jelani *et al.*, 1999). Furthermore, Bevan and Gray (1969), reported that in a study on palms aged between 9 and 25 years in Malaysia, between 43.5 and 45.4% of the total annual man-days is spent on harvesting. Harvesting from the older trees took more man-days. The situation, most likely has not changed today because harvesting is still being done manually.

Harvesting is the most labor intensive operation in oil palm cultivation, accounting for about 60% of total labor, which is 50% of total production cost (Malek, 1993). Rapid chopping method motorized cutter (cantas) which was developed by MPOM was finding an effective solution to solve the oil palm harvesting issues. But this existing cutter is limited to single cutting mechanism. Developing a lower reach cutter with light weight is necessary demand to solve the cutting problem. The objective of this work is to design and fabricate a combined sickle and saw palm fruit bunch harvester using scotch-yoke mechanism.

2.1 MATERIALS AND METHODS

2.1.1 Design Concept

The dual harvester comprises of three main sections: the cutting head, the pole and the prime mover (2-stroke petrol engine). The harvester is to cut the fronds and the stalk of the fruit bunches mechanically. The cutting process is carried out by fast reciprocating motion of a sickle and chisel blade. Sickle and saw blades were designed to operate on a scotch-yoke mechanism. The cutting head unit which consists of a scotch yoke mechanism was installed on the pole with a shaft inside the pole and was connected to the prime mover (2- stroke petrol engine) through a spline.

2.1.2 Design Considerations

The following general characteristics of a good motorized cutter were taken into consideration in the design of the cutting head namely; ease of handling (by the operator), efficiency and speed in cutting, increases productivity (as compared to manual harvesting) and comfort in handling/ergonomic design.

There are two major factors that greatly influence the design of cutting devices and were taken into consideration (Abdul Razak, 1997). These are: The fronds and bunch stalks are made up of fibre bundles that contain cellulose, which are difficult to cut; and The tight arrangement and limited space of fronds and fruit bunches on the palms leaves very little room for the tool to be placed.

The following specific factors were taken into consideration in the design of the dual palm fruit harvester namely; weight of the machine, height of the palm fruit: the harvester was designed specifically to harvest palm fruit of heights less than or equal to 6.5 ft. horizontal distance between the tree and the operator**:** the distance between the operator and the tree depends greatly on the height of the tree, but it was in a range of 1.0 m to 3 m.

2.1.3 Materials for Construction

The materials used in the course of this research work are: aluminum, mild steel, 2 stroke petrol engine, ball bearing, rubber, galvanized hollow pipe and bevel gear

2.2 Design Analysis

2.2.1 Design of sickle

The sickle was made of hardened steel (mild steel) of 6 mm thickness, guage-16. The maximum cutting force required according to Abdul Razak, (1998) is given in equation (1) as:

$$f = Fc\, cos\beta \qquad 1$$

$$Fc_{max} = f\ (when\ \beta = 0) \qquad 2$$

Where:

Fc_{max} = maximum cutting force (kg)

FC = cutting force (kg)

f = force measured by the load cell (kg)

β = cutting oblique angle (degree)

The shape and dimensions of the sickle were designed by considering the size of the frond and of the bunch stalk, and also the ease of cutting the frond or stalk with minimum cutting force.
This enables the cutting force (Fc) to act in-line with the reaction force (Fr), thus giving maximum cutting force (efficient cutting), and at the same time minimizing significantly the vibrations transferred to the operator. Cutting is performed when the sum of Fc, Fp and W is greater than Fr (Figure 2), as given in equation (3) (Abdul Razak, 1998):

$$Fc + Fp + W > Fr \qquad 3$$

Where:

Fc = cutting force required to accomplish the cutting, N.

Fp = pulling force applied by operator, N.

Fr = reaction force, i.e. the force from the operator to counter the cutting force developed.

W = weight of tool, N.

x = the maximum distance where the point of Fc can be applied.

δx = the distance of point Fc from the sickle holder.

2.2.2 Design of Saw

The chisel was designed using mild steel of 16 gauge with 6 mm thickness. The size of the material used for the chisel blade was based on the surface area of the material. The saw blade is a composition of trapezoidal and rectangular shape. The surface area was determined based on equation 4, according to Audu (2004).

$$\text{Surface Area of a Trapezium} = \frac{1}{2}(a+b) \times h \text{ in } m^2 \qquad 4$$

Where:

a = base width (mm) =120 mm = 0.12 m

b=length of the hopper (mm) = 160 mm = 0.16 m

Volume of hopper = Area × thickness in m^3

A = Surface area of Trapezium

h = height of hopper (m) = 100 = 0.1m

2.2.3 Design of Scotch-Yoke

This mechanism is composed of a disk with a rigidly attached pin that slides within a vertical slot connected to a mass that slides within a frictionless guide. The mechanism produces a purely sinusoidal motion when the faces of the vertical slot are both straight and parallel.

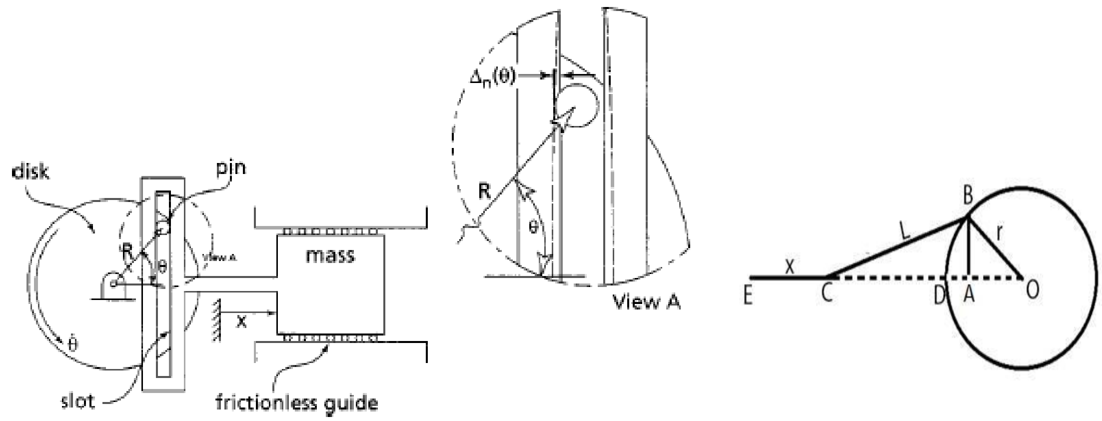

Figure 1: Schematic and space diagrams of scotch yoke mechanism

Determination of length of the cutting stroke

From Figure 3.1 (b), Let 'X' be the length of the cutting stroke

$X = OD + DE - AC - OA$

r – Radius of the Crank.

L – Length of the link AB.

Angle AOB = θ

Angle ACB = Φ

In triangle ABC,

$Cosine\, \emptyset = AC\, /\, L$ 5

$AC = L.Cos\emptyset$ 6

In Triangle OAB, Cosine θ = OA/r

OA = r. Cosine θ

$Sine\, \emptyset = h/L\; Sine\, \theta = h/r$ 7

$Cosine\, \emptyset = \surd\,(1 - Sine^2\emptyset) = \surd\,(1 - (r^2\, Sine^2\theta/L^2))$ 8

n = L / r = connecting rod length/Crank radius

$Cosine\, \emptyset = [1 - (Sine^2\emptyset/n^2)]$ ½

If n≫1, by binomial expansion $Cosine\, \emptyset = 1 - (Sine^2/2n^2)$

$X = r + L - L\,[1 - (Sine^2\theta/2n^2)] - r\; Cosine\, \theta$ 9

$X = r\,(1 - Cosine\, \theta) + L\,[1 - 1 + (1 - Cosine2\theta)/\,4n^2]$

$X = r\,(1 - Cosine\, \theta) + r^2/4L\,(1 - Cosine2\theta)$ 10

Velocity

$V = d\,X\,/d\,t = w\,r\,(sine\, \theta) + r/4L\,(2sine2\theta)$ 11

Acceleration

$a = d^2x/dt^2 = r\,w^2\,(cosine\, \theta + r/L\,(cosine2\theta))$ 12

Assume, Radius of the crank, r = 52 mm

Length of the CR = 100 mm

$At\ \emptyset\ =\ 0, \theta\ =\ 0$

$X\ =\ 100\ +\ 52\ =\ 152\ mm$

At ∅ = 0, θ = 180̇

$X\ =\ 100\ +\ 52\ +\ 0 - 100 Cosine 180\ =\ 152\ mm$

The length of the cutting stroke = 152 – 100 = 52 mm

Scotch yoke design dimensions

- diameter = 100 mm
- slotted bar length = 110 mm
- slotted bar width 15 mm
- length of slot = 5 mm
- diameter of pin = 10 mm
- distance of pin from the centre = 45 mm

Determination of Cutting Speed

Cutting speed, $v\ =\ N\ L\ (1 + m)/1000\ m/min$ 13

N = the number of double strokes or cycles of the ram per min (take N= 100)

L = Length of the ram stroke in mm

m= return stroke time/cutting stroke time, m = 1

v = 0.021 m/min

Determination of Cutting Force

Power = 736 Watts

Speed = 200 rpm

$P = \frac{2\pi N_2 T_t}{60}$ 14

T = 35.159 Nm

We Know that,

Torque = Force x Radius of crank

F = 296.75 N.

2.2.4 Power Requirement

The power required by the cutting devices was determined based on the rated specifications of the machine are as follows:

- 2-stroke petrol engine
- Power : 1.3 hp

- Fuel capacity : 440 cm^3
- Maximum length : 3.6 m (telescopic)

2.2.5 Design of Spline

The spline is a coupling mechanism which help in the transmission of power from the prime mover (2-stroke petrol egine) to the scotch yoke mechanism. It was design based on the standard spline value by drive train direct (Khurmi and Gupta, 2005).

Major diameter, $D = N + \frac{1}{P}$ 15

Minor diameter, $d = N - \frac{1}{P}$ 16

But, Spline length, L = 1.25 D, Number of teeth, N = 8, Diametral Pitch, P = 2.5

Therefore, Major diameter, $D = N + \frac{1}{P} = 8 + \frac{1}{2.5} = 3.6\,mm$

And, Minor diameter, $d = N - \frac{1}{P} = 8 - \frac{1}{2.5} = 2.8\,mm$

2.3 Description and Operation of the Motorized Harvester

The motorized palm fruit harvester is made up of 1.3 hp, 2-stroke petrol engine (prime mover), which powers a shaft through spline coupling to transmit rotational motion from the engine to the crank of the scotch-yoke mechanism, the sliding yoke which is attach to the crank through a pin in a slot converts the rotation motion to reciprocating motion. The sickle and saw cutting device is attached to the ram stroke of the sliding yoke which enables the cutting operation. A-30 mm external diameter hollow pole with a length of 1400 mm was used to house/shield the rotating shaft. Two handle attached or provided on the periphery of the hollow functions in two capacity; to help the operator to support or balance the weight of the machine while in operation and secondly to control or regulate the speed of the machine. Structural support frame is provided at the cutting head to support the scotch yoke mechanism. The sickle and the saw cutting devices which is attached to the reciprocating sliding yoke with the aid of bolt and nut function to cut the stalks of the front bunch.

Plate 1: Motorized palm fruit harvester with a scotch yoke mechanism

2.4 Performance Testing

The performance of the sickle and saw cutting devices attached to the motorized cutter were tested on four palm trees each. The performance of the devices was tested based on, the average harvesting time (ht) and amount of fuel consumed (fc) per unit time of the cutting operation. The fuel use data was recorded in groups of five to make the quantity significant.

2.4.1 Determination of Harvesting Time

A stopwatch was used to measure the average time it took for the sickle and the saw harvesters to harvest palm fruit bunches from trees. The time of harvest for 2 bunches per test run was taken for the eight trees tested on.

2.4.2 Determination of the Fuel Consumption

The motorized palm fruit bunch harvester was transported to the palm groove for testing. For each cutting operation using the two cutting devices, a measured quantity of fuel was poured into the fuel tank of the 2-stroke petrol engine before the cutting operation was carried out. At the end of cutting operation, the fuel left in the tank was poured out and measured. The difference was recorded as the amount of fuel consumed per cutting operation.

2.5 Statistical Analysis of Data Collected

The data collected was subjected to one-way analysis of variance (ANOVA) to determine the effects of the harvesting device (sickle and saw) (HD) on the Harvesting time (HT) and Number of Bunches (NB). Where significance was indicated, comparison of the mean was carried out to establish the differences among the harvesting device. The relationships between the parameters were determined by regression analysis. All the statistical analysis was performed using Minitab (version 15) software.

3.0 RESULTS AND DISCUSSION

3.1 Performance test result for motorized palm fruit harvester using sickle and chisel

Table 1, shows Result for harvesting time for sickle and saw harvesting device; number of trees; number of bunches harvested and harvesting time (sec) for sickle and chisel. Table 2, shows Result for fuel consumption for sickle and chisel harvesting device; number of trees; number of bunches harvested and harvesting time (sec) for sickle and saw. Table 3, shows average of dependent variable per bunch for sickle and chisel harvesting device; harvesting device and average parameters - harvesting time, ht (sec); fuel consumption, fc (ml).

3.2 Relationship between harvesting time (HT) and number of tress

From the data gathered from the eight palm trees on which the motorized harvester using sickle and saw devices was tested, it was discovered that the average harvesting time were 47 and 42 seconds per bunch (Table 3) for sickle and saw harvesting devices respectively. As can be seen from Figure 2, the time taken to harvest the four palm trees is in the range of 90 to 97 seconds for sickle, while that of saw is in the range of 82 to 87 seconds. The average harvesting time (HT) in harvesting fresh fruit bunch (FFB) using sickle and saw harvesting devices was calculated to be 47 and 42 seconds (Table 3) per bunch respectively.

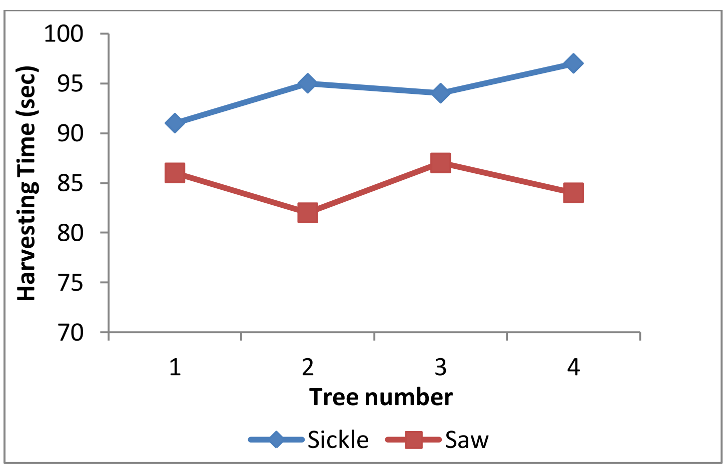

Figure 2: Variation in harvesting time (HT) for trees 1-4 for sickle and saw

3.3 Relationship between fuel consumption (FC) and number of tress

Figure 3, shows the variation in fuel consumption (FC) for trees 1-4 for sickle and saw, it can be seen, the fuel consumption are in the range of 148 to 162 ml; and 123 to 148 ml for sickle and saw harvesting devices. The total fuel consumed for sickle was 618 ml, while the total fuel consumed for saw was 544 ml. This shows that the sickle harvesting device consume more fuel than the saw device.

The average quantity of fuel consumed in harvesting fresh fruit bunch (FFB) using sickle and saw harvesting devices was calculated to be 77 and 68 ml per bunch respectively. The detailed data is shown in Table 3.

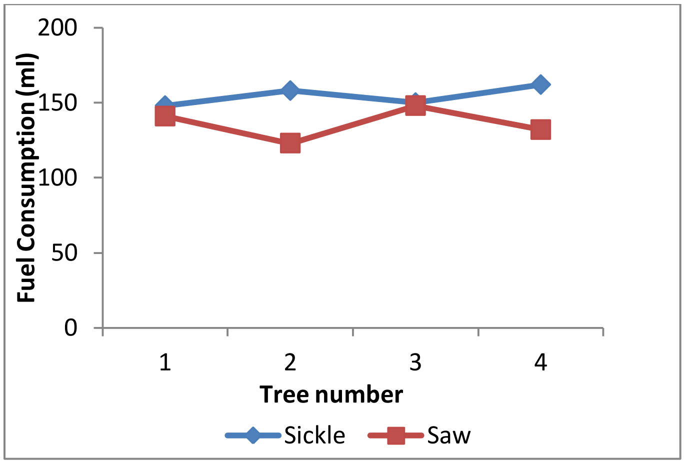

Figure 3: Variation in fuel consumption (FC) for trees 1-4 for sickle and saw

3.4 Relationship between harvesting time (HT) and fuel consumption (FC) for Sickle and Chisel Harvesting devices

From the data in Table 1 and 2 of, the total harvesting time and fuel consumed was 618 ml and 377 sec for sickle; and 544 ml and 338 sec for saw. The average fuel used by the two harvesting devices per unit time was calculated to be 1.64 and 1.56 ml/s for sickle and saw respectively. Figure 4 shows the relationship between harvesting time (HT) and fuel consumption (FC), from the bar-chart, it is seen that the fuel used is directly proportional to the harvesting time; as it increases with increase in harvesting time.

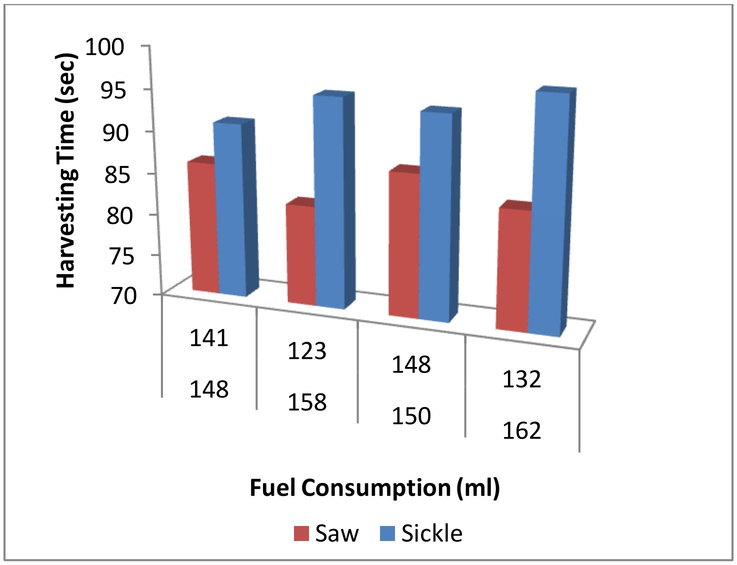

Figure 4: Relationship between harvesting time (HT) and fuel consumption (FC) for sickle and saw harvesting device

Table 1: Result for harvesting time for sickle and saw harvesting device

Tree	Number of Bunch	Harvesting time, HT (sec)	
		Sickle	**Saw**
1	2	91	86
2	2	95	82
3	2	94	87
4	2	97	84
Total	**8**	**377**	**338**

Table 2: Result for fuel consumption for sickle and saw harvesting device

Tree	Number of Bunch	Fuel Consumption (ml)	
		Sickle	**Saw**
1	2	148	141
2	2	158	123
3	2	150	148
4	2	162	132
Total	**8**	**618**	**544**

Table 3: Average of dependent variable per bunch for sickle and saw harvesting device

Harvesting Device	**Average parameters**	
	Harvesting time, HT (sec)	**Fuel consumption, FC (ml)**
Sickle	47	77
Chisel	42	68

3.5 Result of Statistical Analysis

The result of the statistical analysis carried out on the two harvesting devices (sickle and saw) is displayed in Tables 4 and 5. From the ANOVA Tables, it is observed that harvesting time (HT) and fuel consumption (FC) is significantly affected by the harvesting device (HD). From the comparison of mean recorded in Table 3, it is deduced that the chisel harvesting device is faster, more economical and will harvest more FFB than the sickle harvesting device. The regression analysis carried out helped in developing equations describing the relationship between the variables. The relationship between Fuel Consumption (FC_S); (FC_C) for sickle and saw; and Number of Bunches (NB) is described by equations 17 and 18.

$$FC_S\,(ml) = 146.00 + 3.40(NB) \quad 17$$

$$FC\,_C(ml) = 136.5 - 0.20(NB) \quad 18$$

Where;

FC = Fuel Consumption, ml

NB = Number of Bunches

While the equation describing the relationship between Harvesting Time (HT_S); (HT_C) for sickle and saw; and Number of Bunches (NB) is described by equations 19 and 20.

$$HT_S\,(sec) = 90.00 + 1.700(NB) \quad 19$$

$$HT_C\,(sec) = 85.00 - 0.10(NB) \quad 20$$

Where;

HT = Heat Time, sec

NB = Number of Bunches

The positive terms in the equation represent a direct relationship between experimental parameters and interactions with time, while the negative terms represent an inverse relationship between them. It was observed that number of bunches have a direct relationship with harvesting time and fuel consumption. Increase in number of bunches leads to increase in harvesting time and fuel consumption.

Table 4: The result of one-way ANOVA on effect of Harvesting Device (HD) – sickle and saw on fuel consumption (FC)

Source of Variation	DF	Sum of Square	Mean Square	F-Value	P-Value
Harvesting Device (sickle and saw)	1	180.50	180.500	32.33	0.001
Error	6	33.50	5.583		
Total	7	214.00			

Table 5: The result of one-way ANOVA on effect of Fuel Consumption (FC) – sickle and saw on fuel consumption (FC)

Source of Variation	DF	Sum of Square	Mean Square	F-Value	P-Value
Harvesting Device (sickle and saw)	1	684.5	684.50	8.47	0.027
Error	6	485.0	80.83		
Total	7	1169.5			

4.0 CONCLUSION

From the results obtained from the performance testing and comparative analysis of the sickle and saw harvesting devices, the following conclusions can be reached:

- The saw harvesting device is faster, more economical and will harvest more FFB when compared to the sickle harvesting device.
- The saw harvesting device in terms of average bunch harvested per unit time is better than the sickle harvesting device.
- The sickle harvesting device is more energy consuming than the saw harvesting device.

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THE ROLE OF ENGINEERING AND TECHNOLOGY IN INFRASTRUCTURE DEVELOPMENT: FOCUSING ON ABUNDANT FOOD PROVISION AND THE DIVERSIFICATION OF NIGERIAN ECONOMY

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ABSTRACT
Development may be regarded as antonymous to poverty. If that is so, in a developed society, the level of poverty would be relatively low; this implies that the basic aim of development is the eradication of poverty. The basic step is to ensure that the labour force of the nation be put on deck and in order to optimally operate them with a view to providing basic human requirements such as food, shelter, medical welfare, telecommunication, road development, provision of portable drinking water , security and education. Since provision of all these are normally regarded as infrastructure, it is proposed that provision of abundant food in the country should be put in the same category as basic infrastructural requirements for development. Some items, like Fertilizer and Herbicide, Agricultural implements, food processing and storage facilities for preserving the produce and information technology were highlighted in this research work. Recommendations and suggestions were given with a view to enhancing the diversification of Nigerian Economy through the use of Engineering and Technology.
Keywords: Engineering; Technology; Abundant Food; Diversification and Nigerian Economy

1.0 INTRODUCTION
In Nigeria, about 60% of the population is employed and engaged in farming which according to (Adegoke, 1993) was higher than those of United State of America (USA), despite this, Nigeria is still unable to adequately feed her citizens. Lack of basic infrastructures has been known to be one of the major problem responsible for the low level of food production.

The provision of basic infrastructures such as electricity, water and housing in farm centres, then good road and rail networks to link these farm centres with the urban centres will help in attracting the interest of the youths to the farms. With such a development, cooperative farming using locally manufactured farm implements or fully mechanized farming using more sophisticated farm implements will result in higher utilization of fertile lands with better and higher farm products yields.

2.0 STRUCTURE OF THE NIGERIAN ECONOMY

Structurally, the Nigeria economy has been dominated by two sectors. They are agriculture and crude petroleum sectors. In terms of revenue generation, however, the economy is so far mono-cultural. In the 1960s and early 1970s, the major revenue earner was agriculture and since the late 1970s, it has been the oil sector. Accordingly, two approaches will be adopted in the analysis of the structural performance: the relative contribution to GDP and to revenues. The highlights of the structure of the Nigerian economy and changes, therein, are as follows:

- Nigeria is the largest geographical unit in West Africa, with land area of 923,768 square kilometers and an estimated population of 180 million. About 47 percent of who are below 15 years of age and 3 percent aged 65 years and above. These, according to Adedipe (2004), give a dependency ratio of 1:1 against 1:3 or less in advanced countries.
- Agriculture dominated the GDP, but its contribution has reduced gradually over the years since 1960. The ratio dropped from 65.6 percent in 1960/61 to 32.00 percent in 2006.

Manufacturing improved in the early post independence years, reaching a peak of 10.00 percent contribution in 1981 from a mere 3 percent in 1960/61. Its contribution has nosedived steadily since 1990 to as low as 2.57 percent in 2006.

- Crude petroleum became prominent, contributing less than one percent to GDP in 1960/61 and increased steadily to 47.7 percent in 2000 and dripping slightly to 37.6 percent in 2006.
- Dualistic nature, in which there is a mix of formal (organized) and informal (curb, markets) systems. The later is a huge sector that is difficult to measure, as it owes its existence to institutional weaknesses, policy inconsistencies, and policy implementation deficiencies. Estimates often indicate it to represent between 40 and 50 percent of economic activities in Nigeria (Adedipe, 2004).
- Increasing inequalities in interpersonal incomes and a widening gap between urban and rural incomes, especially with the adoption of SAP in 1986.
- Weak social and institutional structures in education and health. Enrollment figures show improved distribution in favor of secondary and tertiary education, but there are concerns about the quality of education regarding the dynamics of work environment and its requirements.
- A vibrant financial system that has seen cycles of stability/prosperity and distress, pronounced in the early to mid 1990s. The improved enforcement of regulation and increasing commitment to corporate governance principles by the operators assures soundness of the financial system moving forward.

- External trade is dominated by oil, which accounted for 34. 2 percent of total external trade in 1970 and 64.5 percent in 2003. External trade/GDP ratio stood at 64.6 percent in 2002, making the economy highly susceptible to external shocks
- Raw materials and consumption goods dominate imports, while primary products dominate exports, contributing over 95 percent of export earnings, further entrenching the Nigerian economy as import dependent and reliant on crude petroleum as the major export.

3.0 INFRASTRUCTURE ITEMS

It has been said that the input of the ordinary farmer rather than large scale farming is what is required for feeding the nation and for export (Adegboke, 1933) The needs of the small scale farmers are basic and simple. What the famers need are fertilizers, herbicides and basic agricultural implements, storage and agro-allied processing facilities. All these requirements are results of engineering technology and can be provided easily if we look inwards. In other words, they can be provided with little or no foreign exchange component. Hitherto, the practice has been based on importation of such farm implements at the expense of locally produced ones. Besides, the nation seems belief that industrialization and state of development are functions of size and cost of equipment and the country of origin. Value addition to locally produced farm implements should be linked with the amount of local input provided. Less dependent on foreign exchange will tend to indicate the degree of economic independence of a nation if the policies are properly implemented.

4.0 FERTILIZER AND HERBICIDE

The Nation has fertilizer manufacturing plants in various part of the country and the required raw materials are available from our crude oil. Besides, traditionally agricultural by-products have been used as manure to aid crop production. There is no reason why the citizen of the country should not experiment into ways of producing other forms of manure or fertilizer without getting involved in grand multi-million Naira plants. Certainly, in other developing countries that are not as endowed as we are, other simpler means have been found to go round the problem. Indeed in the Republic of China (ROC) several small plants have been developed for various items. Efforts and ability to get some of the results lie within the capability of the nation in areas of allied disciplines, which can, with proper national leadership and motivation, be mobilized for the benefit of all.

5.0 AGRICULTURAL IMPLEMENTS

Traditional farming implements have been modified and where this has not been done the society should as a matter of urgency, sponsor research in this area, through the use of fund, by the creation of a research fund for this purpose should be encouraged. And when results of such researches have been accepted, the Society should, in cooperation with interested individuals, or encouraged such members to set up establishments for large scale production of these items. This will not only make these items readily available but ensure that they are affordable. These and others are some of the ways in which our society can show the way to other nations. (Ogo et al, 2005).

5.1 Classifications of Agricultural Implements

Agricultural implements can be broadly classified into simple, medium and heavy machine implements.

(a)**Simple Implements:** Majority of the farmers in the rural area in Nigeria. Commonly uses simple implements, like cutlass, hoe, spade, rake, axe and head pan etc, the implements are mainly driven by human power to carry out the various farming operations. These implements are used for clearing of bushes, cuttings, digging transplanting, making heaps, leveling, spreading manure, removing weed and stones etc, these farmers use this implements without taking any maintenance culture into consideration.

(b)**Medium / Heavy Implements:** These implements are mainly powered by mechanical / work animals, these include ploughs, harrows, ridgers, springs coil cultivator. The accessories for the implements include ploughshare, frogs, ox-rigder, spool, furrow wheel, couplings, plough shear etc, the implements are widely used by farmers in the agricultural developed countries where farmers have large farms or agricultural mechanized farm. They enable farmers to cultivate large farm for commercial purpose and to carry out their farm operations with ease.

5.2 Materials Selection for Implements: The selection of materials for agricultural implements production is the first and most important design decisions. The Metallurgical / Material engineers consider the fitness of the chosen materials for the production of farm implements. It is a matter of whether the materials will perform adequately, during the production and service of the implements in operations. The choices are made partly on the basis of experience, and partly on the scientific evidence of the materials science and engineering. Three major factors are considered in selecting a material for agricultural implements production (Suleiman et al, 2005) .

.(i) Physical and mechanical properties of the materials

(ii) Availability of such materials

(iii) Cost consideration.

Other basic properties which are not exhaustive could also include abrasive wear, toughness and high strength when selecting materials for agricultural implements.

6.0 ENGINEERING INFRASTRUCTURE

The Federal Government of Nigeria has vividly understood the problems in the agricultural sector and has established agencies or institutions to address the problems. Some of the institutions are Operation Feed the Nation (OFN) and Agricultural Development Projects (ADP's) etc. Research centres were also established to furnish the institutions with practical data towards improved agricultural productivity. In addition faculties of agriculture and three specialized universities of agriculture were established. Government had also imported tractors through her hiring agencies. These efforts of government are commendable.

In spite of the above investment by government, the level of mechanization is still minimal when compared with India, Malaysia, Indonesia, Thailand and Pakistan. Most of these countries have mechanized their agricultural production.

There is the problem of inadequate manpower to man and maintain the infrastructures. There are few and highly dispersed tractor repair shops thus leaving maintenance into the hands of inexperienced mechanics. The dearth of trained drivers of farm vehicles creates the assumption that any heavy vehicle driver is qualified to operate the tractor. Underdevelopment of the infrastructure therefore undermines the efficient utilization of the available infrastructure and impedes production of abundant food to the citizens of the nation. Ajibola (1998) stated that "Nigeria has the lowest percentage of labour force(4%) committed to manufacturing compared with 17.3% for Malaysia , 32% for Taiwan 28% and 24% for South Korea and Japan respectively". Nigeria must be able to make her farm implements by using talents and skills trained for the industry. Engineering infrastructure for skill development and manufacturing requires (i) Skilled manpower Trainer (ii) Relevant Technology (design manufacture, operation and maintenance of the machine) (iii) Materials conversion systems for raw materials.

7.0 FOOD PROCESSING AND STORAGE FACILITIES

The production of most of our food crops in this country is seasonal. As perishable items; they go bad shortly after harvest unless storage facilities are provided for their preservation. Yams tubers are known to grow very well during the raining seasons. The challenge therefore for the preservation of yam tubers occurs during the hot seasons. It therefore becomes pertinent to provide storage facilities to take care of these challenges when the need arises. If such challenges are not taken care of there are tendency that such items will get spoilt and may not readily be available during the season. This may also lead to scantly in the off harvest month therefore causing setback for the production of abundant food for the nation. This situation is becoming unacceptable; hence the need for adequate preservation of these food items for all the year round availability should be encouraged.

The preservation of food and other agricultural produce using solar refrigeration and solar drying could be adopted. The technological developments have made it possible to use sun in the conventional refrigeration methods but with the vapour absorption cycle more amenable for solar energy utilization. Some items such as meat, poultry and fishery products, citrus fruits, banana and sub-tropical fruits are better preserved in the fresh form a desirable requirement of maintaining the original states. On the other hand, some food items such as grains and vegetables are better preserved in dried form.

Just as in the above, there is need to embark on large scale production of these facilities. Simple traditional storage systems can be improved upon and made available cheaply. In this regards, Aderibigbe developed a simple storage facility using Ferro-cement at the University of Lagos some-time ago. Similarly, Tower Aluminum a company based at Ikeja, Lagos exhibited a small storage plant at one of the Lagos international Trade Fair events a few years ago. (Salawu, 1993). In any other country the results would have been picked up and developed. Also, some of our professors in the field of Agricultural Engineering, for example Professors Odigboh & Makanjuola, have developed several food processing plants that can be picked up and put on large scale production by our Society (Salawu, 1993).

8.0 INFORMATION TECHNOLOGY

Information Technology, or IT, is one of the fastest growing industries in the world. The use of computers to process information has increased astronomically since the systems were introduced to the business world in the 1950s. E-mail is augmenting and even replacing physical mail which is now referred to as "snail mail." The internet facility has also provided a great access to information in all field of human devour. A luxury automobile now contains over 70 computers, providing functionality to make sure we know when to stop for gas – sometimes in audio. Our bills, updates to insurance policies, and stock certificates are produced by computer programs and sent to us with a computer generated address label (Susan Hodge 2003) .

Computers affect both our work and personal lives, but while there is certainly much overlap, the business world has additional systems, terms, and acronyms that are not used in personal computing. A basic knowledge of the technology, companies, IT groups, and IT software used in business computing has become a part of almost everyone's job. The computer industry is an exciting and challenging field that can look complex and difficult. New systems appear daily, and there's no end to new terms and acronyms that join the technical vocabulary list.

While we get involved in production technology put forward, there are need to begin to look into the development of Information Technology, an area in which we can easily develop expertise in this regards. And Nigerians are capable people when given the challenge. The fact we do not need much imported items makes it an attractive area. Here through the development of software engineering a lot of foreign exchange can be save and also earned for the country. If the nation joins the information technology group now, the country will not be left behind in the age of information technology and advancement as they affect production of abundant food for the nation. This effort could also lead the country to development as it could be considered in the comity of nation in the production of abundant food for its citizens (Adegboke, 1993).

9.0 COMMUNICATION DEVELOPMENT

Provision of good communication network between the farm and the urban centres is essential for effective communication. In fact most of the accidents on our roads could be avoided if there is good communication network as most business transactions that put people on the road could have been done on the phone. In effect, telephone facilities need to be provided in village and farm centres.

Communication development could also be looked at in the light of dissemination of information between Agro- Research Institutions and the farmers. As Fajemirokun 1992, rightly pointed out, a lot of research has been carried out in this regards, through International Agencies and Federal Government efforts, to find the best conditions under which tropical seeds, tubers, woods, vegetables etc would thrive. There is not much evidence, however, to show that information on the result of these researches get to the farmers. The Fulani cattle rearer knows nothing about artificial insemination. The piggery farmer is not aware of what research findings can do to his yield and poultry farmers are also ignorant of how advanced engineering and technology can improve the weight of their crops and animals.

Through the use of advance engineering and technology, it is possible to attain increased agricultural produce yield with minimum energy input but such good news need to be communicated to the farmers through close liaison between them and the technologist, scientists and agricultural engineers.

10.0 SUGESSTIONS AND RECOMMEDATIONS

A country that cannot feed its citizens can best be described as a poor nation. The following engineering and technological infrastructural development are suggested and recommended for consideration If these are carefully followed then the provision of abundant may be ensured.

- The Government , the stakeholders and those that are saddled with the provision of basic infrastructures such as good housing, portable drinking water, electricity supply, good roads and rail network and available agricultural implements should be encouraged to do
- Federal Government of Nigeria should make efforts to reactivate and rehabilitate some of the ailing industries which have been moribund, with a view to manufacturing most needed agricultural implements and spare parts.
- Federal Government should make it as a matter of urgency and importance to embark on the rural telephony project, which will provide telephone services to these farm centres and have a link between the research Institutes and the farmers for more effective dissemination of information on research findings via information technology.
- The stakeholders should target these areas of production and information technologies and improve on the development of varieties of food for the growth of the nation's agricultural sector.
- The Government and agricultural establishments, research institutions should encourage the sponsoring of researches and development activities in areas of agriculture and should assist 'Agriculural engineer' entrepreneurs by creating faourable environments.
- Government and all the stakeholders should be involved in establishing scale production of agricultural equipment and agro-allied infrastructures for small scale and rural farmers
- Government should invest in computers and software engineering development so as to launch the country into the era of telematics and information technology for the improvement of Agriculture and for the provision of abundant food for the citizens.

11.0 CONCLUSIONS

Abundant food production should be regarded as infrastructural requirement that must first be handled because it forms the basic required for getting the nation out of the poverty viscous circle. The agricultural engineers must be encouraged to invest in research with a view to developing simple implements for agriculture and equipment for agro-allied industries. The agricultural engineers should not to be left out of the Telematics and information age, as investment in these technologies will encourage Nigerian in infrastructural development for the provision of abundant supply of food to the populace.

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THE EFFECTS OF FERTILIZERS ON GROUND WATER QUALITY - A CASE STUDY OF AKAEZE, IVO L.G.A, EBONYI STATE, NIGERIA

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ABSTRACT

It can be possible that intensive fertilizer application to crops can give rise to the ground water quality degradation other than contamination by hydrocarbon of petroleum or heavy metals. Ground water is one of the sole sources of drinking water for many rural communities and some large cities and thus application of fertilizers during agriculture is considered to be one of the major pollution sources to water bodies, including ground water. A nutrient loss from agricultural activities causes many problems to the aquatic environment and to human at large. During this study, a groundwater model is simulated in Civil Engineering Laboratory using a PVC pipe of 1500mm length, 150mm diameter with five taps of 12mm diameter, spaced at 200mm intervals filled with clay loam soil collected from Akaeze, Ivo L.G.A of Ebonyi State. It was discovered that, on application of N:P:K 15:15:15 to the soil, concentration of PO_4^- increased from depth 500 to 900mm but decreased from depth 900mm to 1300mm. The concentration of nitrates and potassium increased depth. For N: P: K 20:10:10 and Urea, the concentration of nitrates and potassium increased down the depth Phosphate concentration decreased down the depth for N: P: K 20:10:10. Urea had phosphate concentration increased from depth 500mm to 1100mm but decreased from depth 1100mm to 1300mm. From our findings, there are generally higher concentrations of nitrates and potassium in the groundwater modeling than the concentration of phosphate. Therefore, this study supports the call that human activities in farm land have led to the degradation of groundwater quality particularly in an unconfined aquifer.

KEYWORDS: *Effects, Fertilizers, Ground Water, Quality*

INTRODUCTION

Ebonyi State, a state in the South- Eastern part of Nigeria which is rich in rice and other food production is considered for study, considering the fact that it has one of the leading and biggest fertilizer and chemical producing company which produces different kinds of organic fertilizer. Research has also shown that the State groundwater table depth is not far from the ground surface making its groundwater table viable to contamination. Therefore, Akaeze, Ivo local government in the Southern part of the State is being used as a case study in studying the leaching and seepage of different kinds of fertile through the soil (THISDAYLIVE News, 2016).

To ensure that these various agricultural targets and higher productivity are achieved, mechanized methods of farming are being employed which include the use of fertilizers and technically advanced farm machineries. Despite the advantages of these mechanized methods of farming, it is paramount to consider its ill-effect on the environment to ensure the safety of human and aquatic life. One of the mechanized methods of farming which is the use of organic fertilizer is being studied to investigate its effect on groundwater quality (Hounshell, 1984).

Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. It can stay underground for hundreds of thousands of years, or it can come to the surface and help fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink. About 50 percent of our municipal, domestic, and agricultural water supply is groundwater **(**California Department of Water Resources, 2009).

Soil is a highly variable medium. There are four main ingredients (fractions) that are consistent with all types of soil: minerals, organic matter, water and air. These four fractions fall into two categories which aresolid (minerals and organic matter) and non-solid (water and air). The solid section makes up approximately 50-70% by volume of the total soil. Combined, the mineral and organic matter fractions give the soil a characteristic known as texture (*McCarthy, 2006).* A good mix of sand, silt and clay particles will allow the soil to hold sufficient nutrients as well as allowing adequate exchange of air and water essential for plant growth.

Fertilizers are manufactured mixtures of chemical products that contain N, P, K and other necessary nutrients. They are spread over the soil to supply the soil with the proper amount of these nutrients. The three numbers on the front of the fertilizer bag represent the percentage by weight of N, P and K in that particular mixture. These numbers are used to calculate how much of a particular fertilizer to apply at one time (*Leigh, 2004).*

Ground water pollution in most cases occur due to the contaminations from the intensive use of different fertilizers from farm land, these fertilizers leaches and mixes with groundwater which then pollute the water. Generally, all water pollution affects organisms and plants that live in water bodies. In almost all cases the effects are damaging either to the individual species or from the populations but also to the natural biological communities (Jain, 1993).

Nitrate is a chemical found in most fertilizers, manure, and liquid waste discharged from septic tanks. Natural bacteria in soil can convert nitrogen into nitrate. Rain or irrigation water can carry nitrate down through the soil into groundwater. Your drinking water may contain nitrate if your well draws from this groundwater (Kross et al, 1993).

Nitrate is a component in fertilizer, and nitrate is found in sewage and sanitary wastes from humans and animals. Certain construction activities, such as blasting, can be another source of nitrate in bedrock wells. Fortunately, nitrate concentrations are not normally high in New Hampshire wells or surface waters. Nitrate levels can become elevated when the surrounding area is heavily developed, used for agricultural purposes, or subject to heavy fertilization. (Dykhanov & Slept, 1979)

Nitrate concentration in ground water generally increase with higher nitrogen input and higher aquifer vulnerability. Therefore, where people live and the depth of their groundwater supply determines the quality of the water they drink, thus people who consume shallow groundwater are likely to drink high nitrate water. Nitrate contamination generally decrease with depth to ground water median nitrate concentration and percent of wells from which water exceeds the EPA drinking water standard for nitrate (10mg/l) are highest for shallow groundwater (up to 100 feet deep). The water table in shallow wells is closer to the land surface and to potential sources of contamination, such as fertilizers and septic systems which have several adverse effects on our health (Kross et al, 1993).

Thus this research aims at providing an assessment of the current state and trends in the groundwater quality at Akaeze, Ivo L.G.A, Ebonyi State. The assessment will provide information on the degree of contamination by NO_3-N, $PO_4^{3-}$and K_2O found in N:P:K 15:15:15, N: P: K 20:10:10 and Urea; in shallow wells located in unconfined aquifers.

MATERIALS AND METHODS

A model bore-log was simulated in Civil Engineering Department, University of Nigeria, Nsukka using the following: 1500mm length PVC pipe of 150mm diameter; shower pump; five taps of each 12mm diameter; clamp; sieve; bucket; and gum. This is shown in the experimental set-up in figure 1. Soil was collected from Akaeze, Ivo L.G.A, Ebonyi State at one of the rice farms. This soil was tested in Soil Science Department, University of Nigeria, Nsukka where it was certified as Clay Loam. The fertilizers N:P:K 15:15:15, N: P: K 20:10:10 and Urea; were procured from Crop

Science Department, University of Nigeria, Nsukka. Rain water was collected from the Sanitary Section of Civil Engineering Department, University of Nigeria, Nsukka.

EXPERIMENTAL PROCEDURE

The clay loam soil was used to fill the model bore-log up to tap A level, then fertilizer (N:P:K 15:15:15) was applied up to 50mm depth and another soil was applied up to a depth of 50mm to cover the fertilizer. Shower pump was used to apply rain water gently to the soil until it got saturated. On saturation water started coming out of each of the taps (i.e. TAP A, TAP B, TAP C, TAP D and TAP E) at different time intervals and was collected with containers labeled sample A, B, C, D, E respectively. For each sample, the concentration of Nitrate, Phosphorus and Potassium were tested using recognized standard methods (ALPHA, 2005); which therefore determines the concentration of each parameter at different depth. This procedure was repeated for N:P:K 20:10:10 and Urea. The laboratory set-up is shown in figure 1. The moisture content the clay loam soil was determined for each fertilizer application.

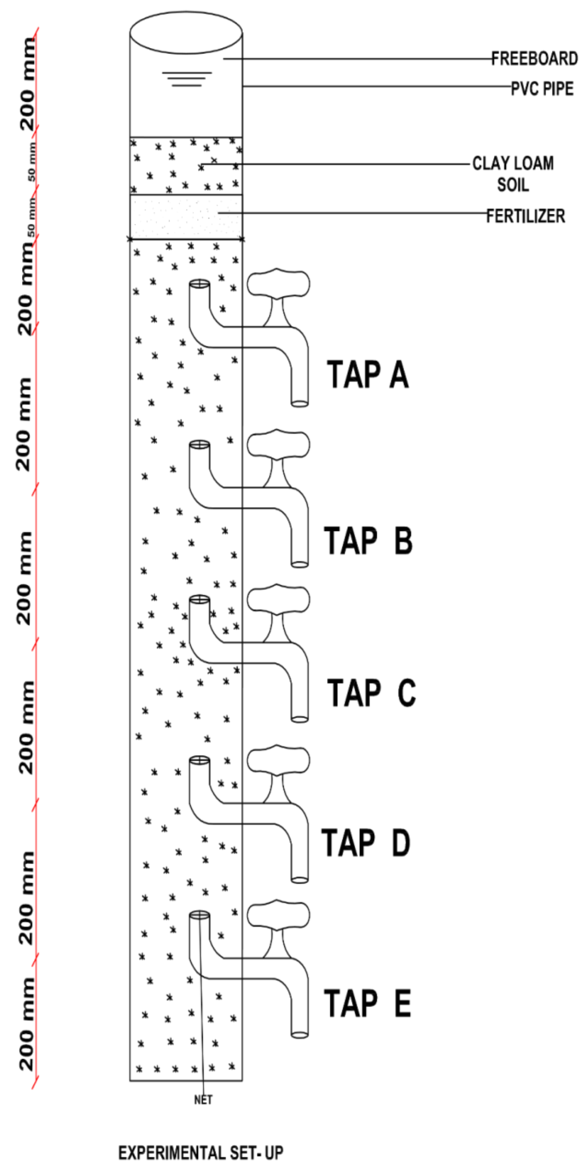

Figure 1: Experimental Set-Up

RESULTS AND DISCUSSIONS

The result of PO_4^-, NO_3^- and K^+ for N.P.K 15:15:15 are given in table 1

Table 1: Readings for N.P.K 15:15:15

SAMPLE	DEPTH(mm)	TIME (Sec)	CONCENTRATION (mg/l)		
			PO_4^-	NO_3^-	K^+
A	500	480	37.80	1.686	1.00
B	700	780	37.95	1.866	1.60
C	900	1140	38.40	2.357	3.70
D	1100	1500	37.40	2.388	8.90
E	1300	1980	31.60	2.582	11.20

The result of moisture content of soil sample for N.P.K 15:15:15 is given in table 2

Table 2: Moisture Content of Soil Sample for N.P.K 15:15:15

Moisture content can number	A_1	A_2
Weight of wet soil + can (W_1)	45.5	54.6
Weight of dry soil + can (W_2)	40.0	51.0
Weight of can only (W_3)	11.2	22.8
Weight of moisture (W_1 - W_2)	5.5	3.6
Weight of dry soil (W_2 - W_3)	28.8	19.2
Moisture content $\frac{w1-w2}{w2-w3}$ X 100%	19.0 %	18.8 %
Mean moisture content	18.9 %	

The result of PO_4^-, NO_3^- and K^+ for Urea are given in table 3

Table 3: Readings for Urea

SAMPLE	DEPTH(mm)	TIME (Sec)	CONCENTRATION (mg/l)		
			PO_4^-	NO_3^-	K^+
A	500	360	36.57	1.521	1.01
B	700	1680	37.25	1.971	1.50
C	900	3060	37.85	2.277	2.99
D	1100	4200	38.40	2.401	5.75
E	1300	5200	36.95	2.599	10.55

The result of moisture content of soil sample for Urea is given in table 4

Table 4: Moisture Content of Soil Sample for Urea

Moisture content can number	B_1	B_2
Weight of wet soil + can (W_1)	44.4	53.0
Weight of dry soil + can (W_2)	40.1	48.4
Weight of can only (W_3)	13.5	20.1
Weight of moisture (W_1 - W_2)	4.3	4.6
Weight of dry soil (W_2 - W_3)	26.6	28.3
Moisture content $\frac{w1-w2}{w2-w3}$ X 100%	16 %	16 %
Mean moisture content	16 %	

The result of PO_4^-, NO_3^- and K^+ for N: P: K 20:10:10are given in table 5

Table 5: Reading for N: P: K20:10:10

SAMPLE	DEPTH(mm)	TIME (Sec)	CONCENTRATION (mg/l)		
			PO_4^-	NO_3^-	K^+
A	500	422	28.20	0.662	0.07
B	700	1232	27.70	0.910	1.69
C	900	2102	27.30	1.344	2.99
D	1100	2853	26.50	1.395	8.10
E	1300	3590	24.90	1.591	10.92

The result of moisture content of soil sample for N: P: K20:10:10is given in table 6

Table 6: Moisture Content of Soil Sample for N: P: K 20:10:10

Moisture content can number	C_1	C_2
Weight of wet soil + can (W_1)	43.4	51.2
Weight of dry soil + can (W_2)	40.2	47.3
Weight of can only (W_3)	15.6	17.2
Weight of moisture (W_1 - W_2)	3.2	3.9
Weight of dry soil (W_2 - W_3)	24.6	30.1
Moisture content $\frac{w1-w2}{w2-w3}$ X 100%	13.0 %	13.0 %
Mean moisture content	13.0 %	

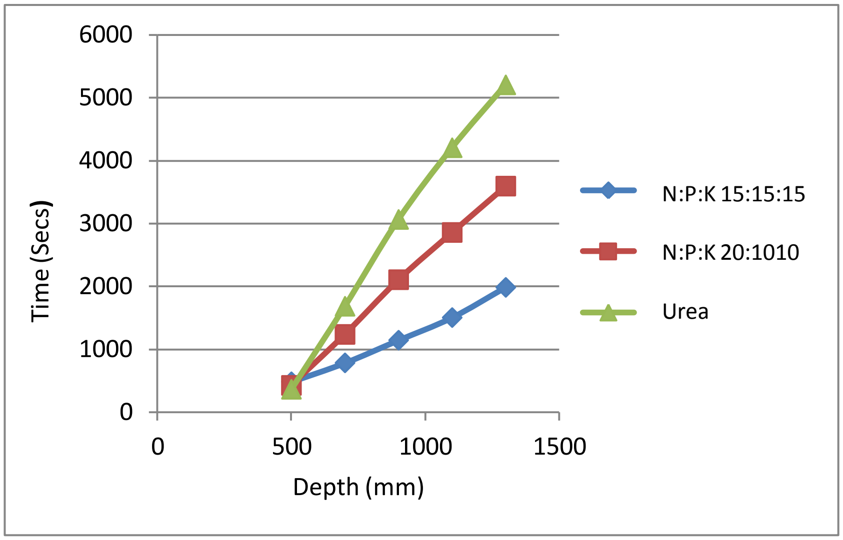

Figure 2: Graph of Time against Depth for the three fertilizers

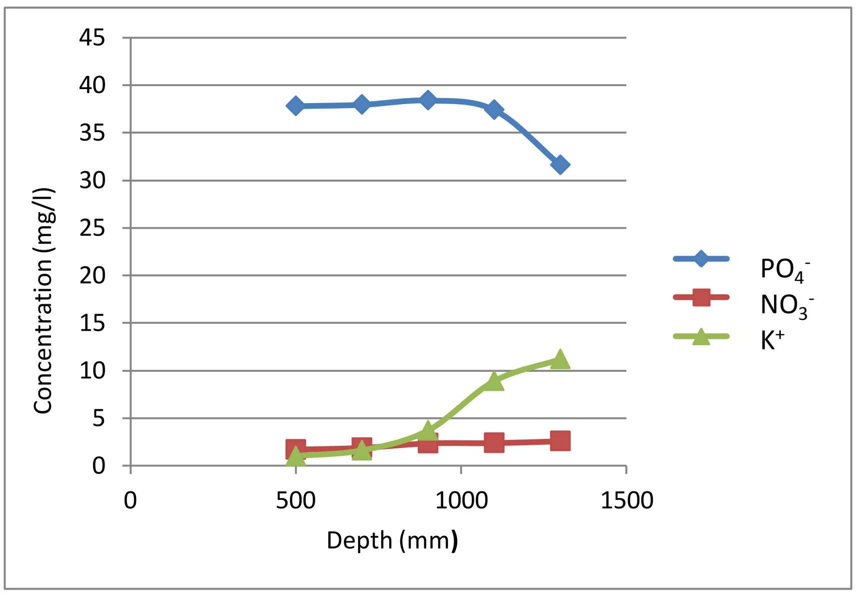

Figure 3: Graph of Concentration against Depth for N:P:K 15:15:15

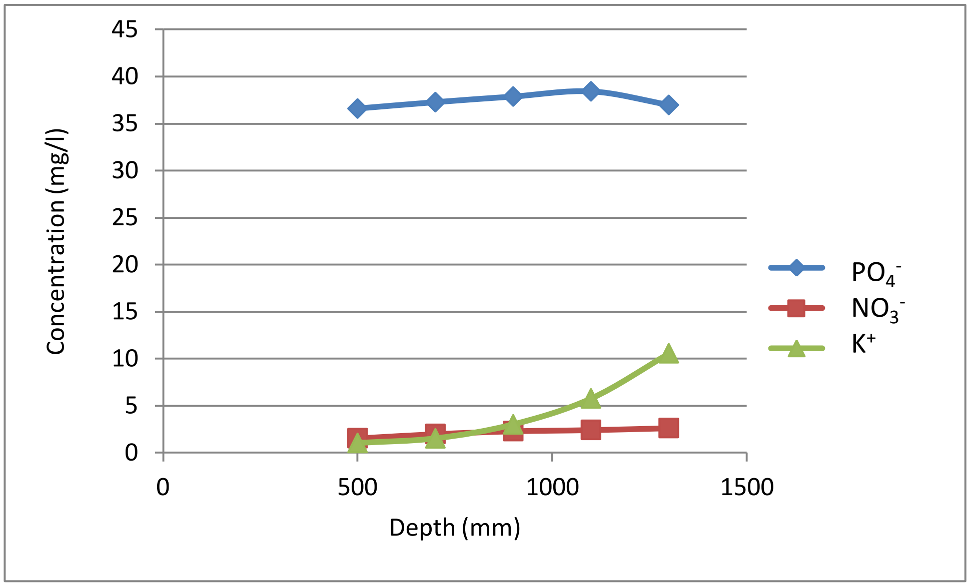

Figure 4: Graph of Concentration against Depth for Urea

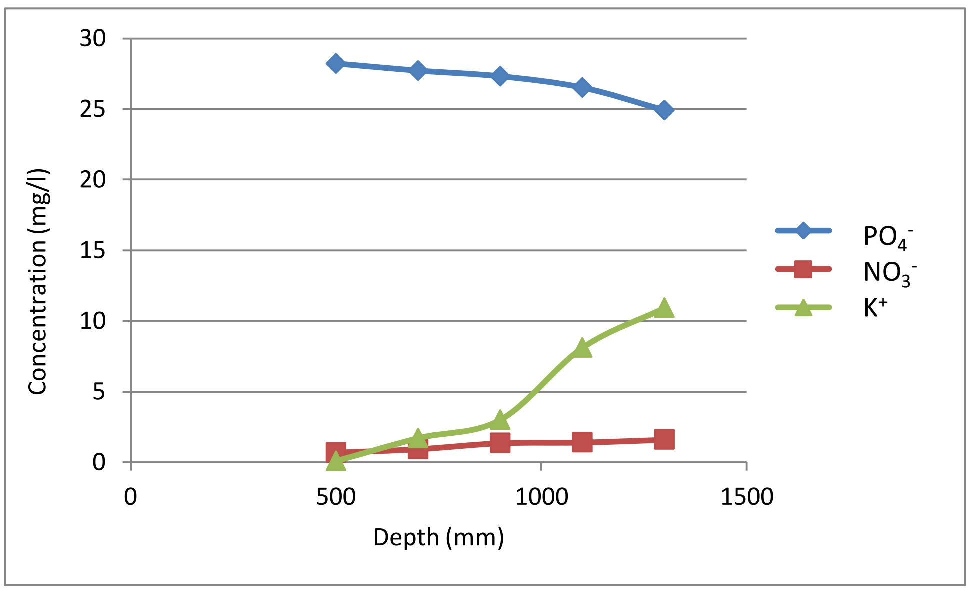

Figure 5: Graph of Concentration against Depth for N:P:K 20:10:10

ANALYSIS OF RESULTS

Result of table 1 shows that concentrations of NO_3^- and K^+ increases with time and depth for N:P : K 15:15:15. The increase of PO_4^- concentration with time and depth occurred up to 900mm depth and 1140s. From depth 1100mm to 1300mm and time (1500s to 1980s), there was a decrease in concentration of PO_4^- for N:P:k 15:15:15. Result of table 3 shows similar trend for Urea. Table 5 shows that concentration of NO_3^- and K^+ increases with time and depth for N: P: K 20:10:10. The reverse was the case for PO_4^- which decreases with increase in time and depth. The mean moisture contents of the clay loam soil for N: P: K 15:15:15, Urea and N: P: K 20:10:10 were 18.9%, 16% and 13% respectively (from tables 2, 4 and 6).

Research carried out in U.S by U.S Environmental Protection Agency (EPA), 2015 showed that fertilizer can leach up to 100 feet deep for shallow wells, with nitrate concentration exceeding the drinking water standard (10mg/l), generally increasing risk of contamination of ground water table. This implies that as Nitrate and potassium concentration increases with depth and time in our Model, at 100 feet or more the groundwater is thus contaminated and would exceed 10 mg/l following EPA standard for drinking water.

CONCLUSIONS

Fertilizer is an organic and synthetic substance usually added or spread on the soil to increase its ability to support plant growth and for greater increase in farm output or production. Although this fertilizer supports the growth of plants, but its intensive use on farm land and soils results to nitrate pollution of groundwater and even surface water which causes a lot of damage to humans and animals as well.

From our findings, there are higher concentrations of nitrates and potassium as the time and depth of penetration or seepage increases. Phosphates on the other hand generally decreases down the depth on groundwater modeling for the three types of fertilizers used in carrying out this experiment. It therefore implies that nitrate and potassium concentration would be high at some depth and would be unsafe for consumption.

This study therefore supports the call that human activities on farm land have led to the degradation of groundwater quality particularly in an unconfined aquifer. It also supports that people living in rural areas and around farmlands having well drained soil where intensive fertilizers are being used are at higher risk of groundwater contamination while places with poorly drained soil are less affected. Thus, the groundwater table of Akaeze, in Ivo L.G.A of Ebonyi State is vulnerable to nitrate contamination since it has groundwater table close to soil surface. The high level of nitrate on groundwater cause blue baby syndrome which leads to the hypoxia and in turn results to coma reducing the human life span if not properly treated. This high concentration of nitrates on human body causes a lot of damages especially on pregnant women. It causes miscarriages, various kinds of cancer**,methemoglobinemia, etc.** Therefore, groundwater has to be properly treated to satisfy human consumption.

RECOMMENDATIONS

The loss of soil fertility is inherent in all agricultural systems. Nutrients are taken up from the soil through the plants and needs to be replaced for subsequent plant growth. There is need to consider alternative sources of fertilizer. Other remedial actions in agricultural activities that could prevent or reduce the excessive use of fertilizer include:

- Early planting of crops at the beginning of the raining season in savanna climate to make use of the mineralization flush of nitrogen upon rewetting of the soil.
- Install vegetation covers after forest or fallow clearly to avoid nutrient losses on soils.
- Application of fertilizers (especially Nitrogen) in several small applications during the cropping season rather than all at once.
- Application of fertilizer at the zone of maximum root activity of tree crops.
- Also research on urine as a fertilizer is carried out all over the world, in settings ranging from much applied demonstration trials to rigorous scientific studies. The use in agriculture of excreta from urine-diversion toilets can be an alternative solution to the high concentration of nitrates in groundwater. As human urine contains N: P: K (Nitrogen, Phosphorous, and Potassium) as well as other micro-nutrients which are present in organic fertilizer, urine can be used as a fertilizer. (Rajani et al, 2014)
- Finally, the soil benefits greatly from the addition of compost. Fertility, water-holding capacity, bulk density and biological properties are improved.

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THE IMPORTANCE OF SCHEDULING IRRIGATION TO FARMERS: A REVIEW

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ABSTRACT

Many farmers are suffering from the negative effect of not being able to know when to irrigate their field crops, how much water to apply to their fields and how should it be applied. These common factors have made many farmers not to harness the potential of irrigation properly and as a result they incur more expenses than necessary. Being ignorant of when to irrigate, how much to irrigate and how to irrigate have made many farmers to over-irrigate or under-irrigate. The effects are always detrimental to crop production. Scheduling irrigation is the only solution that can help to eliminate the issue of water stress to crops, prevent water logging, excess run off, deep percolation and unnecessary evapotranspiration. The criteria that can be used by farmers to schedule irrigation are plant criteria (plant appearance, stomatal opening, critical period of water need), soil water status (soil water content, depth – interval of irrigation, critical level of soil water, soil water tension and electrical resistance), climatic approach (Irrigation Water/Cumulative Pan Evaporation ratio IW/CPE ratio, Rate of Evapotranspiration and Class A Pan). Some of the instruments that farmers can use to determine when to schedule irrigation include tensiometer, infrared thermometer, electrical resistance and neutron probe. With this in place many farmers will know how and when to schedule irrigation in their crop field that will promote the growth of crops with the attendant increase in crop yield.

KEYWORDS: Scheduling, Evapotranspiration, Tensiometer, Irrigation Water, Stomatal, Percolation.

1. INTRODUCTION

The worldwide demand for fresh water is increasing steadily especially in water scarce areas, producing an unprecedented need for efficient water use in irrigated agriculture (Sabine et al., 2016). Regardless of the of the scarcity of water many farmers still conduct full irrigation to reach soil water content to the extent of reaching field capacity in order to increase crop yield and quality there by wasting water as a result of being ignorant of irrigation scheduling. (Mckeown et al., 2010).

According to Hengeller et al., (2011), irrigation scheduling is simply the determination of when and how much water to apply. Irrigation scheduling is generally based on estimating water needs using a model that takes into account weather conditions and crop characteristics (Allen, et al., 1998). There are many modern scientific irrigation scheduling that uses a single approach or combination of weather, soil or plant based approaches.

The relationship between yield and crop water use has been investigated by many researchers. Information on the optimum time to apply limited amount of water to obtain maximum yield of high quality crops is essential for efficient use of irrigation water (Matsunaka et al., 1992). Recent studies show that proper irrigation management is critical to spring wheat yield quantity and quality (Sharma et al., 1992). Sharma et al., 1992 also found that when the same amount of water was applied at different growth stages, there was a significant difference in productive tillers. Chaudhary and Kumar (1980) reported that maximum reduction of productive tillers was obtained when moisture stress occurred at the tillering stage. And also grain yield of wheat was significantly increased with increasing irrigation frequency.

Matsunaka et al., (1992) found that soil moisture conditions affect nutrient availability to the crops. Optimum irrigation increases Nitrogen (N) absorption by the crop leading to a greater number of wheat tillers and a greater yield.

Water applied directly to the root zone minimizes water loss through runoff and deep percolation. Precise and controlled water applications are necessary to achieve the desired yield and water efficiency (Madhi et al., 1997).

The objective of this review was to explore the importance of scheduling irrigation and on how to determine when crops are in need of water with regard to the moisture content of soil. In this review, the author has painstakingly reviewed many researchers' works, who has used different instruments like neutron probe, infrared canopy, resistance block and tensiometer to inspect crop fields and also the leaves of the crops in order to know when to irrigate and how much water to apply. This will go a long way in reducing the negative effect of water stress as a result of under irrigation or improper timing and at the same time correct the negative effect of over – irrigation .

2. IMPORTANCE OF SCHEDULING IRRIGATION

According to Mahdi et al., (1997) the importance of scheduling irrigation were enumerated as follows:

- When water is applied as at when due the issue of run off and deep percolation will be eliminated.
- It helps to increase water use efficiency by the crops.

- Once water is applied on time, the crops will not suffer from water stress thus they will be increase in crop yield.
- It helps farmers to economize their limited resources by prudent concerning the quantity of water supplied to the crop field.
- Adequate moisture content aids the plants to absorb the necessary nutrient required by plants for optimum growth and yield.

3. FACTORS THAT GOVERN SCHEDULING OF IRRIGATION

According to Jensen (1990), the factors that govern the scheduling of irrigation in the field are current level and expected change in available soil water for each field over next 5 to 10 days. In order to estimate the probable date of next irrigation on each field so as to avoid adverse effect of water stress on crops and the amount of water to be applied, the irrigator should be able to control or measure that amount of water accurately. This will help in increasing irrigation efficiency. Apart from that, the targeted soil water level will be maintained and the adverse effect of too early or late irrigation will be curtailed.

4. CRITERIA FOR SCHEDULING IRRIGATION

4.1 *Plant indicator*

According to Dilip (2009), plants show certain characteristics in their constitution, appearance and growth behavior with changes in available soil water and atmospheric conditions. These changes in plants are often an indication that plants are suffering from water stress. Some of the plant criteria considered for scheduling irrigation are general appearance, plant water potential, critical period of water need, stomatal opening, and plant temperature.

4.1.1 *Stomatal opening*

According to Jensen *et al.*, (1990), plants transpire through little opening called stomata. Once plants reached water stress, they begin to close their stomata and cease to transpire, thereby causing the plant to heat up and the canopy temperature to rise.

4.1.2 Critical period of water need

According to Majumdar (1988), Dilip (2009), irrigation scheduling may be decided based on stages growth in crops in which the physiological stages are distinct to locate the critical period of water need. The critical stages are the crown initiation, tillering, flowering, milk and dough stages, branching, tasseling, pegging, pod setting, and grain filling. Table 1 illustrates the sensitive stages of some important crops for irrigation scheduling.

Table 1. Sensitive stages of some important crops for irrigation scheduling

Crop	Sensitive stages in order of decreasing importance
Rice	Flowering, grain filling, tillering, panicle initiation, transplanting
Wheat	Crown root initiation, flowering, jointing, milk and dough
Maize	Tasselling, silking, grain filling, and knee height
Sorghum	Flowering, seedling and grain filling
Groundnut	Pegging, pod setting and pod filling
Rapeseed-Mustard seed	Flowering, pod development and branching
Sesamum	Flowering, capsule development and branching
Soybean	Flowering, pod development and branching
Sunflower	Flowering, seed feeling, 4 to 6 leaf
Safflower	Flowering and seed filling
Nigerseed	Flowering and seed development

Source: Majumdar, 1988

4.1.3 Plant appearance

With water stress, plants generally show some unusual appearance like changing colours, rolling of leaves, curling of leaves, wilting and dropping. Dilip (2009), said that some plants such as wheat change their normal deep green colour to lighter green and then to yellow when water stress occurs. Also deep green and light green colours in alfalfa are indicative of water stress and adequate supply of water respectively. Water stress is also shown by rolling of leaves in wheat or rice or by temporary wilting of plants as with sunflower and sugar beet during the hottest part of the day.

4.2 *Soil water status*

Scheduling irrigation based on soil water content is the most accurate, reliable and dependable method. Determination of available soil water is more important than estimating the total water content of soils. It is important that information concerning the optimum water regime of crops and the available water holding capacity of soil is known. Some of the soil water status criteria are soil water content, depth – interval of irrigation, critical level of soil water, soil water tension and electrical resistance (Dilip, 2009).

4.3 *Climatological approach*

This approach make use of the knowledge of empirical formula in determining the rate of water depletion in the crop field with help of evapotranspiration, Class A Pan and Cumulative pan evaporation ratio in scheduling irrigation. Prihar et al., (1976) observed that scheduling irrigation to wheat based on irrigation water/cumulative evaporation ratio (IW/CPE ratio) of

0.75 to 1.00 irrespective of stage saved 34 percent of water for post sowing irrigations compared to the practice of giving five irrigation at five phonological stages.

5. Methods of Determining the Level of Soil Moisture Content

5.1 *Neutron Probe:*

This instrument is used to determine the moisture content of the soil. A neutronprobe or neutron moisture gauge contains a radioactive source that sends out fast neutrons. These fast neutrons are about the same size as a hydrogen atom, a critical component of water. When the fast neutrons hit a hydrogen atom, they slow down. A detector within the probe measures the rate of fast neutrons leaving and slow neutrons being bounced back. This ratio can be used to estimate soil moisture content.

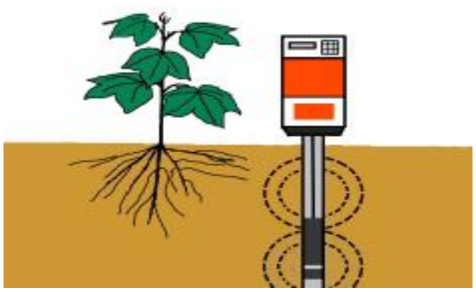

Figure 1. A Neutron Probe (Soil Moisture Guage)
Source: Jensen, 1990

5.2. *Infrared/Canopy Temperature*

An infrared (IR) thermometer measures the thermal
temperature of the plant leaves or a crop canopy. Once plants go into water stress, they begin to close their stomata and cease to transpire, causing the plant to "heat up" and the canopy temperature to rise. Infrared readings can detect this increase in plant temperature. Figure 2 illustrates on how to use infrared thermometer to measure crop temperature.

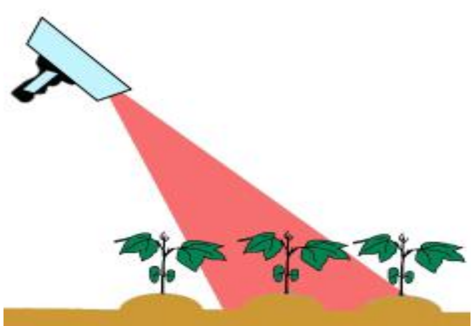

Figure 2: An Infrared Thermometer
Source: National Engineering Handbook, 1997

5.3. *Electrical Resistance*

The principle behind these devices is that the moisture content can be determined by the resistance between two electrodes embedded in the soil. The higher the water content in the soil the lower the soil resistance.

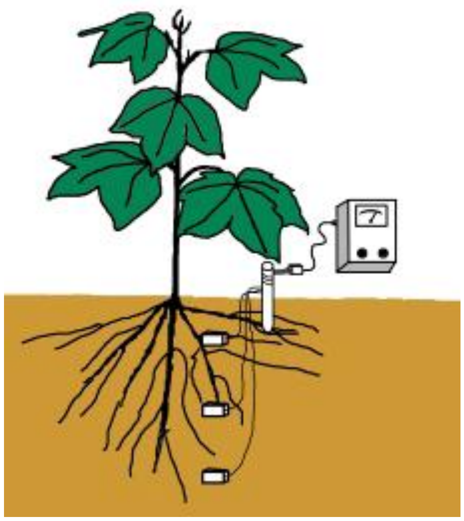

Figure 3. A Resistance Block

Source: Jensen, 1990

5.4. *Tensiometer Method*

Tensiometer works on the principle that as the soil water content decreases, the tensiometer reading increases. Tensiometer is very efficient in measuring soil water tension from zero to 0.85 atm. When tension is higher than 0.85 atm, air gets into the system giving inaccurate reading (Dilip, 2009).

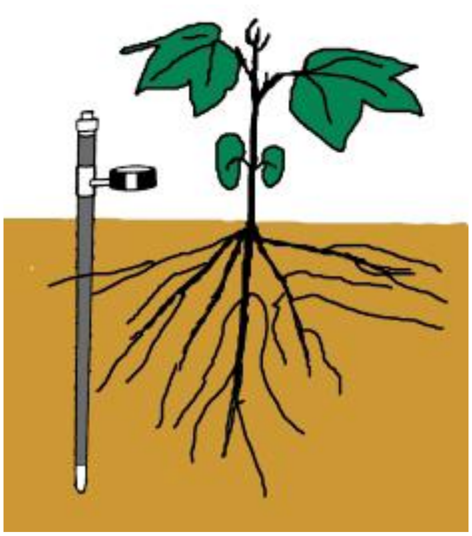

Figure 5: A Tensiometer

Source: Dilip, 2009

6. Why Farmers Needs Scheduling Irrigation

The importance of scheduling of irrigation should not be treated with lackadaisical attitude because of the potential role it is capable of playing in terms of crop yield. Namait et al., (2008) found that there was a significant effect on plant height due to irrigation regime in their study. They also observed that the growth of their crops in terms of height, weight, yield and nutrient uptake was dependent on the level of irrigation regime. Namait et al found that wheat grain yield was higher as the plants were irrigated at 1.25 Evaporation Pan Coefficient (EPC) with increases which reached to 8.00 to 19.11 % for EPC 1.25 treatment over 1.00 and 0.75 EPC treatment by 16.07 %. The superiority of 1.25 EPC shows that sufficient irrigation increased grain yield for wheat crop. This trend also reflects the importance of soil water to increase plant nutrient availabilty in soil solution and improvement in all growth factor and yiewld component, which lead increased production of wheat

Based on experiment conducted by Mushari (2008) on how irrigation scheduling affects the growth parameters and water use efficiency of barley and faba bean crops in Al-Asha, Saudi Arabia, he found that adequate soil moisture content is vital for crop growth and yield. In the study he found that plant height decreased from 65.9 – 60.8, 54.8 and 48.6 cm, leaf area index from 7.1 – 6.4, 5.4, and 3.1 and 1000 grain weight from 41.50 – 39.7, 37 and 35.7 g when receiving irrigation at 15, 30 and 45% depletion of total available soil water respectively than the control treatment (daily irrigation to maintain soil moisture at field capacity). He also observed that harvest index and grain protein (%) decreased significantly with increasing water stress than the control treatment (irrigating to maintain soil moisture at field capacity) mean ranges of different plant characteristics were 1.3 – 2.2 (tillers/plant), 321-914 (tillers/m^2), 1773.4-2995.0 g/m^3 (fresh weight), 546.7 – 1008.5 g/m^2 (dry weight), 3.9-6.8 cm (spike length) in different irrigation treatment.

It is imperative for us to know that the level of irrigation regime is crucial to crop growth and yield. If water is to be applied in the field, it should be applied at the right time and the right amount as well.

7. CONCLUSION

Crop irrigation is a complex, difficult and unavoidable task in which three pertinent questions need to be answered: (i) How much water should be applied? (ii) When should it be applied?
(iii) How should it be applied?. These three basic questions is what Scheduling Irrigation is bent towards to on how to solve them. Scheduling irrigation is simply the determination of when and how much water to apply. It unequivally certain that the yield of crops largely dependent on level

moisture content and available water in the soil. Some of the instruments that can be used to know when to schedule irrigation include tensiometer, resistance block, infra red thermometer and neutron probe. From all indications if a farmers knows when to schedule irrigation, it will go along way in eliminating water stress from the crops and to reduce cost .

8. ACKNOWLEDGEMENT

The authors are grateful to Professor Garuba Sharubutu, the Provost Federal College of Animal Health and Production Technology, Vom, Plateau State.

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ASSESSMENT OF RAINWATER QUALITY AND PRACTICES FOR DRINKING AND IRRIGATION PURPOSES IN ENUGU-EZIKE, IGBO-EZE NORTH LGA, ENUGU STATE.

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ABSTRACT

Rainwater harvesting is one of the reliable water sources in the rural areas because of lack of access to the central water supply. The high concentration of dissolved mineral salts in the surface and ground water which has been used as sources of water for irrigation purposes has made it prudent to think about better alternatives, hence, rainwater harvesting. Rainwater samples were collected from rainwater harvesting systems in 25 households in Enugu-Ezike in Igbo-Eze North Local Government Area (LGA) of Enugu state. In all, 25 rainwater samples were collected and analysed for temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, nitrates, dissolved oxygen (DO), sulphates, chloride, total alkalinity, bicarbonate, total hardness, calcium, magnesium, total iron, chromium, arsenic, zinc, lead, cadmium, E.coli and enterococci according to standard procedures. In addition, sanitary survey was carried out in 100 households. There was consistency in the results of the assessment with respect to those reported by other studies with the exception of the absence of lead and cadmium. As expected, 72% of the tested samples had pH value below that of the drinking water guidelines (WHO, NSDWQ and NAFDAC) while other physicochemical parameters were well within the guideline limits. Also, 76% and 48% of the samples tested positive to E.coli and enterococci respectively. The water quality index (WQI) and irrigation water quality index (IWQI) results show an average value of 55.33 (marginal)and 96.46 (NR) which indicates that the harvested rainwater is unsuitable for drinking but can be used for irrigation and other domestic purposes such as cooking, bathing and laundry.

***Key words**: rainwater quality, irrigation, rural areas*

INTRODUCTION

Access to clean water poses a serious challenge to developing countries such as Nigeria (Song et al., 2009). Water deficit is the main factor that affects crop productivity in the arid and semi-arid regions globally (Ali et al., 2017). Also, access to good irrigation water has been a problem in some places especially in the rural areas. Irrigation has been carried out traditionally by lifting water from perennial streams, lakes, dams and basins in many parts of Africa (Yakubu et al.,

2017) .Most of the residents in the rural areas in Nigeria rely on the self-water supply such as streams, wells (shallow), rivers and rainwater thus making them vulnerable to some water borne diseases such as typhoid fever, cholera, dysentery and malaria parasites (Ishaku et al., 2011; Obeta and Chukwu, 2013; Ezenwaji et al., 2012). Since water is very important to the existence of mankind, the quality and quantity of any water supply planning scheme is important especially when it is for irrigation purposes (Yakubu et al., 2017). For long-term productivity, the knowledge of irrigation water quality is important to make informed management decisions (Brady et al., 2002). Good water quality is required for the irrigation of crops (FAO, 1985). The use of surface and ground water for irrigation purposes can expose the soil to problems such as salinity, sodicity, alkalinity and toxicity. But problems related to salinity, water infiltration rate and toxicity are the major soil problems used to evaluate irrigation water quality (Ayers and Westcot, 1994). Salinity in irrigation water reduces the water available for plant uptake by increasing the osmotic exertion required for plants to absorb water from the soil thereby resulting to reduced plant yield, desiccation of plant leaves and discoloration of fruits (Ajon et al., 2014). Leaching and dilution with water of good quality can be used to solve salinity problems in the soil as a result of using low quality water for irrigation (Ajon et al., 2014). Sodicity simply means the presence of excess sodium in water (Singh, 2000). This aggravates infiltration problems by causing swelling and dispersion of clay particles, surface crusting and pore plugging (Bauder et al., 2011), thus making it more difficult for plants to get enough water. Toxicity problems arise when plants take up ionic constituents (boron, sodium and chloride) from soil. These ions reduce transpiration by blocking the stomata thereby adversely affecting the plant growth. Infiltration is a very important process whereby water is provided to the root zone of plants. Infiltration problems occur when infiltration is reduced to undesirable extents. This makes less amount of water available for plant uptake thereby reducing productivity. Due to these highlighted problems associated with surface and ground water, it is imperative to assess the quality and practice of rainwater harvesting. To ascertain its suitability for drinking and irrigation with minimized problems in Enugu-Ezike. Enugu-Ezike is a rural community in Igbo-Eze North local government area of Enugu state, Nigeria. They lack surface water such as streams and rivers, so they depend on rain and borehole water as their primary source of water. They also depend solely on rainfall as the source of water supply for agricultural activities. Adoption of rainwater harvesting as a supplemental irrigation scheme will go a long way in reducing water deficit in the study area.

Rainwater Harvesting (RWH) can be defined as the interception of rainwater from the hydrological cycle to be used for domestic or agricultural purposes (Barron and Salas, 2009). Most people that adopt rainwater harvesting do so due to lack of high quality fresh water supplies or where households are motivated by environmental concerns (Mendez et al., 2011). Countries like

China, Brazil, Australia, Germany, India, Japan and New Zealand have used RWH techniques for supplemental irrigation to improve agricultural productions and also in water-stressed areas around the world (Jiang et al., 2013).

Table 1.1: Selected studies on the quality of irrigation water.

No	Country	Source	Chemicals Violated	Remarks	Refrences
1	Illorin, Nigeria	Josepdam irrigation scheme (river)	Sulphate, Potassium	Requires treatment before use	Adejumobi and Ojediran, 2015
2	South Eastern Oromia, Ethiopia.	River	none	Normal for agricultural production for all types of crops	Husien et al., 2017
3	Zaria, Nigeria	River	none	Normal for agricultural production for all types of crops	Yakubu et al., 2017
4	Kebeles, Northern Ethiopia	Ground water	TDS, Carbonate	Requires treatment before using for agricultural activities.	Brhane, 2016
5	Jigawa, Nigeria	Stormwater	none	Normal for agricultural production for all types of crops	Sabo and Karage, 2016
6	Karbala city, Iraq.	Ground water (confined aquifer)	none	Normal for agricultural production for all types of crops	Khalaf and Hassan, 2013

Many researchers have made attempts at assessing the physicochemical quality of roof captured rainwater (RCR) for domestic purposes such as drinking. Daoud et al., (2011) carried out a research in the West Bank, Palestinian Authority to assess the physico-chemical and microbial quality of roof-harvested rainwater in tanks. They found that the drinking water quality guidelines set by the WHO were not met by the physico-chemical quality of the harvested water with exceptions of pH, turbidity and lead (Daoud et al., 2011). A similar study by Radaideh et al., (2009) in Jordan concluded that all the physicochemical parameters complied with the Jordanian Drinking Water Standards (JDWS) except pH, Pb, and Cr. Not all studies of roof-harvested rain water stored in tanks have lead in concentrations exceeding the drinking water guideline (Magyar and Ladson, 2015). E.coli was found to be above zero CFU/100mL in some studies (Spinks et al., 2006; Ahmed et al., 2008; Ahmed et al., 2010; Sazakil et al., 2007).

Also, some researchers have done extensive research on the quality of irrigation water using surface and ground water. Dissolved mineral salts of various kinds are contained in all surface and ground water (Adejumobi and Ojediran, 2015). Sabo and Karaye (2016) carried out a comparative analysis of harvested rainwater quality for domestic and agricultural purposes and found that the concentrations of the physicochemical parameters are within the WHO drinking water guideline while the microbiological parameter violated it. This implies that the harvested rainwater cannot be used for drinking purposes without disinfection but can be used for agricultural purposes. Ali et al (2017) investigated the role of supplemental irrigation to crop (soghum) water use with rainwater harvesting. They concluded that the use of harvested rainwater reduced soil percolation, increased water availability and improved root growth.

The main objective of this research is to assess the quality and practice of rainwater harvesting in Enugu-Ezike to ascertain its suitability for drinking and irrigation. The specific objectives are to determine the physicochemical and microbiological quality of the harvested rainwater samples and compare results with the established drinking water guidelines (NSDWQ and FAO), ascertain the suitability or otherwise of the water samples using the CCME water quality index, calculate the irrigation water quality index (IWQI) of the harvested rainwater.

METHODOLOGY

Description of the Study Area and Rainfall Patterns

Enugu-Ezike is the area of study. It is a community located in Igbo-Eze North Local Government Area (LGA) in Enugu state, Nigeria. It is located at $6^0\ 4^{'}\ 7^{''}$ north and between $7^0\ 10^{'}\ 4^{''}$ east, lies within the transitional zone between the rain forest region of the Middle Belt zone of Nigeria (Agbedo, 2007). Demographically, it has a total population of 259, 431 at the 2006 census and 19.2 kilometers from the University of Nigeria, Nsukka (Ogbochie, 2011). Enugu- Ezike has an annual rainfall of 1698 mm (66.9 in) (NIMET, 2017). Figure 3.1 shows the map of the study area.

Data Collection

Rainwater samples were collected from 25 rainwater tanks (cisterns) using sterilised sampling devices (Fig. 1.1).

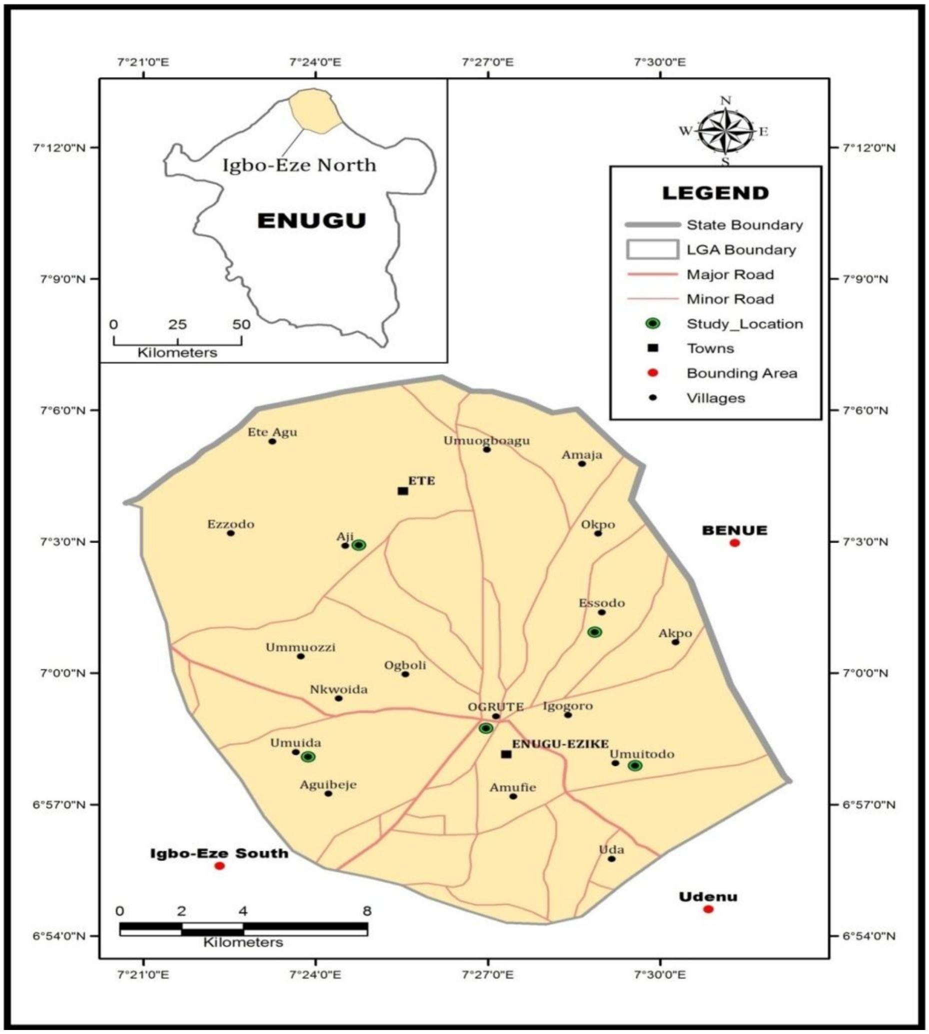

Figure 1.1: Map showing the study area (Enugu-Ezike)

These samples were transported to the National Water Quality Reference Laboratory, Federal Ministry of Water Resources, Enugu, within 24 hours of sampling. A total of 22 parameters were tested for each sample. Temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, nitrates, dissolved oxygen (DO), sulphates, chloride, total alkalinity, bicarbonate, total hardness, calcium, magnesium, total iron, chromium, arsenic, zinc, lead, cadmium, E.coli and enterococci concentrations of the rainwater sample were measured according to standard procedures (APHA, 2005). The method of sampling and sampling preservation as stated in the Standard Method for The Examination of Water and Wastewater (22^{nd} edition) by American Public Health Association (APHA) were followed strictly. Sanitary survey was also carried out in the study area to determine site specific conditions that affect rainwater quality. Data obtained from the interviews were coded and processed using SPSS 20 (Statistical Package for Social

Sciences) software. The survey was designed and administered to 100 households. The sample size was determined using the equation 3.1 below (Chowdhury, 2013):

$$n \geq \frac{\frac{N}{\varepsilon^2}}{\frac{1}{\varepsilon^2}+N} \tag{3.1}$$

Where, n is the sample size, N is the population size and ε (0.05) is the sample error which ranges between 0.01 and 0.2 (Chowdhury, 2013). The physicochemical and microbiological test results were compared with three different drinking water guidelines namely: World Health Organization (WHO), National Agency for Food and Drug Administration and Control (NAFDAC), Nigerian Standard for Drinking Water Quality (NSDWQ).

RESULTS AND DISCUSSIONS

Physicochemical and Microbiological Water Quality in Rainwater Tanks

The results of the physicochemical and microbiological analyses of rainwater samples collected from rainwater tanks in Enugu-Ezike are presented in Table 1.2. These results were compared with two guidelines namely Nigerian Standard for Drinking Water Quality (NSDWQ) and Food and Agriculture Organisations (FAO). Only pH exceeded the acceptable limits for drinking water where 68% of the samples tested were found to be acidic. Though there are exceptions, roof captured rainwater is usually acidic and generally has a pH below drinking water guidelines (Magyar and Ladson, 2015).

Table 1.2: Descriptive statistics of the physicochemical and microbiological assessment of the rainwater samples in Enugu-Ezike

Parameters	**Method**	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**NIS 554: 2007**	**FAO (1985)**
Temperature (0C)	-	25	30.300	31.600	30.94800	.360694	-	-
pH @ 25.0 0C	APHA 4500H$^-$B	25	6.000	6.900	6.38400	.230362	6.5-8.5	6.0 – 8.5
Conductivity (µS/cm)	APHA 2510B	25	5.12	113.00	56.1376	38.54993	1000	3000
Total Dissolved Solids (mg/L)	APHA 2510B	25	3.070	67.800	33.67880	23.128965	500	2000
Turbidity (FAU)	APHA 2130 B	25	.000	2.500	.32280	.598349	5	-
Nitrates (mg/L)	APHA	25	.300	9.800	3.72000	3.130628		10

	4500-NO3E						50	
Dissolved Oxygen (mg/L)	APHA 4500 O	25	6.800	7.200	7.01200	.130128	-	-
Sulphate (mg/L)	APHA 4500 SO_4^{2-} E	25	.000	12.000	2.24000	3.072458	100	960
Chloride (mg/L)	APHA 4500 Cl^- B	25	.000	4.000	1.00000	1.154701	250	1065
Total Akalinity (mg CaCO3/L)	APHA 2320 B	25	1.000	62.000	21.28000	18.467359	-	-
Bicarbonate (mg CaCO3/L)	APHA 2320 B	25	1.000	62.000	21.28000	18.467359	-	-
Total Hardness (mg CaCO3/L)	APHA 2340 B	25	1.000	50.000	22.36000	17.206782	150	-
Calcium (mg/L)	APHA 3500 Ca B	25	.000	16.800	6.04800	5.727501	-	400
Magnesium (mg/L)	APHA 3500 Mg B	25	.000	6.720	1.73760	1.792357	20	60
Totaliron (mg/L)	APHA 3500 Fe A	25	.000	.240	.10280	.083092	-	-
Chromium (mg/L)	APHA 3500 Cr A	25	.000	.000	.00000	.000000	0.05	-
Arsenic (mg/L)	APHA 3500 As A	25	.000	.007	.00060	.001607	0.01	-
Zinc (mg/L)	APHA 3500 Pb A	25	.010	1.200	.30960	.390710	3	-
Lead (mg/L)	APHA 3500 Pb A	25	.000	.000	.00000	.000000	0.01	-
Cadmium (mg/L)	APHA 3500 Cd A	25	.000	.000	.00000	.000000	0.003	-
E.coli (cfu/100ml)	APHA 9222B	25	.000	800.000	62.64000	167.250282	0	-
Enterococci (cfu/100ml)	APHA 9230	25	.000	72.000	7.04000	15.503978	0	-

Electrical conductivity (EC) is used to measure salinity of the water. Higher electrical conductivity causes a decrease in the amount of water available to crops (Khalaf and Hassan, 2013). From our study, EC has minimum, maximum and mean values of 5.12, 113 and 56.14µS/cm respectively which are well below the limit for drinking (1000µS/cm) and irrigation (3000µS/cm). Ayer and Westcot (1999), stated that water with EC values less than 700µS/cm are considered to be a good quality for irrigation. Chloride concentration has a range of 0 – 4mg/l and a mean of 1mg/l which is below the drinking water and irrigation guideline limit. Total dissolved solids (TDS) concentration varies between 3.07 and 67.8mg/l with a mean value of 33.68mg/l. All the physicochemical parameters are within the NSDWQ drinking water guideline limits except for pH whereas FAO guideline limits for irrigation water were not violated.

Violation of Physicochemical and Microbiological Parameter Values from Drinking Water Guidelines

In this section, the water quality parameters results were compared to four (4) different drinking water guidelines namely: WHO, NSDWQ and NAFDAC drinking water and FAO irrigation water guidelines.

Table 1.3: A table showing the percentage violation of the concentrations of parameters from various drinking water guidelines.

PARAMETERS	WHO (2017)	NSDWQ (2007)	NAFDAC (2001)	FAO (1985)
pH at 25^{0}C	-	18(72%)	18(72%)	0%
E.coli (cfu/100ml)	19(76%)	19(76%)	19(76%)	-
Enterococci (cfu/100ml)	12(48%)	12(48%)	12(48%)	-

- = not reported

The number of samples that exceeded the drinking water guidelines and their percentages are presented in Table 1.3. From the table, (18)72% of the samples had pH below the limit set by NSDWQ and NAFDAC drinking water guidelines. Another parameter that its concentration exceeded in all the drinking water guidelines values is E.coli. A total number of 19(76%) of the tested samples exceeded the limit in all drinking water guidelines. Also, 12(48%) of the samples exceeded the limit for enterococci in all four drinking water guidelines. All the other tested parameters were within the guideline limit for all four drinking water guidelines considered. However, none of the parameters violated the FAO irrigation water guidelines. Overall, this shows faecal contamination of the roof- captured rainwater in Enugu-Ezike.

Rainwater Harvesting Practice in Enugu-Ezike

Almost every household practice rainwater harvesting in Enugu-Ezike and 14% rely solely on rainwater all year round (Fig. 1.2). The results of our survey show that 86% of the population use other sources of water supply such as boreholes.

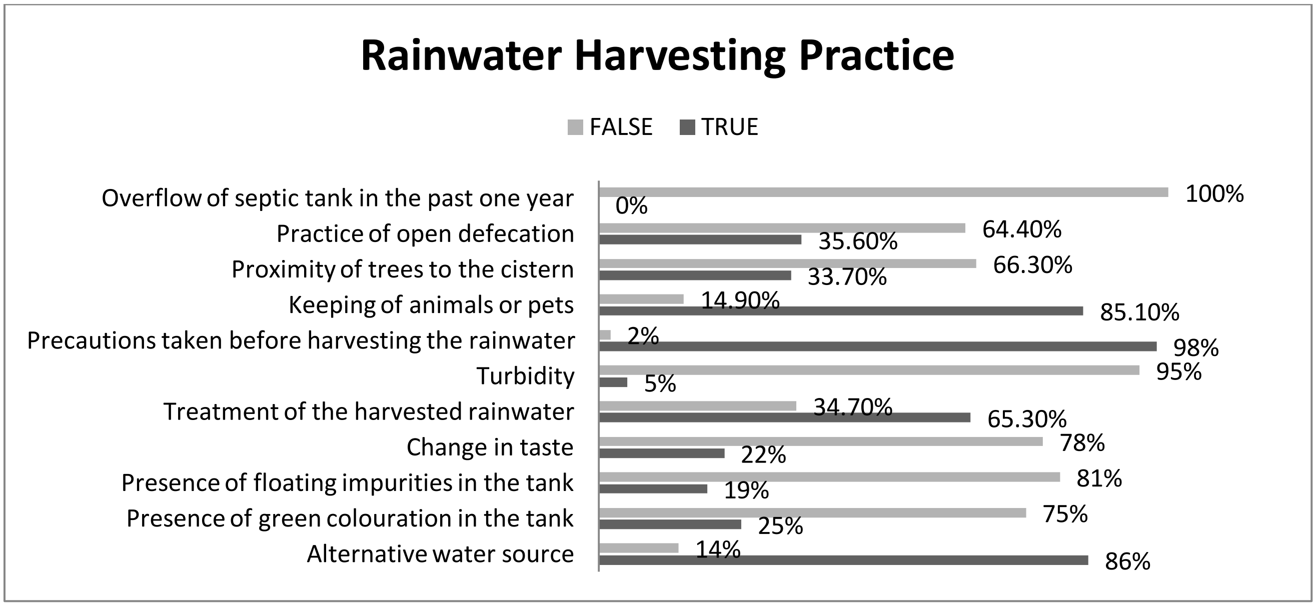

Figure 1.2: Practices relating to Rainwater Harvesting.

Water Quality Index

Drinking water

The Canadian council of ministers of the environment (CCME) method of Water Quality Index calculation shows an average CCME WQI value of 55.33 for the four drinking water guidelines. This falls into the category of marginal quality (Table 1.4). The water can be best used for non-potable purposes such as washing of clothes, bathing and watering of the garden.

Table 1.4: Water quality index values for various drinking water guidelines

Drinking water guidelines	WQI value	CCME WQI classification
WHO (2017)	56	Marginal
NSDWQ (2007)	55	Marginal
NAFDAC (2001)	55	Marginal

CCME WQI classification: Excellent = 95-100, Good = 80-94, Fair = 65-79, Marginal = 45-64, Poor = 0-44.

Irrigation water

From table 1.5, the results of irrigation water quality index (IWQI) which was developed Meireless et al (2010) shows an average value of 96.26 using the FAO irrigation water guidelines. The result of the IWQI can be classified as non restriction (NR) according to Meireless et al (2010). This means that there is no risk of toxicity for most plants.

Table 1.5: Irrigation water quality index values using FAO irrigation water quality guidelines.

Samples	IWQI values	IWQI Classification
1	95.95	NR
2	99.70	NR
3	99.48	NR
4	92.88	NR
5	95.48	NR
6	99.52	NR
7	99.66	NR
8	96.75	NR
9	91.47	NR
10	96.14	NR
11	99.76	NR
12	99.74	NR
13	99.39	NR
14	99.78	NR
15	97.51	NR
16	96.75	NR
17	95.96	NR
18	94.92	NR
19	92.60	NR
20	90.70	NR
21	95.83	NR
22	93.38	NR
23	92.70	NR
24	96.62	NR
25	94.86	NR

IWQI classification: 86 ≤ 100: No restriction(NR), 70 ≤ 85: Low restriction, 55 ≤ 70: Moderate restriction, 40 ≤ 55: High restriction, 0 ≤ 40: Severe restriction.

CONCLUSIONS

The physicochemical properties of rainwater were well within the drinking water guidelines values except for pH. This shows that the harvested rainwater is slightly acidic in nature. The microbiological analyses show high microbial contamination of the rainwater. This can be attributed to open defecation, low freeboard, proximity of trees to rainwater tanks and manual abstraction. The results of water quality index (WQI) and irrigation water quality index (IWQI) calculations show that the harvested rainwater is unsuitable for drinking but can be used for agriculture and other domestic activities such as cooking, bathing and laundry.

In conclusion, harvested rainwater in rural areas is not safe for drinking without treatment but can be used for irrigation with minimal problems.

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CONSTRUCTED WETLANDS AS GREEN INFRASTRUCTURE FOR SUSTAINABLE AGRICULTURAL WASTEWATER MANAGEMENT

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Abstract

Intensive agriculture has been indicted in the escalation of pollution and climate change indices mostly in developing countries where poor waste management still hold sway and resources for grey infrastructures are scarce. Constructed wetlands have been advocated as a veritable infrastructure of green classification capable of providing ecological balance and for polluted wastewater treatment services through effective removal of nutrients. Waste management by livestock farmers is still ineffective and unsustainable due to the huge investments necessary to construct, maintain and improve wastewater treatment amenities suitable to their scale of production and lack of information in developments in use of low cost wastewater treatment technologies in curbing the danger of wastewater pollution. The development of low cost, energy effective and sustainable wastewater treatment facilities is one way of solving the problem but, the existing wealth of knowledge for application of CW as a waste management technology is scarce and CW has not taken a strong root in Nigeria's intensive livestock farming operations because it is yet to benefit from vast amount of research and developmental efforts. Case study on the treatment performance of a subsurface flow constructed wetland for piggery wastewater presented in this paper provide an insight on the efficiency of constructed wetlands to remove the nutrients in agricultural wastewater to acceptable limits.

Keywords: Green infrastructure, constructed wetlands, piggery wastewater, nutrient removal, nitrogen, phosphorus

1.0 Introduction

In many emerging countries, agriculture plays a vital role in the rural economy by addressing the issues of poverty alleviation, food security and acts as a source of stable income generation. In Nigeria, majority of rural poor depend on agriculture for their livelihood and over 70 percent of the active labor force is employed in agriculture (World Bank, 2007). The Federal Government of Nigeria (FGN) has identified agriculture as the key development priority in its efforts to fight poverty and diversify the economy away from the oil sector.

Global growth of the population has necessitated the intensification of agriculture to produce large quantities of crops and livestock through industrial techniques for the purpose of sale.

Although intensive livestock agriculture increases productivity, the adoption of concentrated animal farming systems (CAFOs) of meat production and consumption sit at the nexus of climate change, health, environment, and well-being for communities around the globe. Livestock retains only about 15 percent of the nutrients contained in their feed stuff by transforming them into animal product. The remaining 85 percent are expelled as waste (Kiely, 1998, Ogbuewu *et al.*, 2012). Once wrongly managed, livestock manure can pose significant risk such as contamination of the environment, soil erosion, public health and water quality and water ecosystems. In terms of environmental degradation, livestock farming in particular – is very important source of pollution globally and especially in livestock production areas with a high animal density.

The increasing emissions of methane, perhaps the most damaging of the greenhouse gases, can be traced to the expanding population of ruminant animals, especially in developing countries (Keller, *et al.*, 1990; Mosier *et al.*, 1991). In Nigeria, there is abysmal mismanagement of piggery wastewater and although data on piggery effluent management is scarce but the evidence of environmental consequences and risks are vast and noticeable (Figure 1). It has been estimated that the daily total piggery waste produced in Nigeria is 5.2 million kilograms per day (Balogun and Ohemeyan, 1998 Itodo *et al.*, 2000).

Figure 1: Piggery productions on a perennial stream floodplain

2.0 Sustainable Agriculture

Sustainable agriculture is a type of agriculture that focuses on producing long-term crops and livestock while having minimal effects on the environment. This type of agriculture tries to find a good balance between the need for food production and the preservation of the ecological system within the environment. The term is frequently used in connection with biological systems and can be defined as the ability of an ecosystem to maintain ecological processes, biodiversity and productivity into the future (Steinfeld et al.,2006; FAO,2009). At a fundamental level, impacts of human activities are now seen in harmful changes to the global geochemical cycles that are critical for life on earth and thus the elementary pillars of the ecological dimension of sustainability. Sustainable agriculture can only be clearly understood by examining it from ecosystem concept of ecological perspective.

3.0 Ecosystem Concept

The ecosystem concept is fundamental to understanding of sustainable agriculture generally and animal agriculture specifically. An ecosystem is simply an assemblage of organisms and their associated chemical and physical environment (Briske and Heitschmidt, 1991). As such, sustainable agriculture may be broadly defined as ecologically sound agriculture aimed at maintaining increased agricultural production while maintaining high levels of ecological efficiencies. Green Infrastructure technologies enhances the maintenance and (or) increase product yields while increasing ecological efficiencies.

4.0 Green infrastructure

Green Infrastructure (GI) is an emerging concept, based on the realization that natural systems can deliver a range of engineering and human services known as ‘ecosystem services.’ The concept emphasizes the ‘life support’ functions provided by the natural environment. The term 'green' is nowadays widely used (and misused) in connection with many types of technologies. If a technology is 'green' it usually means that the technology requires less non-renewable energy sources than other alternatives. However, other parameters need to be considered as well, such as sustainability, recycling potential, treatment capacity and potential, conservation of ecosystems, etc.(Brix, 1999). GI, is broadly seen as a specialized form of engineering infrastructure replacing conventional engineering structures with ‘green’ elements that is good for the environment and which can promote sustainable development and perform ecosystem service functions, such as waste management (Margolis and Robinson, 2007) This could include more typically, artificial ecosystems like constructed wetlands for wastewater treatment which can be used to reduce the need for expensive gray infrastructure—pipes, storage facilities, and treatment systems.

GI can be designed to capture agricultural wastewater close to where it is produced to be used by plants, soaked into the ground, evaporated, or recycled for irrigation or other uses. GI can also improve water quality by slowing down and filtering polluted runoff before it reaches surface waters or percolates into groundwater (CNTAR, 2010).

5.0 Constructed Wetland as Green Infrastructure

Constructed wetland (CW) are a specialized form of engineering infrastructure which mimic the functions of natural wetlands to capture storm water, reduce nutrient loads, and create diverse wildlife habitat. CWs are an alternative approach than conventional/mechanical (grey) technologies designed to function under controlled conditions. It is a smart option for wastewater management and is cost effective with reduced capital costs, green and sustainable. They are often created in engineered growth media in trenches, small islands, and pools. CW retains and filters water and support water-loving vegetation and soils. They fulfill critical ecological needs, cycling nutrients and providing habitat for a range of species as well as buffers or transitional environments between different ecosystems. Constructed wetlands may be built solely for capturing and filtering storm water or wastewater treatment. Plants when considered in CW, can be chosen for performance, so constructed wetlands often do not contain the breadth of vegetation found in natural or restored wetlands, or provide all of their ecological services. In arid climates CW include plants and bacteria which grow all year round and provision of more efficient pollutant removal at high temperatures are the advantages.

6.0 Constructed Wetland and Conventional Infrastructure Systems

Green infrastructure such as CW systems for wastewater management are distinguished from conventional (grey) infrastructure systems based on the source(s) of energy that prevail in the two treatment categories .In grey infrastructure wastewater treatment systems, nonrenewable, fossil fuel energies preponderate in the treatment process. While grey system treatment relies largely on naturally occurring, biological pollutant transformations, these processes are typically enclosed in concrete, plastic, or steel basins and are powered by the addition of forced aeration, mechanical mixing, and/or a variety of chemicals. Because of the power intensity in grey treatment systems, the physical space required for the biological transformations is reduced considerably compared to the area required for the same processes in the natural environment (Kadlec and Knight, 1996)

GI treatment systems entail the same amount of energy input for every kilogram of pollutant that is degraded as grey biological treatment systems; however, the source of this energy is different. GI treatment systems depend on (to a greater or lesser extent) on renewable, naturally occurring energies, including solar radiation; the kinetic energy of wind; the chemical-free energy of rainwater, surface water, and groundwater; and storage of potential energy in biomass and soils. GI treatment systems are land intensive, while conventional treatment systems are energy intensive.

Grey infrastructure technologies have been an attractive alternative for wastewater treatment in many locations because they provide a compact, controllable method of pollution abatement where large amounts of fossil-fuel energies can be focused to deal with increasing wastewater flows and mass loads. But, the building and operation of conventional wastewater treatment schemes are not appropriate solutions in wastewater treatment in developing countries like Nigeria where land is available, areas pestered with energy challenges abound and tropical temperatures are advantageous for optimal metabolic rates. Table 1 outlines the major advantages of a green infrastructure technology (wetland system) over grey or conventional system.

Table 1: Constructed Wetlands vs conventional treatment system

	Conventional Systems	Constructed Wetlands (CWs)
Operational costs	High – intensive maintenance	Low – minimum maintenance
Raw materials	Non-renewable materials (concrete, steel, polymers, electricity, chemicals)	Almost exclusive use of renewable sources (solar, wind) - "ecological"
Lifetime	Up to 10 years	Up to 20-25 years
Energy input	High	Low
Use of chemicals	Required	Not required
By-products	Large daily volumes of sludge	No by-products
Greenhouse Gas Emissions	High	Low
Staff	Demand for specialized staff	No specialized staff needed
In-country value	Only 20% of materials/equipment sourced within the country	More than 80% of materials/equipment sourced within the country

Kadlec and Knight (1996)

7.0 Types of Constructed Wetlands

With regards to differences in the wastewater input and flow, there are three types of constructed wetlands (CWs) which comprise: Free water surface (FWS) constructed wetland or surface flow (SF) wetlands, vertical flow (VF) constructed wetlands and sub-surface flow constructed wetlands (SSFCW) (Adelegan, 2012).

FWS or surface flow wetlands shown in Figure 1 contain areas of open water and are akin in appearance to natural marshes. As the wastewater moves through the wetland, it is treated by the processes of filtration, sedimentation, oxidation, reduction, adsorption and precipitation. They are suitable for treatment of urban, agricultural and industrial storm waters since they can handle pulse flows and fluctuations in wetland levels. It however requires much land area but less energy input compared to other types of constructed wetlands.

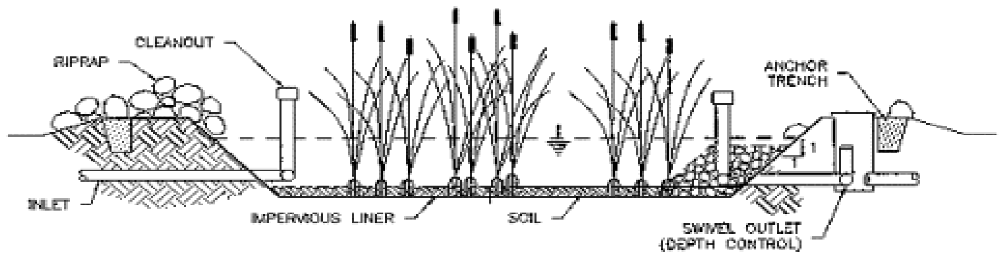

Figure 2: FWS or Surface flow constructed treatment wetlands (Constructed wetlands 2002)

A **vertical flow wetland** shown in Figure 3 is a planted filter bed that is drained at the bottom. Wastewater is discharged onto the surface from above and the water flows vertically down through the filter medium to the bottom of the basin where it is collected in a drainage pipe. The main variance between a vertical and horizontal wetland is not only the direction of the flow path, but rather the aerobic conditions. Through intermittent dosing of the wetland, the wetland medium goes through stages of being saturated and unsaturated, and consequently, different phases of aerobic and anaerobic conditions. In a flush period, the wastewater percolates down through the unsaturated bed and, as the bed drains air is drawn into it and the oxygen has time to diffuse through the porous media. The media acts as a filter for removing solids, a fixed surface upon which bacteria can attach and a base for the vegetation. The upper layer is planted and the plants develop deep wide roots, which infiltrate the media. The vegetation transmits a small quantity of oxygen to the root zone so that aerobic bacteria can populate the area and reduce pollutants.

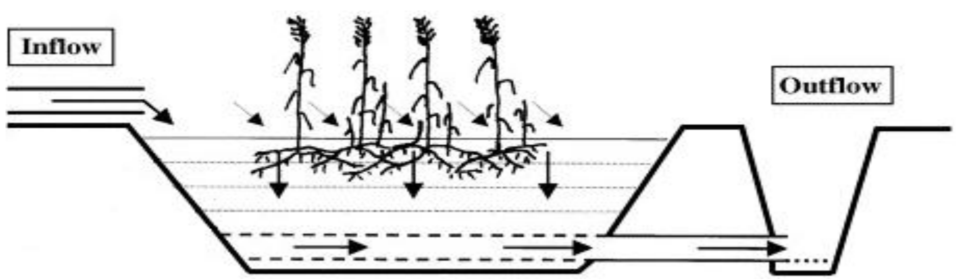

Figure 3: Vertical flow constructed wetland (EPA, 2000

In **subsurface flow constructed wetland** (SSFCW) shown in Figure 4, the water surface is kept below the surface of the media, which might support diverse kinds of rooted emergent plants. (Kadlec and Wallace, 2009). Among the treatment wetlands, horizontal subsurface flow constructed wetlands (HSSFCWs) type is a commonly used concept.

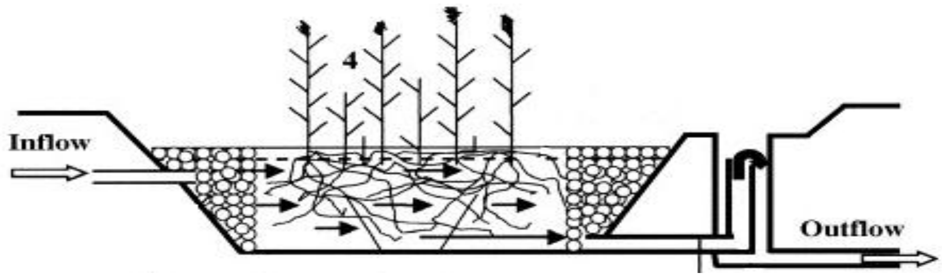

Figure 4: Subsurface flow constructed wetland (EPA, 2000)

Wastewater flows horizontally through the filter bed, typically comprising of sand or gravel medium and the wetland roots and rhizomes. This medium is habited by attached microorganisms that form a biofilm. Treatment is accomplished by a wide-ranging diversity of physical, chemical and biological processes, such as sedimentation, filtration, precipitation, sorption, plant uptake, microbial decomposition and nitrogen conversions. HSSFCWs are normally designed to treat primary effluent before either soil disposal or surface water discharge. Since wastewater stays below the surface of the media during treatment process, the risk linked with contact to pathogenic organism is reduced.

7.1 Components of Constructed Wetland

To comprehend the wastewater treatment in the wetland, it is essential to know the key components of the wetland and the dynamics that influence the wetland performance. The components include wetland soil or media, vegetation, water column with living organisms in the wetland.

Soil or media for wetland include soil, sand, gravel, rocks, etc. Constructed wetlands commonly use gravel as the media as it offers a greater surface area for biological and chemical processes to take place and also offer site for suspended solids and removed pollutants. Coarse gravel as opposed to soil or fine gravel will offer high hydraulic conductivity in the wetland, which is vital to stabilize the hydraulic retention time of the wetland. The sand or gravel media provides a very large surface area for development of microbial biofilm.

Vegetation or plants used in wetlands are expected to be able to acclimatize to saturated conditions and local climatic conditions and should be unaffected by high pollutant levels. Frequently used plants in constructed wetlands are reed canary grass, soft stem bulrush, sedges, wild rice, etc. Several of the important roles of vegetation in the wetlands are (Kadlec and Wallace, 2009):

(i). to production of oxygen (needed for aerobic reactions) during photosynthesis,

(ii) reduction of velocities of inflowing water for sedimentation of suspended solids,

(iii) improvement of hydraulic conductivity of the media,

(iv) uptake of nutrients from wastewater and,
(v) stabilization of media and enhancement of its permeability.

Water Column with Living Organisms in the wetland is mandatory for the incidence of the biochemical reactions. Similarly, it functions as a medium of transport for organic solids, nutrients, gases, etc. Among the living organisms found in a wetland, microorganisms like bacteria, fungi, protozoa, etc. play a key part in the treatment of wastewater. These microorganisms assist in wetland biochemical reactions as a part of the treatment process.

8.0 Wastewater Treatment in Constructed Wetlands

Wastewater treatment in wetlands include removal of pollutants like organic material, suspended solids, pathogens, toxic waste, etc. and nutrients like nitrogen and phosphorous. Processes of removal of pollutants and nutrients in wetlands can be broadly classified in to physical, chemical and biological processes (Sundaravadivel and Vigneswaran, 2001). **Physical processes** include filtration and sedimentation. Vegetation in the wetland acts as hindrance for the flowing water, thereby reducing velocity and helping in sedimentation of suspended solids. The substrate in the wetland acts as a medium for filtration process.

Chemical processes that occur in constructed wetlands are precipitation of heavy metals, destruction of pathogens due to photochemical reactions.

Biological processes occurring in wetlands that results in removal of pollutants and nutrients are: photosynthesis, respiration. Fermentation, nitrification, denitrification and phosphorus removal. Photosynthesis helps in maintaining the oxygen supply for plants. Respiration helps in maintaining dissolved oxygen content in the water. Fermentation leads to decomposition of organic carbon. Nitrification and denitrification are processes of nitrogen cycle that results in removal of nitrogen. Phosphorus removal process results in removal of phosphorous from the wetland. Removal of BOD (biochemical oxygen demand), which is a measure of rate of oxygen consumption of organic matter by microorganisms), is removed by processes of biological degradation and sedimentation. Biological degradation of organic carbon in the organic matter takes place in the wetland in aerobic conditions to produce CO_2 (carbon dioxide) and in anaerobic conditions to produce methane. Suspended solids are removed by sedimentation, filtration. Suspended solids are removed by adsorption on the substrate (gravel). Pathogens trace metals are removed by sedimentation, filtration, adsorption and exposure to sunlight. Trace metals are reduced by processes like plant uptake, soil or substrate adsorption and precipitation of the compounds of the metals.

9.1 Nutrient Removal Processes in Constructed Wetlands.

Nitrogen and phosphorous are two key nutrients present in agricultural wastewater in high amounts. Nitrogen is typically found in the form of nitrates in the water. Piggery wastewater comprises high intensities of these nutrients and constructed wetlands are capable of plummeting their levels. Wetlands eliminate nitrogen and phosphorus by a mixture of physical, chemical, and biological processes. These processes adsorb/absorb, transform, and remove the nutrients and other chemicals as water gradually flows through the wetland.

The key physical routes of nutrient removal are particle settling (sedimentation), volatilization (releasing as a gas into the atmosphere), and sorption. Sorption embraces a nutrient sticking to a solid (adsorption) or diffusing into another liquid or solid (absorption). Chemical processes comprise transformations of nutrient forms and chemical precipitation, in which a solid compound is made out of a liquid by a chemical reaction. The chief biological processes are uptake (or assimilation) by plants, algae, and bacteria and transformation processes piloted by microbes. Altogether, these processes happen all through the various wetland compartments (Xie*et al.*, 2018). Together nitrogen and phosphorus can be present in many forms (particulate, dissolved, organic, inorganic, etc.), and these forms are acted upon separately by the various processes inside the wetland compartments. Wetland processes are influenced by the presence or absence of oxygen, season, temperature, water inflow rate, nutrient loading rate, and retention or holding time of the water within the wetland. So although a wetland is continually working to remove nutrients, the rapidity of this removal is contingent on a great variety of factors (Kadlec and Wallace, 2009; Abtew and Mellesse, 2013)

While the principal removal processes for nitrogen and phosphorus are different, both nutrients are utilized by wetland biota. Wetland plants uptake inorganic nitrogen and phosphorus forms (i.e., nitrate, ammonia, and soluble reactive phosphate) over their roots and/or foliage and convert them into organic compounds for growth. Nevertheless, this merely provides short-term storage of the nutrients. The bulk of these assimilated nutrients are freed back into the water and soils when plants grow old, die and decompose. A minor amount of the nutrients (10–20%) are put in storage in hard-to-decompose plant litter and becomes assimilated in wetland soils, but this is comparatively negligible compared to other removal processes (Vymazal and Kropfelova, 2009).

Nitrogen removal specifically involves a large group of bacteria that carry out numerous chemical reactions. The key transformation routes are ammonification (organic nitrogen to ammonia), nitrification (ammonia to nitrate or nitrite), and denitrification, where nitrate (NO_3) is changed to harmless nitrogen gas (N_2). These processes are represented in Figure 5 below.

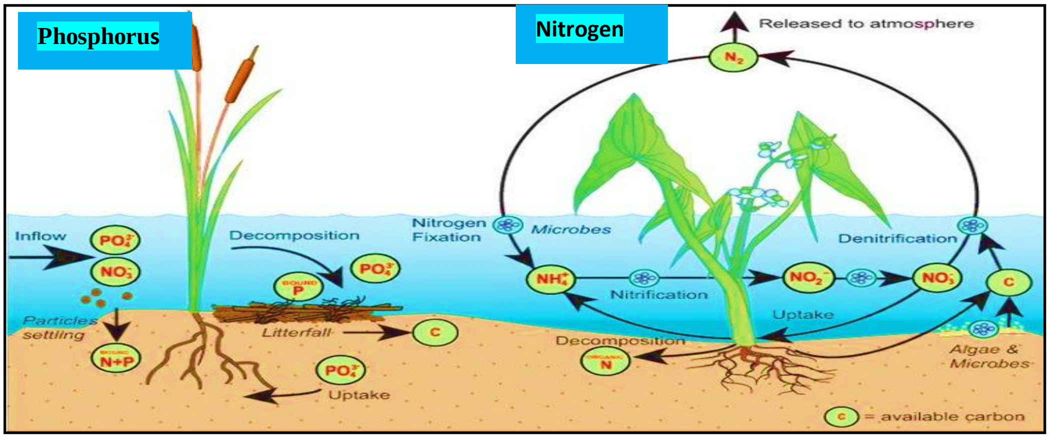

Figure 5: Nitrogen and phosphorus cycles in a wetland (Kostel, 2015*)*.

9.1.1 Nitrogen removal

Ammonification (mineralization) is the process in which organic nitrogen is converted into inorganic nitrogen, primarily ammonia. Mineralization can occur under aerobic or anaerobic conditions and results in the release of energy (Wallace and Knight, 2006, Vymazal, 2007). Typical formula of ammonification of urea is as given by Mitch and Gosselink (2007).

$$NH_2CONH_2 + H_2O \rightarrow 2NH_2 + CO_2 \qquad 1$$

$$NH_3 + H_2O \rightarrow NH_4 + OH^- \qquad 2$$

Ammonification rates in CWs are quickest in oxygenated areas. As the microbial population shifts from facultative anaerobic to obligate anaerobic micro flora, ammonification rates decrease. The rate of ammonification in wetlands is reliant on temperature, pH, carbon-nitrogen (C/N) ratio of the residue and, existing nutrients in the system. Characteristics of the wetland media such as texture and structure can similarly influence mineralization rates (Reddy and DeBusk, 1987). The optimal pH range for ammonification is between 6.5 and 8.5 and the rate of ammonification doubles through temperature increase of 10^{o}C (Wallace and Knight, 2006). Ammonification rates reported in literature varies widely with values ranging between 0.004 to 0.53 g Nm^{-2} day^{-1} (Vymazal, 2007).

Nitrification is the biological (microbial mediated) oxidation of ammonium to nitrate with nitrite as an intermediate in the reaction arrangement. In many CW systems, nitrification is the principal transformation mechanism that changes ammonium nitrogen into oxidized nitrogen compounds (Kadlec and Wallace, 2009). Nitrification is exactingly an aerobic process and is restricted to aerobic water columns, aerobic soil-flood water interface and aerobic root zone. Oxidation of ammonium to nitrate is a two-step progression. First, chemoautotrophic bacteria oxidize ammonia to nitrate. Second, is the oxidation of nitrite to nitrate by facultative chemolitotrophic bacteria.

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O \qquad 3$$

$$NO_2 + 0.5O_2 \rightarrow NO_3^- \qquad 4$$

Nitrification requires aerobic conditions to oxidize nitrite. At dissolved oxygen (DO) levels less than 0.5mg/L nitrite oxidation is inhibited. Nitrification process is influenced by temperature, pH, inorganic carbon source, microbial population and concentration of ammonium-N and dissolved oxygen (Vymazal, 2007).

10.0 Wetland Performance

The performance of a constructed treatment wetland is defined as the efficiency of the wetland in removing pollutants and nutrient from the wastewater. The performance of wetland depend upon the following factors: inflow rate, outflow rate, pollutant loading rate, hydraulic retention time (HRT), hydraulic loading rate, climatic conditions, temperature, pH, oxygen availability, wetland design components – substrate, vegetation and living organisms. (DeBusk 1999). The wetland design factors, that include influent and effluent concentrations, inflow and outflow rates, HRT, loading rate, etc, should be selected accurately to meet the objectives of the constructed wetland. The wetland performance tends to decrease if the influent concentration becomes close to the background concentration of the wetland, while the effluent concentration is in its desired range. But the wetland performance will increase if the loading rate increases while the outflow concentration may or may not change.

Performance evaluation of constructed wetland is achieved by computation of influent (C_1) and effluent (C_2) concentrations and discharges Q_1,Q_2 respectively as well as influent (M_1) and effluent (M_2) mass loading rates for each constituent at sampling events. Mass removal rates are calculated as a difference between input and output mass loading rates. Percentage mass removal for each constituent is calculated as mass removal (%).

$$\textbf{Mass Removal } \% = \frac{M_1 - M_2}{M_1} \times 100 = \frac{Q_1C_1 - Q_2C_2}{Q_1C_1} \times 100 \qquad 5$$

11.0 Constructed Wetland Research in Nigeria

In developing countries, the wise use of natural and artificial wetlands for water purification is valuable and exploitable for the protection of water quality in catchments, rivers and lakes. Constructed wetland research in Nigeria has been very scanty. Reported wetland researches in Nigeria are shown in table 2 below.

Table 2: Constructed Wetland Research in Nigeria

Type of waste water	Type of wetland	Scale	Type of macrophyte	Parameters Considered	Influent load (mg/l)	Effluent load (mg/L)	HRT (Days)	Removal efficiency (%)	Source
Sewage waste water	FWS+	Pilot	Water hyacinth	BOD	-	-	-	70	Olukanmi, 2013.
				COD	-	-	-	68	
				TSS	255	150	-	41	
				PO_4	-	-	-	+29	
				Zn	-	-	-	100	
				No_3	-	-	-	30	
				cl_4^-	-	-	-	38	
				SO_4	-	-	-	94	
				Potassium	-	-	-	2.	
	Combined FWS & SSF*	Pilot	Water hyacinth & cattail (*Typhalatifola*)	TDS				75.27	Adeniran *et al.*, 2012
				Turbidity				98.18	
				Colour				89.72	
				Conductivit				74.00	
				y				58.08	
				DO				75.27	
				Iron				67.14	
				So_4^-				92.73	
				Nitrate				89.92	
				Manganese				76.53	
				BOD				92.80	
				Total coliform					
Leachates	-	Labor a-tory	Forsk (*Ipomoea aqutica*)	TSS	197.5		8 hrs	81.01	Aluko and Sridher, 2005.
				BOD	-		8 hrs	86.03	
				NH_3	-		8 hrs	97.77	
Refinery effluent	VSSF**	Labor a-tory	Bermuda	NH_3 – N	1.8			54	Mustapha *et al.*, 2013.
				NO_3-	1.6			53	
Brewery waste	SSF	Labor a-tory		BOD				96.83	Adelegan, 2012.
				TSS				88.42	

water	Faecal coliform	96.29

+Free water surface wetland, *Subsurface flow wetland, ** Vertical subsurface flow wetland

Constructed wetlands are potentially good, low-cost, appropriate technological treatment systems for domestic wastewater in rural areas. Better still, they can be integrated into agricultural production systems where the products are useable and/or re-cycled for optimal efficiency. However, currently, constructed wetlands are rarely installed (Denny, 1997). In Nigeria, research on constructed wetland (CW) have been very scanty and selective in types of wastewater treated as shown in table 2 above.

12.0 Case Study

Udom et al., 2017 carried out a study on the treatment efficiency of subsurface flow constructed wetland (SSFCW) for wastewater from an intensive piggery production facility. The study adopted research and development, and experimental approach. First order reaction kinetics with plug flow was assumed as design principle. Kikuthand Darcy's models were selected for the design of the wetland area and determination of the capacity of the wetland to conduct flow through it respectively. Both the wastewater inlet and outlet sections of the wetland basin were filled up to 0.60 m depth with 30 mm crushed granite rock extending one meter from the walls into the treatment area. The wetland basin was filled up to 0.60 m depth with coarse sand as substrate. Seven months composite samples data were collected before and after the wetland detention time

Table 3: Influent-effluent wastewater characteristics in constructed wetland

Parameters	Wastewater characteristics before primary treatment in wetland system(mg/l)	Influent characteristics of wastewater after primary treatment in wetland system(mg/l)			Effluent characteristics of wastewater after treatment in wetland system(mg/l)		Pollutant removal (%)	Discharge standard
		Range	Mean ± st.dev	N	Control (Mean ± st.dev)	N		
pH	**8.45**	**6.3 - 8.2**	**7.04 ± 0.6**	**14**	**7.59 ± 0.6**	**14**	**7.67**	**6.9**
BOD(	**150.31**	**102.4 –**	**125.26 ±**	**1**	**49.75 ± 11.3**	**1**	**60.27**	**50**

mg/l)		**162.3**	**16.8**	**4**		**4**		
COD(mg/l)	**246.29**	**165.16 – 250.4**	**205.24 ± 20.1**	**14**	**130.60 ± 38.8**	**14**	**36.37**	**-**
TN(mg /l)	**33.62**	**21.9 – 38.7**	**28.02 ± 4.6**	**14**	**13.97 ± 4.0**	**14**	**50.14**	**20**
TP(mg/ l)	**12.50**	**7.94 – 13.32**	**10.42 ± 1.6**	**14**	**6.12 ± 1.6**	**14**	**41.27**	**5**
TDS(m g/l)	**234.84**	**161.5 – 251.2**	**195.70 ± 24.3**	**14**	**92.21 ± 21.2**	**14**	**52.88**	**2000**
Temp (^{o}C)	**28.66**	**24.4 – 27.2**	**26.05 ± 0.8**	**14**	**24.58 ± 0.8**	**14**	**5.64**	**<40^{o}C**

of three days. The data (Table 3) were analyzed for biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) and total dissolved solids (TDS)

Wetland treatment performance was evaluated in terms of efficiencies in mass and concentrations reduction. Six rectangular horizontal subsurface flow wetland cells sized 3.5 m x 1.75 m x 0.60 m were designed and constructed in the field with concrete blocks for treatment of piggery wastewater. The results of the treatment performance of the constructed experimental wetland for a retention time of three days and mean hydraulic loading rate of 0.26 /day showed mean reduction of BOD by 60.27%, COD 36.37%, TN reduction was 50.14% , TP was reduced by 41.27%, TDS 52.88%**.**

pH: There was decrease in the acidity of the wastewater by the wetland system. This might have been due to the oxidation of part of the unstable fatty acids in the wastewater and ammonification of the organic nitrogen. High pH in wetland system can modify the solubility of other chemical pollutants, and cause higher release of ammonia through mineralization of organic nitrogen source (Singh and Agrawal, 2012). Low pH can escalate the availability of metals since hydrogen ions have the affinity for contending with metal ions and liberating them in soil solution for plant uptake. pH of effluent wastewater samples in the wetland fell within 40^{o}C limit required Nigerian limit for discharge to surface water (FEPA, 1991).

BOD: From Table 3, the inlet BOD concentrations ranged between 102.40-162.30 mg/l with mean inflow values and 125.26 ± 16.79 mg/l. The BOD effluent concentrations ranged between and 32.27-70.30 mg/l with mean value of 49.75 ± 11.3mg/l. BOD removal was higher than other parameters with effluent values always within allowed limits.

COD: From Table 3, the inlet COD concentration ranged between 165.16-220.40 mg/l with mean inflow values of 205.24 ± 20.1 mg/l while that of the outlet ranged between 60.12-178.74 mg/l and 26.62-60.20 mg/l with mean effluent values of 113.20 ± 41.5. The outlet COD concentration ranged between 72.80 – 192.4249mg/l with mean effluent value of 130.60 ±38.75. High COD value in wastewater is an indication of low degradation rate of organic matter due to low microbial activity. Treatment efficiency for this study was 36.37%. Effluent concentrations of 130.6 mg/l achieved in this study were all within the 500mg/l limit for discharge into surface waters in Nigeria.

TN: The inlet N concentration ranged from 21.90-38.70 with a mean of 28.02 ± 4.649mg/l. Reduction of N concentrations in the cell ranged from 8.55-21.12 mg/l with mean 13.97 ± 3.9.Nitrogen reduction efficiency during the period of operation was 50.14% as shown in Table 3.Effluent concentrations in this study were below acceptable limit.

TP: Phosphorus concentration in the influent wastewater ranged between 7.94-13.32 mg/l with mean 10.42 ± 1.65mg/l. Effluent concentrations ranged from 4.41 – 9.58mg/l with mean 6.12 ± 1.60mg/l. Removal efficiency of 41.27% was observed in the treatment process. Effluent concentrations in this study were however above the allowed limit for discharge into surface water in Nigeria but below allowed limit for land discharge. The characteristics of the wetland media and hydraulic retention time (HRT) have important influence on the amount of phosphorus removal inCW. This is because contact time plays a key role in the distribution of pollutants in a constructed wetland.Low P removal efficiencies are characteristic of SSFCW used in this study. Vymazal (2007) reported an average mass based removal efficiency of 32%. Pucci et al., (2000) obtained 20% removal efficiency. The P removal efficiency reported in this study compared favourably with typical average removal efficiencies for several countries reported by Frazer-Williams (2010).

TDS: The mean influent TDS value was 195.70 ± 24.3. Mean effluent value was 92.21 ± 21.2. Removal efficiency was 52.88%. TDS removal is very effective in SSFCW and is used as a wastewater quality parameter to monitor the efficacy of constructed wetlands for the removal of organic matter and to measure the degree of pollution in industrial wastewater effluents. When wastewater high in TDS is discharged to surface or groundwater, these dissolved solids may represent a significant pollution source (Kadlec and Wallace, 2009).

13.0 Conclusions

The above case study shows that constructed wetland can effectively treat wastewater with respect to organic matter (BOD_5 and COD), TDS and nutrients (N and P) removal. For nitrogen and phosphorus which are the parameters of major concern in pollution abatement, the effluent quality of nitrogen met the minimum standard for discharge into surface water courses in Nigeria at fairly short hydraulic retention time. For phosphorus, the effluent quality failed to meet the limit for discharge into water courses but was within the limit for land discharge. The short hydraulic retention time and operating period may have resulted in low TP effluent quality of 22.4% above the minimum limit. The removal efficiency compared favorably well with results of similar studies elsewhere.

The study concludes that constructed wetland is a viable on-farm green infrastructure alternative technology to the conventional treatment of primary piggery wastewater in Nigeria.

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ASSESSMENT OF TREND AND DETECTION OF MUTATION OF RAINFALL OVER SOKOTO - RIMA RIVER BASIN, NIGERIA

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Abstract

Time-based characteristics of hydro meteorological processes are of great significance in the planning, designing and operation of water systems. In view of this, attempt was made to assess general trend characteristics and change point (mutation) of rainfall over the Sokoto -Rima River Basin, in Nigeria. Investigations were carried out by using rainfall data from selected gauging stations across the basin; Three statistical tests: (i) Pettit's Test, (ii) Robust Mann-Kendall Test, and (iii) Sequential Mann–Kendall test (SQ-MK test) were employed for the analysis. The results obtained indicated that few stations showed insignificant trends in annual and seasonal series. However, Pettit's' test showed that 100% of the station exhibited significant trend. Mann- Kendall test on annual rainfall series for some stations showed a mixture of varying contrast in negative and positive trend; for instance, Katsina, Gusau and Sokoto showed increasing positive trend (48.86% of the stations) while for Goronyo, there were indications of decreasing trend (14.28% of the stations). On the other hand, Jibiya, Bakalori and Zobe do not indicate discernible trend pattern. Generally, the seasonal Mann-Kendall revealed that the sum percentage of the negative significant trend far outweighed that of the positive trend at the ratio of 4:1 while for SQ- MK, it is of 11:1; i.e., ratio of significant negative trend to positive significant trend. The consequence is that for every 1% increase in rainfall amount, there is a 4% or 11% decrease in trend signature. The results showed that most of the significant mutation points began in 1990s. Considering the results obtained, there is need to examine other hydrometeorology variables in addition to rainfall in order to have a thorough understanding of the time-space dependent behaviour of the hydro-meteorological processes and their correlating aggregate effects. It is pertinent therefore that several statistical approaches should be used to capture trend and mutations; as one approach may not truly give a snapshot of hydrological variability in a particular basin; for the purposes of drawing effective conclusions.

Keywords: Stochastic, rainfall, mutation, trend, variability, climate change

1. Introduction

In recent years, rainfall variability is now accepted as a serious environmental issue because it is a threat to sustainable development and food security (Olaniran, 1999). As reported by Hulum (2001), rainfall variability is a major characteristic of the Sokoto Rima Basin climate; to be precise, the last 40 years (since 1969) have witnessed dramatic changes in terms of mean annual rainfall throughout the region. Rainfall is a complex atmospheric processes, which is space and time dependent and basically not easily predictable (Lu *et al*.,2004). In this regard, the assessment of the dynamics and regime of a particular hydrological phenomenon such as rainfall is imperative; especially the time-based characteristics (Otache *et al*., 2011).Against this backdrop therefore, as noted by Kottegode (1990), the lack of complete understanding of the physical processes involved and the consequent uncertainties in the magnitudes and frequencies of future events highlight the importance of time series analysis. Within this general context, assessment of trend and change point detection of time series can enhance our understanding of the underlying hydrometeorological dynamics of these process, especially in a changing climate.

Generally, trend is a steady and regular movement in a time series through which the values are, on average, either increasing or decreasing (Otache *et al*., 2011).This type of behaviour can be local, in which case the nature of the trend is subject to change over short intervals of time, or, on the other hand, a global trend that is long lasting. In contrast to long-term trends usually appropriate for steady growth in economics, if a trend in a hydrological time series appears, it is, in effect, part of a low-frequency oscillatory movement induced by climatic factors or through changes in land use and catchment characteristics (Otache *et al*., 2011).Over the years there have different methods (e.g. Robust Mann-Kendall, Sen's slope estimator, Turning point, etc) have been employed for trend analysis with their associated attributes. On the other hand, statistical change point (Mutation) detection have been done by using, for instance, the Pettit's Test, a nonparametric test, is useful for evaluating the occurrence of abrupt changes in climatic records (Sneyers, 1990). One of the attribute of this test is that it is more sensitive to breaks in the middle of the time series (Wijngaard *et al.*,2003). In addition, others like the Sequential Mann-Kendall (SQ-MK) can also be used. It has the power to indicate the beginning and ending of trend, and its intensity, respectively.

It suffices to note that quantitative estimation of the temporal characteristics of rainfall and perhaps its modelling are important considering the fact that it is a critical weather parameter in the estimation of crop water requirement, and development of long lead time flood and flash -

flood warning systems. However, it is interesting to note that despite substantial progress, several issues still remained unresolved. For instance, the best appropriate approach to be adopted in evaluating trend analysis and statistical change point (Rammana *et al.*, 1980) Most of the researches focused on singular approach to quantify hydrological time series variability which could be misleading in terms of accuracy and prediction. For example (Boroujerdy, 2008) used Mann–Kendall test to define trend in annual and seasonal precipitation for the period 1960–2001, (Modarres *et al*., 2017) analysed the time series of annual rainfall, number of rainy-days per year and monthly rainfall of 20 stations using the Mann–Kendall test to assess climate variability in the arid and semi-arid regions of Iran and Hess *et al*., (1995), examined trends in the dates of onset, termination and duration of the rainy season in north-eastern Nigeria based on the standard climatic normal periods using Sequential Mann-Kendall test; the findings are different to some degrees and interpretations. Therefore, it is important to note that single approach may not give exact snapshot of hydrologic variability signatures of a given basin. Considering this therefore, the central thesis of this paper is the evaluation of the effects of different approaches in trend and mutation or statistical change point (SCP) analysis.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Study Location and Data Assembly

The study location is Sokoto-Rima Basin; it is located between 10^oN - 14^oN and 4^oE - $9^o5'E$. It belongs to the semi-arid region of the country, precisely of a predominantly Sudan vegetation. It is characterised by a distinct bi-seasonal weather pattern; i.e., wet and dry. The wet season starts in April and ends in October, while the dry season starts in November and ends in March (Sombroek *et al.,* 1971). **Figure 1** shows the map of Sokoto-Rima Basin. For this study, historical rainfall time series of the Basin was used. To do this, mean monthly rain gauge rainfall values (i.e., point rainfall) for substantial decadal time period were collected from NIMET and Sokoto- Rima River Basin Development Authority Zonal offices across the catchment States of Katsina, Zamfara, Sokoto and Kebbi, respectively. (i.e., the gauging stations of Katsina, Sokoto, Zobe, Goronyo, Gusau Jibiya and Bakalori, respectively). The available data for the seven gauging stations were for these respective periods: Bakalori (1953 - 1970), Goronyo (1961 - 2015), Gusau (1953 - 2010), Katsina (1931 -2011), Sokoto (1910 -2015), Zobe (1950 - 1975). and Jibiya (1950 - 1968).The segmentation was based on the available time series, which was unequal in length. Therefore, it is important to note, that the objective here is to bring to fore significant variability in hydrometeorological phenomenon in the basin not inter- stationary comparison, that is often based on equal assessment parameters or dimensions**.**

Figure 1: Map of Sokoto Rima River Basin.
Source: (Danmagaji, 2017)

2.2. Methodology

(a) General Trend Analysis

In this regard, Time series plot was examined to establish whether it does exhibit intermittency or otherwise as well as seasonal characteristics like trends. Three statistical techniques were used for the study: (i) Pettit's Test, (ii) SQ-MK Test and (iii) MK Test. To examine the time series appropriately, the data for each station was divided within a given range in order to give a snapshot of the variability, especially with respect to climate change implications.

(i) Mann-Kendall Test

The Mann-Kendall test was implemented for both annual and monthly rainfall series. To do this, the annual time series was pre-processed via a pre-whitening strategy Wang (2006), as in equation (1).

$$m_i = x_i - \phi x_{i-1} \quad (1)$$

where, m_i is the pre-whiten series value, x_i is the original series value, and ϕ is the estimated lag 1 serial correlation. The entire Mann-Kendall approach was done by evaluating the following test statistics as in equations (2 - 4).

$$S = \sum_{i=1}^{N-1} \sum_{k=i+1}^{N} \operatorname{sgn}\left(x_k - x_i\right) \quad (2)$$

where

$$\operatorname{sgn}(x) = \begin{cases} +1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

$$\tau = \frac{2S}{N(N-1)} \tag{3}$$

and

$$\sigma_s^2 = \frac{1}{18}\left[\begin{array}{l} N(N-1)(2N+5) - \\ \sum_{i=1}^{m} p_i (p_i - 1)(2p_i + 5) \end{array}\right] \tag{4}$$

Where, m is the number of tied groups in the data set and p_i, the number of data points in the i^{th} tied group. Similarly too, under the null hypothesis, the quantity z is taken to be standard normally distributed. Based on this,

$$z' = \begin{cases} (S' - 1)/\sigma_{s'} & S' > 0 \\ 0 & S' = 0 \\ (S' + 1)/\sigma_{s'} & S' < 0 \end{cases} \tag{5}$$

Though the tradition most often times is to use annual time series for trend analysis, it is necessary to examine what is happening at lower time scale; here at a monthly temporal scale. The essence is to be able to critically bring to fore probable changes at this level due to the implications of seasonality. Thus, the seasonal Mann-Kendall test was employed. The implementation of this approach is according as in equations (6-11).

Monthly rainfall series was represented by the matrix

$$\mathbf{X} = \begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \tag{6}$$

Here, p is the number of seasons for n years under consideration.

$$\mathbf{R} = \begin{pmatrix} R_{11} & R_{12} \cdots & R_{1p} \\ R_{21} & R_{22} \cdots & R_{2p} \\ \vdots & \vdots & \vdots \\ R_{n1} & R_{n2} \cdots & R_{np} \end{pmatrix}, \tag{7}$$

Equation (7) denotes the ranks corresponding to the observations in x where the n observations for each season are ranked among themselves. Thus each column of **R** is a permutation of (1, 2, . . ., n); specifically, the rank matrix $\mathbf{R_{ij}}$ was computed as

$$R_{ij} = \frac{1}{2}\left[n+1+\sum_{k=1}^{n}\operatorname{sgn}\left(x_{ij}-x_{kj}\right)\right] \qquad (8)$$

The Mann-Kendall test statistic (z) for each season was computed by employing equations (9 - 11); i.e, based on (6 and 8).

$$S_i = \sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}\left(x_{ji}-x_{ki}\right) \qquad (9)$$

where, n is water year, i = number of seasons (12) and a season is defined as one calendar month, and S_i is the S-statistic in the MK test for season i (i = 1, 2, …, 12)

$$S^{'} = \sum_{i=1}^{p} S_i \text{ , p = seasons; } \sigma^2_{s'} = \sum_{i=1}^{p} Var\left(S_i\right) \qquad (10)$$

In the presence of serial correlation, as in the monthly rainfall series, the variance of $S^{'}$ is defined as

$$\sigma^2_{s'} = \sum_{i=1}^{p} Var\left(S_i\right) + \sum_{g=1}^{p-1}\sum_{h=g+1}^{p}\sigma_{gh} \qquad (11)$$

where, the covariance matrix σ_{gh} is expressed according as equation (12- 13)

$$\hat{\sigma}_{gh} = \frac{1}{3}\left[K_{gh} + 4\sum_{i=1}^{n} R_{ig}R_{ih} - n\left(n+1\right)^2\right] \qquad (12)$$

$$K_{gh} = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\operatorname{sgn}\left[\left(x_{jg}-x_{ig}\right)\left(x_{jh}-x_{ih}\right)\right] \qquad (13)$$

This is for a ***no missing data*** situation, and g and h are different seasons respectively with the test statistic z' which is standard normally distributed, and evaluated as in equation (14).

$$z' = \begin{cases} \left(S^{'}-1\right)/\sigma_{s^{'}} & S^{'} > 0 \\ 0 & S^{'} = 0 \\ \left(S^{'}+1\right)/\sigma_{s^{'}} & S^{'} < 0 \end{cases} \qquad (14)$$

(b) Detection of Statistical Change Point (Mutation)

The detection of Statistical Change Point in the probable trend of the rainfall series was done by employing: (i) Pettit's and Sequential Mann- Kendall (SQ-MK) tests as in equations (14 - 15)

i. Pettit's Test

The Pettit's test for change point detection was implemented by following the steps according as:

1. Compute U_k statistic by using the formula

$$U_k = 2\sum_{i=0}^{n} m_i - k(n+1) \qquad (15)$$

where,

m_i is the rank of the i^{th} observation when the values $x_1, x_2, \ldots, x_n$ in the series are arranged in ascending order and k takes values from 1, 2, ..., n.

2. Define the Statistical Change Point test (SCP) as follows:

$$K = \max|U_K| \qquad (16)$$

where, $1 \le k \le n$

when U_k attains maximum value of K in a series, then a change point will occur in the series. The critical value according Zarenistanank *et al.* (2014), as reported in Danmagaji (2017), is

$$K_\alpha = \left[-\frac{\text{In}\alpha\left(n^3 + n^2\right)}{6}\right]^{\frac{1}{2}} \qquad (17)$$

where, n is the number of observations and α is the level of significance which determines the critical value. For this study, α = 0.05 was adopted; that is 95% significance level.

ii. Sequential Mann–Kendall (SQ - MK) Test

The Sequential Mann- Kendall (SQ-Mk) test as proposed by Sneyers (1990),was employed based on the following steps, viz:-

1. The magnitudes of x_j annual series (j=1, 2, . . ., n) were compared with x_k ,(k=1, . . .,j-1).
2. At each comparison, the number of cases $x_j > x_k$ shall be counted and denoted by n_j.
3. The test statistic t was computed according as

$$t_j = \sum_{1}^{j} n_j \qquad (18)$$

4. The mean and variance of the statistic:

$$e(t_j) = j(j-1)/4 \qquad (19)$$

and

$$\text{Var}\, t_j = \frac{j(j-1)(2j+5)}{72} \qquad (20)$$

5. The sequential values of statistic U was then calculated as

$$U(t_j) = \frac{t_i - e(t)}{\left[Var(t_j)\right]^{\frac{1}{2}}} \qquad (21)$$

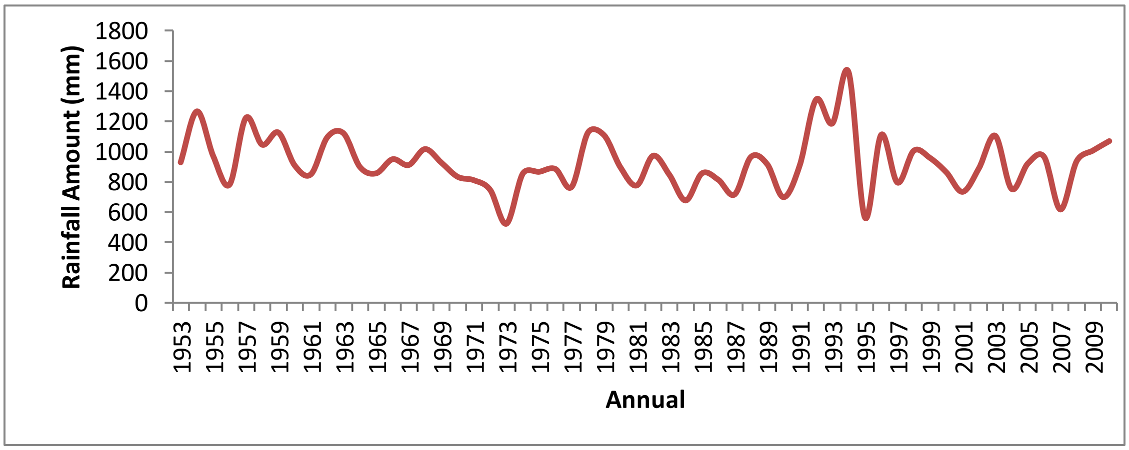
6. Similarly, the values of u' (t), the retrograde was computed backward, starting from the end of series. The approaches were applied to annual rainfall series for the selected gauging stations.

3. Results and Discussion

3.1 General stochastic characteristics of the rainfall series

Hydrologic processes such as rainfall evolve on continuous time scale. The implication(s) of this is simple; as shown by **Figure 2**, the rainfall time series for selected stations exhibit typical stochastic or random characteristics. This phenomenon translates into statistical characteristics which vary within an annual cycle. **Figure 2** shows clearly a discernible random nature of the rainfall; precisely periodic over an annual cycle.

(a)



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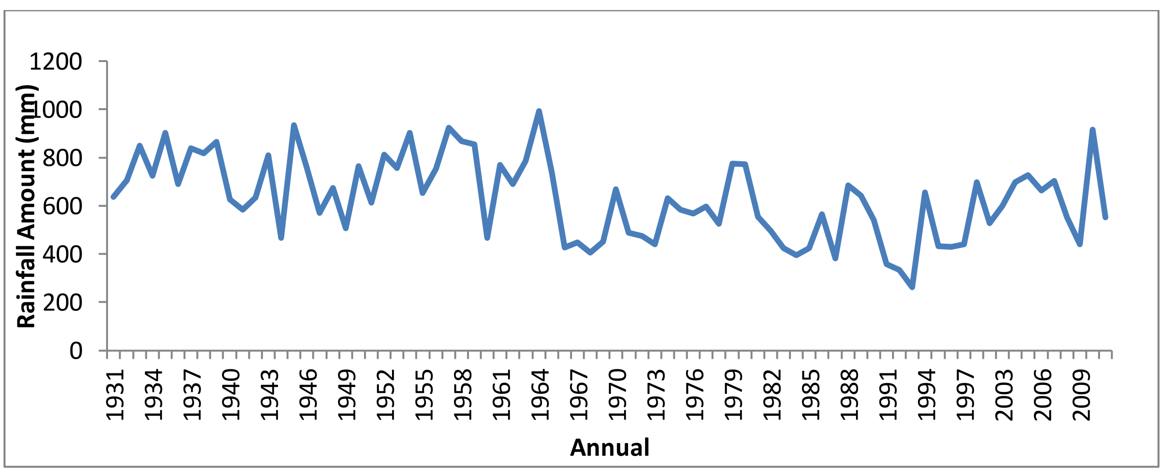


(c)

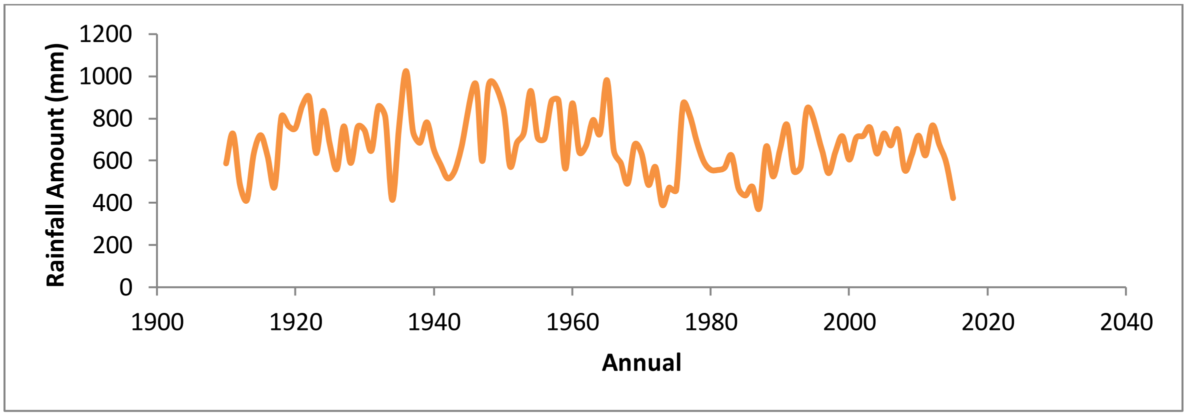


Figure 2: Annual rainfall hydrograph for selected stations (a) Gusau (b) Katsina (c) Sokoto

1. Statistics of Rainfall over the Basin

Table 1 shows the values of moment statistics for annual series. The values indicate significant dispersion or deviation from normality though over the entire basin, on the average, the characteristics of Table 1 portend a probable contiguous transition, especially values of the Skewness coefficient

Table 1: Stochastic Characteristic of the Basin

Stations	Means	Standard Deviation	Skewness
Katsina	629.84	168.5	-0.293
Sokoto	668.78	141.035	0.20
Gusau	926.04	**180.93**	0.586
Jibyia	719.27	174.47	-0.04
Bakalori	771.529	168.478	-0.31683
Zobe	837.87	**186.36**	-0.626
Goronyo	60.68	122.70	-0.44

Figure 3 below shows periodic nature of the rainfall series. As is usually typical of monthly time series, the extent of persistence is not strong though serial dependence decreases with temporal lag; the lack of strong dependence in the autocorrelation structure connotes a seeming short-term memory. Perhaps, this could be explained against the backdrop of heteroscedasticity, a form of volatility; it is imperative to state that this phenomenon may suggest that rainfall series cannot be treated as purely stochastic but with traces of nonlinear determinism at best.

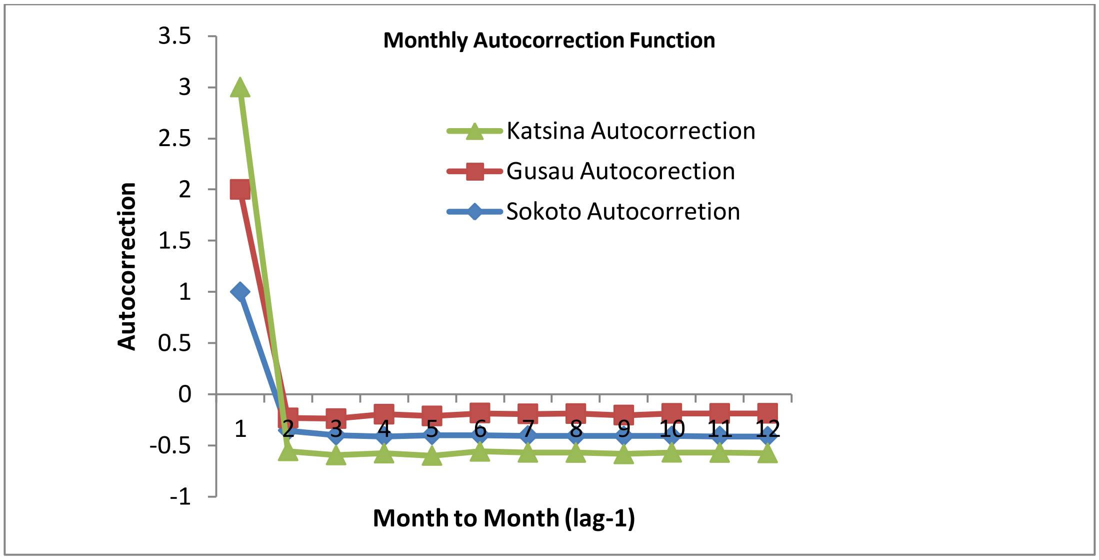


Figure 3: Monthly autocorrelation function for selected stations in the basin

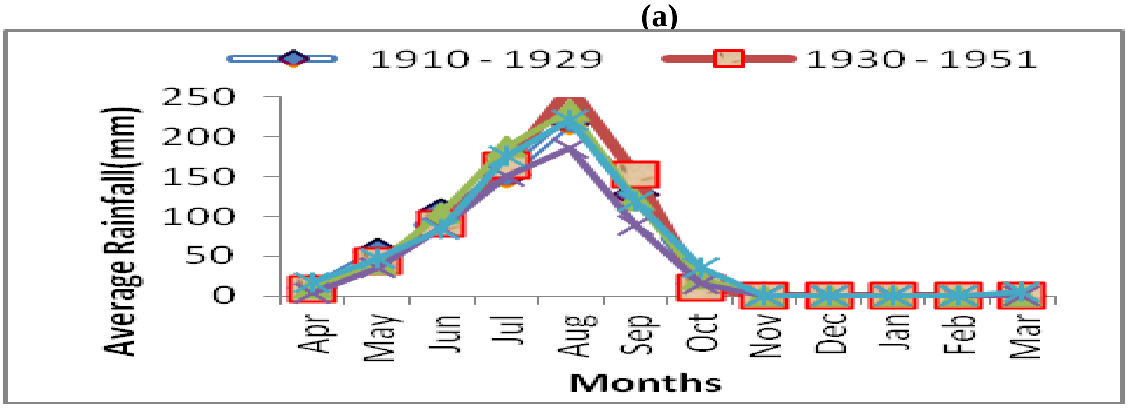
3.2 Trend Analysis

I. Annual trend behaviour

a) Inter-annual Rainfall Variation

Figure 4 shows inter-annual variation in the rainfall series. From the figure, inter-annual variability is copiously discernible in all the stations; in all instances, the trend pattern is characterised by sharp rises and sudden recession in the hydrographs with uni-modal peaks. From figure, the segmentation was based on the available time series, which was unequal in length. Therefore, it is important to note, that the objective here is to bring to fore significant variability in hydrometeorological phenomenon in the basin not inter- stationary comparison, that is often based on equal assessment parameters or dimensions .

(a)



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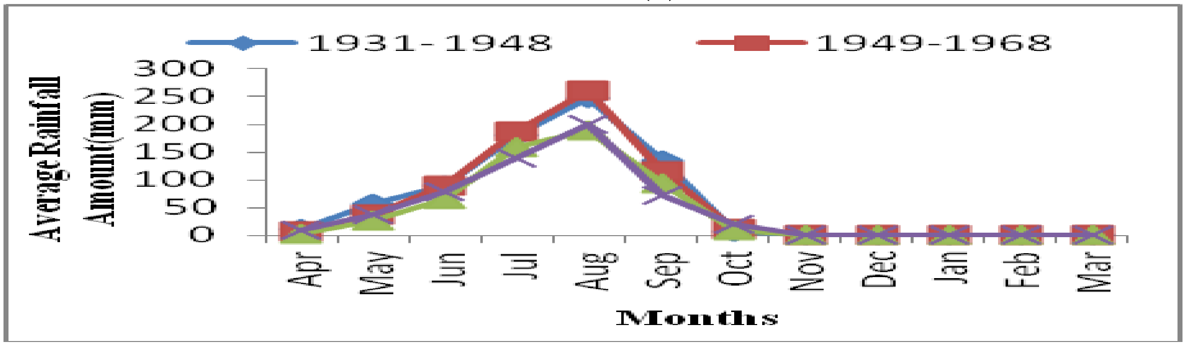

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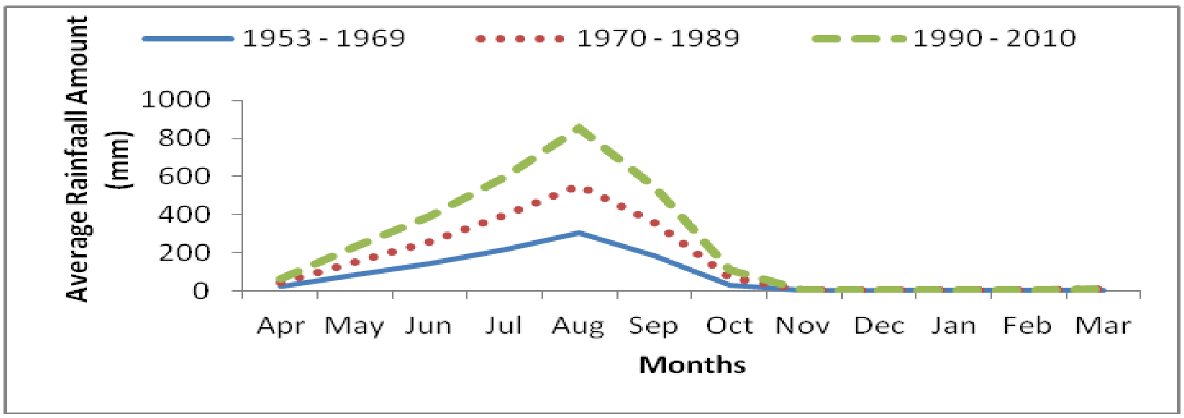


Figure 4:Inter-annual mean monthly rainfall variation pattern for selected stations (a) Sokoto (b) Katsina and (c) Gusau

II. Seasonal Mann-Kendall Trend Test

The Mann-Kendall test results as shown below in **Table 2**, indicate that at 5% level of significance, i.e., ± 1.96, the computed value of the test statistic z, (i.e., two-tailed) for monthly rainfall for each stations is not within the range of ± 1.96 except Bakalori and Jibiyia. Notable of interest, Katsina experienced significant decrease in rainfall at the peak of raining season with the most severe months being September, May and August, with respective Z statistic of **-22.28, -13.11** and **-11.9**. The total decreasing trend value amounts to **41.7%** of the total months of the water year. Similarly, **Sokoto** exhibited significant decreasing trend throughout the period of the raining season, with the most acute month being May amounting to -**25.87** of Z-statistic value. In Sokoto station about **41.7%** of total months of the water year suffered deceasing trend and **8.3%** experienced increasing positive trend. On the other hand, **Gusau** also experience a similar pattern with the months of April, July September, November, January, February and March constituting **58.3%** and **8.3%** of positive and negative trends respectively for the period under discourse.

Goronyo experienced positive trend at the months of September and October indicating significant positive change in the behaviour in the rainfall pattern; obviously skewed towards the end of the year with **25%** positive trend and **8.3%** negative trend. **Zobe** station on the other hand, showed negative trend at the month of October, which is normal because there is often decreases in the amount of rainfall towards later part of the year; the negative trend accounts for **8.3%**. **Jibiyia** and **Bakalori** showed a contrasting situation; there is no significant change in the rainfall. Out of seven stations considered, 71% of the stations exhibit negative trend, 42% positive trend and 28%, no significant trend at all. **Table 3** shows Mann- Kendall test results for annual series; the results depict an admixture of trend regime based on the Z statistic. The variability in both the seasonal and annual trend pattern derives directly from the deleterious implications of climate change.

Table 2: Seasonal Mann-Kendall Trend Test

					Z							
Months	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Station												
Katsina	0.33	**-13.1**	-1.8	**-9.7**	**-12**	**-22.3**	-1.1	**-2.2**	0.0	-0.4	-1.9	0.9
Bakalori	0.13	-0.8	-0.4	0.02	-0.5	-0.6	-0.0	0.0	0.0	0.0	-0.2	0.2
Sokoto	**-7.6**	**-25.9**	**-8.8**	**9.5**	**-15.**	**-12.5**	**12.5**	0.7	0.0	-0.6	1.2	-1.0
Goronyo	**2.2**	**-2.8**	1.08	1.87	1.21	**4.6**	**4.7**	0.0	0.0	0.0	-0.2	-0.5
Zobe	0.3	0.2	-0.1	-1.1	0.0	-1.4	**-2.6**	0.13	0.0	-0.13	0.0	0.0
Gusau	**-2.5**	-0.82	-0.4	**-2.7**	0.1	**-3.6**	**2.9**	**-2.0**	0.0	**-3.0**	**-4.7**	**-4.7**
Jibiyia	-0.1	-0.1	0.4	0.7	-0.3	-1.5	-0.71	0.0	0.0	0.0	-0.1	0.0

Table 3: Mann-Kendall Tests on annual rainfall series

Stations	Statistics		
	τ	z	S
Katsina	0.2434	**16.0903**	731.00
Jibyia	0.3333	0.7494	35.00
Goronyo	-0.1039	**-1.6752**	-77.00
Sokoto	0.1148	**13.2690**	603.00
Gusau	0.0926	**3.3503**	153.00
Zobe	0.3247	1.6311	75.00
Bakalori	0.3676	1.0800	50.00

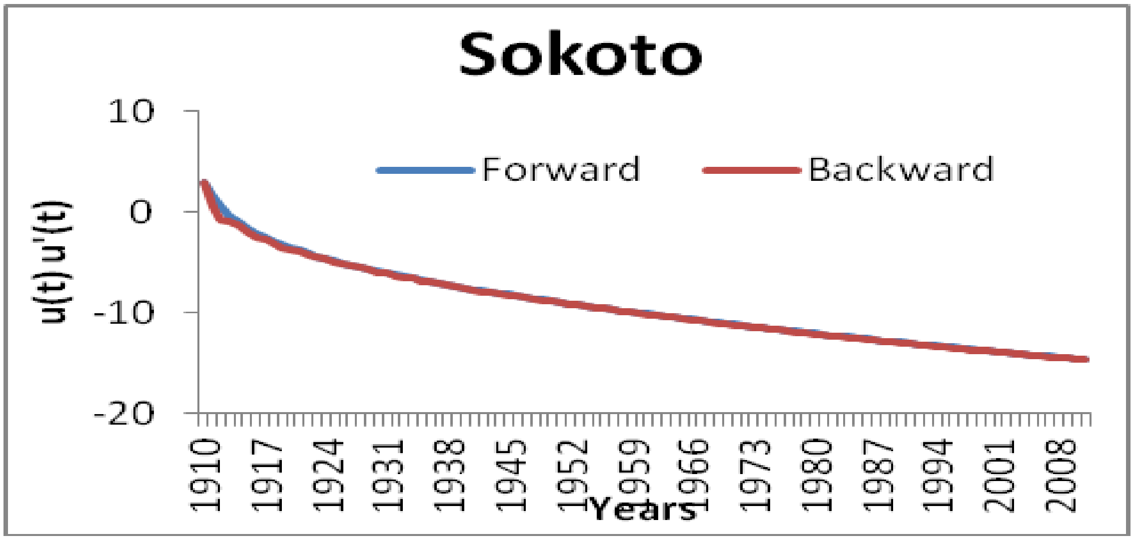
3.3 Detection of Statistical Change Point (SCP)

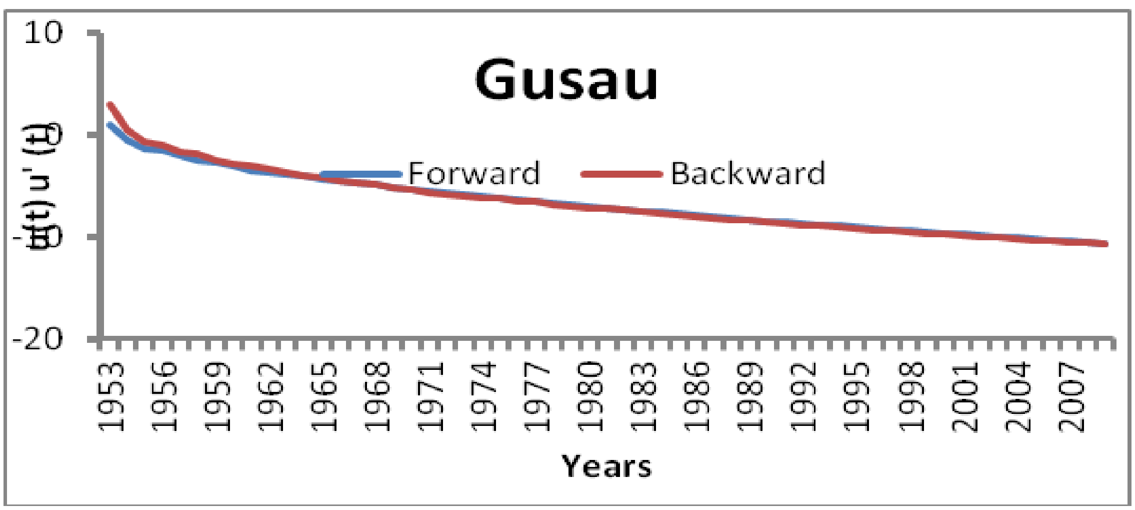
I. Pettit's Test

Pettit's test was applied to detect statistical change point of annual seasonal trend in the basin. The results revealed the existence of significant change point in all the stations with 100% in the stations.

II. Sequential Mann- Kendall Test

The results obtained by applying SQ-MK test to annual rainfall series are as shown in **Figure 5**. For instance, **Zobe** has a mutation point at 1954 which amounts to 5.9% of the total years observed; precisely, 1955 to 1971 exhibited downward trend which accounts for 94.1% of the mutation period while 1953 specifically showed upward positive trend corresponding to 5.9% of the observation time period. **Bakalori** has several mutation points; i.e., 1954, 1955, 1957, 1960, 1962 and 1963. This amounts to 27.27%. **Jibyia** experienced mutations in 1951, 1955, 1956, 1957, 1958, which accounts for 33.3% of the mutation period while **Sokoto** had mutation in 1913 which led to 0.9% of the total number of years observed and downward trend of 97.1% and positive trend of 2.91% of the total year, **Katsina** has no mutation point and **Goronyo** experienced mutation in 1963,1962,1963,1965 and 1963 amounting to 13.15% of the total number of years observed. On the other hand, **Gusau** experienced mutation in 1963 corresponding to 1.75% and downward trend from 1963 to 2010 and upward trend from 1963 to 1953 corresponding to 82.75% and 17.24% of the total years observed respectively. In the overall 85% of the total stations observed exhibited significant trend and percentage sum of the negative and Positive significant trend in the stations were **275.85** and **26.05** respectively. As reported in the findings of Raziei (2008) and Shifteh (2012), the probable reason for insignificant trends in some of the stations could be non-availability of century scale data; this could be possible because of variability as short data length may not give room repetitiveness as espoused in the concept of recurrence interval and consistency. **Figure 6 and Table 4** attest to this variability in terms of general trend and mutation, though not starkly discernible. In addition, it is pertinent to bring to bear from **figure 5** that there is no staggering different in mutations and change of point characteristics in the basin and that account for seemly similarity in the appearance of the plots illustrated in the figures .In Anyadike (1993), theoretical explanation for the varying incidence of statistical change points (Mutations) is high seasonal variability and probable influence of Inter-tropical Discontinuity which usually migrates across West Africa in response to the relative intensities of the Azores-Libyan and St. Helena sub-tropical pressure systems. The Inter-tropical Discontinuity is entrenched to the north of the country and thus placing Sokoto-Rima Basin under the influence of the tropical maritime.


Sokoto
Forward
Backward
u(t) u'(t)
10
0
-10
-20
1910 1917 1924 1931 1938 1945 1952 1959 1966 1973 1980 1987 1994 2001 2008
Years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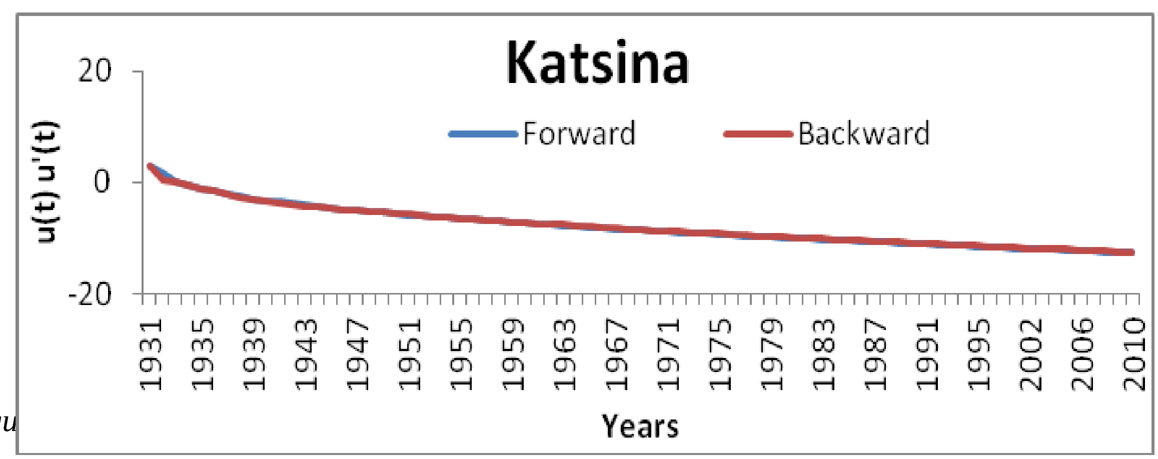
Katsina
Forward
Backward
u(t) u'(t)
20
0
-20
1931 1935 1939 1943 1947 1951 1955 1959 1963 1967 1971 1975 1979 1983 1987 1991 1995 2002 2006 2010
Years

Figu

Table 4: Analysis of SQ-MK Statistics Result

Stations	Positive Trend (%)	Negative Trend (%)	Mutation Points (%)
Bakalori	0.0	0.0	27.3
Zobe	5.9	94.1	5.9
Jibyia	0.0	0.0	33.3
Sokoto	2.1	97.1	0.9
Katsina	0.0	0.0	0.0
Goronyo	17.2	82.75	1.75
Total	**26.05**	**275.85**	**69.15**

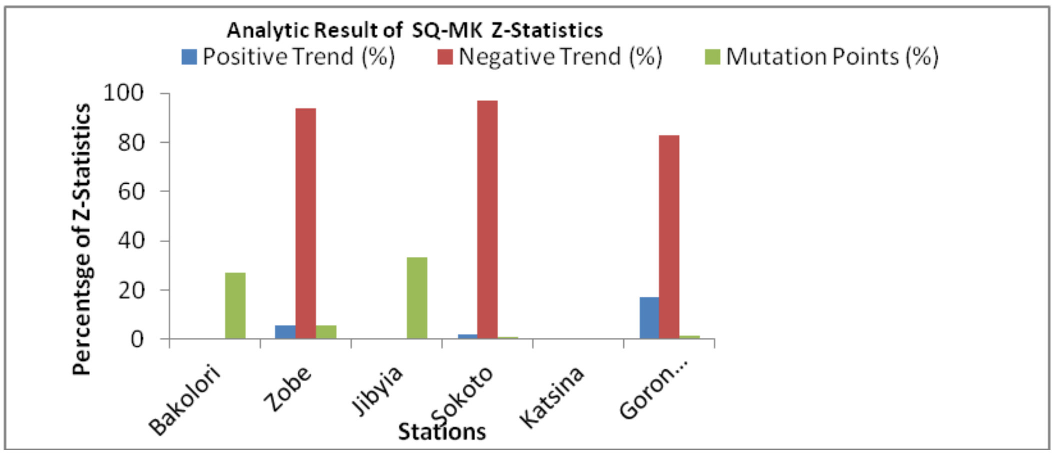

Figure 6: Trend Pattern across the Basin

4. Conclusions

The results of trend analysis and change point detection in rainfall series are important for policy makers, especially for water resources management and agriculture. It was observed that most of the stations showed significant trend in annual and monthly rainfall series using annual and seasonal Mann-Kendall test. The highest number of stations with significant negative trends occurred in the raining season with few significant positive trends. To be precise, Mann- Kendall test on annual rainfall series indicated that **Katsina, Gusau and Sokoto** stations have increasing positive trend; this accounts for 48.86% of the stations while Goronyo station showed a decreasing trend (14.28% of the stations). In contrast, **Jibiyia, Bakalori and Zobe,** respectively have no significant trend. However, traces detected correspond to 48.86% of the stations. In the overall, the seasonal Mann-Kendall test revealed that the sum percentage of the negative significant trend far outweighed the positive trend at the ratio of 4:1 while SQ- MK gave a picture of 11:1; that is, significant negative trend to significant positive trend. The physical implication of this scenario is that for every 1% increase in rainfall amount, there is a 4% or 11% decrease in trend signature.

Generally it can be inferred that, there is evidence of significant change in rainfall regime in the basin for the period (1931–2016). This varying degree in the trend pattern across the basin has the potential of leading to extreme hydro-meteorological conditions of flood and drought. It suffices to note that the variability as epitomised in the mutation results became critical from the 1990s. Significant trends were detected can largely be attributed to global warming caused by anthropogenic emission of greenhouse gasses and the gradual expansion of the tropics during the last 30 years. Based on the results, for effective generalisation in the long-term, it is strongly recommended that extensive data should be employed for analysis. In the same context, a plurality of analytical approaches should be deployed in the assessment while considering admixture of hydro-meteorological variables in the context of the aggregate effects of the interactions of same on the variability evolution of the associated extremes.

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A CONCISE REVIEW OF VARIOUS SOIL MOISTURE MEASUREMENT TECHNIQUES

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ABSTRACT

For centuries, the amount of moisture in the soil has been of paramount interest in dictating engineering, agricultural, geological, ecological, biological and hydrological characteristics of the soil mass.The relevance of the subject of soil moisture and the need for reliable, effective and satisfactory moisture meters and methods of determination prompted engineers, researchers and scientists to develop various techniques and equipment for soil moisture determination, both in the laboratory and in situ. Research is still on-going for more efficient ones.However, ascertaining the applicability of these techniques to soils of different characteristics, effects of soil salinity, organic matter and its overall physical, chemical and mineralogical parameters and types of moisture content (hygroscopic moisture, free/gravity moisture, bound/capillary moisture), which they can measure, is still a point of debate. With respect to this, this paper succinctly and critically discusses and evaluates the various methods and techniques of soil moisture, including recent innovations with respect to their advantages and disadvantages, limitations associated with them.

Keywords: soil, soil moisture, water content, remote sensing, dielectric sensor and soil moisture measurement techniques.

1. INTRODUCTION

Soil can simply mean the top layer of most of the Earth's land surface, consisting of the unconsolidated products of rock erosion and organic decay, along with bacteria and fungi in which plants' growth and development takes place (King, 2008).

Soil is basically a layer of unconsolidated material found at the Earth's surface that has been influenced by the soil forming factors. The gaps between the soil particles are known as pore spaces or voids, which consist of variable amount of air and water. The amount of void space within a soil depends on the distribution of particle sizes, and it is quantified by soil porosity.

Immediately after a rain or irrigation water application, when all the gravity water has drained down to the water table, a certain amount of water is retained on the surfaces of soil grains by molecular attraction and by loose chemical bonds. This water cannot be easily drained under the action of gravity and is referred to as field capacity (in percent by volume). The determination of field capacity is extremely useful because it is one of the factors that allow calculating the amount of water available for plant use. Field capacity corresponds to soil tensions of about 0.3 bars (0.08 bars for sands and up to 0.5 bars for clay soils) (Sharma, 2006).

Soil moisture can be defined as the water in the unsaturated part of the soil profile, i.e. between the soil surface and the ground water level(Johannes, 2009). Soil moisture status is essential for climate change studies, and for conducting soil water balances. Soil moisture data is necessary for parameterizing numerical models, which are used to estimate evapotranspiration from land cover, and deep percolation for groundwater impact studies. Spatial and temporal variability in soil moisture results by variations in soil texture, topography, crop cover, irrigation practices and groundwater level depth (Malik and Shukla, 2014).Soil moisture is defined as the amount or content of water present in the soil. So there is need to handle water with care. Irrigation is the highest form of water withdrawal in agriculture. For this reason, plants should be irrigated only when they need water. This makes soil moisture monitoring of great importance. In times of reduced and unreliable water supply, and in view of existing and upcoming water related regulations, monitoring of soil moisture represents a key method to help farmers match irrigation application with actual soil water conditions and crop water requirement. The primary objective of irrigation scheduling is to reduce to minimum the water stress of the plant, that of over irrigation, and under irrigation.

The amount of water used by a crop at any time depends, among other things, on moisture availability in the soil, air temperature, and soil temperature (Kaur et al, 2016).Quite significant contributions have been made by Briggs (1897) and Terzaghi (1943) in understanding the soil-moisture interactions(Susha Lekshmi et al, 2014). Briggs has reported that the soil moisture exists in three forms viz., gravitational moisture, capillary moisture and hygroscopic moisture, which are explained in the subsequent section. Clayey soil retains more amount of hygroscopic moisture as compared to sand due to its higher surface area (Susha Lekshmi et al, 2014).

Soil water content is one of the most important variables in hydrology. It contributes strongly to the determination of surface runoff during periods of persistent drought, as well in setting up the initial conditions for flood forecasting models. Despite its known importance, in many applications it is commonly inferred using simplified parametric approaches, such as the Palmer Drought Index and the Antecedent Precipitation Index (Maltese et al, 2013).

Over the years, it has been identified that efficient, effective, robust, and automated techniques for the measurement of soil moisture content (SMC) can be very useful and essential to a high degree, in agricultural, environmental and hydrologic applications. In hydrology, its application helps in floods monitoring. It is also useful in considering agricultural and non-agricultural uses of soils hence, their proper purposes rationalization. This recognition has fostered the investment of a considerable amount of ingenuity in developing such techniques. Determination of soil moisture is one of the most difficult measurements required in the field of hydrology. The development of equipment has been directed primarily toward instruments that continuously measure changes in moisture content at a single sampling point (Johnson, 1992).The monitoring and modelling of land surface and vegetation processes is an essential tool for the assessment of water and carbon dynamics of terrestrial ecosystems. Despite the importance of SMC, its accurate assessment is difficult. The standard procedure for soil water determination against which all other SMC methods are calibrated is the gravimetric method, (Verstraeten et al, 2008).

2. HOW WATER IS HELD IN THE SOIL

Generally, the water holding capacity of a soil is dependent upon such parameters as; soil type, structure, depth, organic matter content, past management practices, porosity, specific surface area, mineralogical composition, salinity, pore fluid characteristics, degree of compaction, presence of contaminants, temperature and humidity. This classification depends on the percentage of sand, silt and clay. Sand is the largest, then followed by silt and smallest is clay (Kaur et al, 2016).

The United States Department of Agriculture (USDA) identifies soil types according to a soil texture triangle as shown in fig.1 below. This chart gives different names to different combinations of clay, sand and silt.

The water holding capacity of soil is given by its texture and the organic matter present in the soil. Water is held by soil according to the surface area of particle size. The smaller the particle size the larger the surface area. Hence, the larger surface area allows the soil to hold more amount of water. The organic matter content of the soil also influences the water holding capacity of soil. As the more the organic matter the more the water holding capacity and vice-versa.

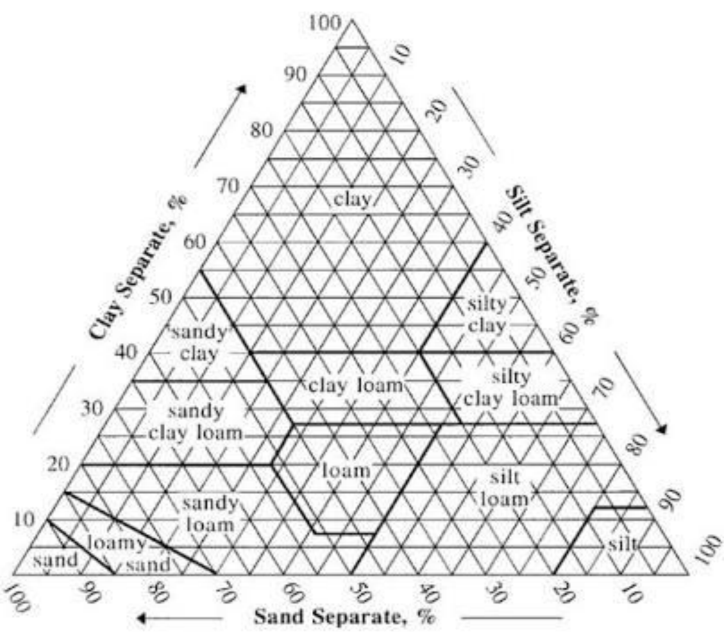

Fig.1 Soil Texture Triangle (USDA, 2017)

3. TERMS ASSOCIATED WITH SOIL MOISTURE

Water Tension: This describes how tightly the water molecules are attached tothe soil and shows the force per unit area that must be exerted to remove water from a soil. Its determination involves the energy measurements in terms of the potential energy of water in the soil measured, usually with respect to free water. Water tension is measured in energy/mass of soil. Units are atmosphere, joules/kg or kilopascal (Kaur et al, 2016).

Gravitational Moisture: Is defined as the free moisture that moves through the soil due to the force of gravity. It is found in the macro-pores and its movement is quite rapid in well-drained soil and hence, it is not considered to be available moisture. Normally, gravitational moisture drains out of the soil in 2–3 days after the rainfall.

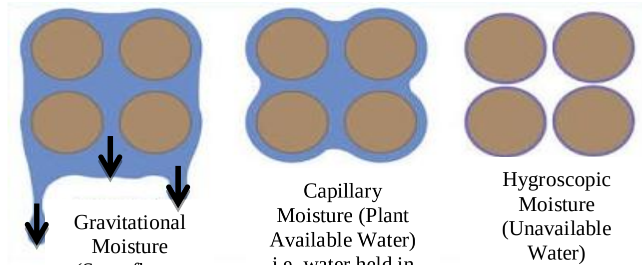

Fig.2 Three Types of Soil Moisture (http://yourej.co/three-types-of-water.html)

Capillary Moisture: Is the moisture present in the micro-pores of the soil and is held within the soil due to cohesion and adhesion against the force of gravity. This moisture is available as pore moisture and is responsible for all physico-chemico-mineralogical–biological interactions between the soil and the environment.

Hygroscopic Moisture: Forms a very thin film around the surface of the soil particles. Since, it is not held in the pores of the soil, but is on the surface of these particles, it is very difficult to remove due to the presence of extremely high forces of adhesion.

Gravimetric Soil Moisture Content, *w*: Is defined as the ratio of the mass of moisture present in the soil sample to the dried mass of the same.

Volumetric Soil Moisture Content, Θ: Is defined as the ratio of the volume of moisture present in the soil to the total volume of the soil.

Saturation Point: This is that point when excess amount of water is present in the soil. This is also known as the readily available water. At this point the plants can easily extract the water from soil.

Refill Point: As the amount of water reduces due to evaporation and removal of water from soil, there occurs the condition when the plants cannot easily extract the water from soil. Because the small amount of water present in the soil cling more tightly to soil particles and in small pore spaces. This condition of soil is refill point.

Field Capacity: This is the amount of water retained on the surfaces of soil grains by molecular attraction and by loose chemical bonds proximately after a rain or irrigation water application, and all the gravity water has drained down to the water table.

Permanent Wilting Point (PWP): Wilting point (PWP) is the water content of the soil below which plants start to wither. It is also a condition when there is very little amount of water present in soil that cannot be extracted from soil by plants roots.

Available Water: This is the accessible water for the plants which can be absorbed by plant roots and it is the difference in water content of the soil between the permanent wilting point and the field capacity.

Unavailable Moisture: This is the water left in the soil after the permanent wilting point is reached. It cannot be removed, and it is inaccessible to plants.

Dielectric constant: of any material is defined as capacity to transmit the electromagnetic pulses or waves. The dielectric constant of water is much higher than soil.

4. SOIL MOISTURE MEASUREMENT TECHNIQUES

Soil moisture content determination techniques can be categorized into; **(i)** Classical techniques **(ii)** Modern techniques.

4.1 Classical Soil Moisture Measurement Techniques

These are traditional techniques used by farmers in determining the soil moisture content (MC). They include **(i)** Feel method, and **(ii)** Appearance method.

In the earlier times when the technology was not much developed, the farmers use their hands to know how much water content present in soil. From the appearance of soil, they tried to guess the water content by its physical appearance. These methods were approximation and unreliable methods (Kaur et al, 2016).

4.2 Modern Soil Moisture Measurement Techniques

As the technology gets advanced, new technologies emerged and new sensors and meters come into origin. These methods provide accurate results and are quite efficient. There are three approaches, generally applied these modern days for soil moisture determination. These are: **(i)** In-situ or point measurements, **(ii)** Soil-water models, and **(iii)** Remote sensing techniques.

4.2.1In-Situ or Point Measurements

The water level in the soil can be expressed as soil water content or water tension (potential). Soil water content can be represented in three ways: **(i)** percentage water by weight, **(ii)** percentage water by volume and, **(iii)** inches of water per foot of soil in this approach, various point measurements techniques are used to determine the soil moisture content. The measurement techniques are based on two concepts; one is volumetric and second is based on water tension. Volumetric involves calculation by mass or volume. It gives output in the form of present content. The water tension measurement involves the energy measurements, which is measured in energy/mass of soil. Units are joules/kg or kilopascal. Several in-situ methods used in this regard are; **thermo-gravimetric (oven-drying) technique, calcium carbide technique, nuclear technique or neutron moisture meters (NMM), gamma ray attenuation, electromagnetic techniques, tensiometric technique, dielectric techniques (time domain reflectometry (TDR), capacitive technique, frequency domain reflectometry (FDR)), gypsum blocks and hygrometric techniques**.

4.2.1.1 Thermo-gravimetric Method: Gravimetric is the term related to analysis based on quantitative measurement of mass or solid. In gravimetric method of moisture measurement, the moisture content is expressed by ratio as weight of water to the weight of dry soil. This has been employed as the standard reference for determining soil moisture content. Different soil samples are taken from any depth from any farm or garden. The collected samples are put into an air tight container. The samples are weighed and then heated in oven at temperature 100-110ºC, more specifically at 105ºC for 24hours, so that no more content of water is present (Kaur et al, 2016).However, for organic soils and gypsiferous soils, the temperature is usually decreased to 50–70ºC, since organic matter may be lost due to volatilization at elevated temperatures (Susha Lekshmi et al, 2014). Then dried soil samples are weighed and at the end the percentage moisture content is calculated using formula;

$$Moisture\ Content = \frac{(weight\ of\ wet\ soil - weight\ of\ dry\ soil)}{weight\ of\ dry\ soil} \times 100$$

Gravimetric technique is accurate, cost-effective and involves simple procedure. However, it is a laborious and tedious method; it is destructive for soil and sometimes very difficult to take samples from rocky soil.

4.2.1.2 Calcium Carbide Technique: Is a rapid soil moisture determination technique, employed either in laboratory or in field. Soil moisture content of a specified wet or moist soil is determined by the gas pressure developed due to the chemical reaction of calcium carbide reagent with the moisture present in the soil. Acetylene gas is produced in proportion to the amount of available moisture present in the soil and is measured by confining the resultant gas in a sealed chamber. The apparent moisture content can be obtained from a pressure gauge of the apparatus and is calibrated with the gravimetric soil moisture content (Susha et al, 2014). It has quick response time, quite reliable, and it can be employed in laboratory or in field. Its major drawbacks are; ineffectiveness in highly plastic clay or non-friable soils, development of chemical reaction in the soil, and needs efficiently skilled operator.

4.2.1.3 Neutron Moisture Meters (NMM): Neutron probe moisture meters involve the detection of soil moisture using radioactive element (americium 241). A probe is fed deep into the soil and connected to power supply, microcontroller, display and keypad via wire. The probe contains a source and detector. The fast neutrons are emitted by the source and the detector detects the neutrons that come back after collision and absorption with nuclei of soil and water. The number of neutrons that come back to probe depends upon the hydrogen and oxygen atoms present in the soil. When a neutron encounters the hydrogen atom, it loses energy. This collision slows down the emitted neutrons, some loose energy to such extent that they cannot come back to the detector. Boron tri-fluoride gas is used in the detector. Gas emit photons when it absorbs the neutrons, so the number of neutrons that come back can be calculated by using an electronic circuit that counts the photons emitted by Boron tri-fluoride. Neutron probe method gives fast and reliable measurement, repeated measurements can be taken at any depth of soil and at any location (Kaur et al, 2016). On the contrary, the major disadvantage of NMM is involvement of radioactive element. It needs extensive care to handle and license, expensive, presence of salts affects readings of meter, and needs efficiently skilled operator.

4.2.1.4 Gamma Attenuation Technique: The gamma ray attenuation technique is a radioactive technique that can be used to determine soil moisture content which is restricted to a soil depth of 2.5cm or less with high resolution. Changes in saturated density are measured by the gamma transmission technique and the moisture content is determined from this density change. It is a non-destructive in situ technique having response time of approximately less than 1 min which measures the volumetric moisture content (Susha Lekshmi et al, 2014). This is a non-destructive in situ technique with good response time. However, it is affected by soil bulk density, it is sensitive to the surface soil moisture, difficult to use due to its cumbersome nature, relatively more dangerous to work than NMM, and relatively high operational cost.

4.2.1.5 Electromagnetic Induction: In the Electromagnetic Induction (EMI) technique, primary and secondary magnetic fields are imposed in the soil-water mixture through a transmitter coil placed on the soil surface. The ratio of these two fields at the receiver coil provides an estimate of the apparent electrical conductivity of the soil (Zegelin, 1996). This technique does not need to be inserted in the ground. It is easy and quick to operate, and can provide estimates over large areas and substantial depths (of order 10 m). However, the task of isolating the effects from soil moisture content at a particular depth is difficult (Zegelin, 1996). This difficulty is due to the fact that the results are site – specific and can vary depending on the complex interaction among multiple, interacting and variable soil properties (Doolittle and Brevik, 20014)

4.2.1.6 Tensiometric Method: Tensiometers measure the capillary tension (energy with which water is held by the soil) which is defined as the common log of the height of a water column in centimeters equivalent to the soil moisture tension and can be expressed as a suction i.e. negative pressure or a potential i.e. energy per unit mass., through a liquid filled porous cup connected by a continuous liquid column to a manometer. The readings are in kpa (kilopascals) or centibars. This technique provides direct and continuous readings, no power supply is required, variable length tensiometers are available to take any variable depth moisture measurement, minimal skill is required to read the gauge, it is an inexpensive system (Kaur et al, 2016). Its disadvantages include; it functions only from zero to about 1 atm (atmospheric pressure) which represents a small part of the entire range of available moisture. it has a relatively slow response time, careful handling of equipment is required, and it requires frequent maintenance.

4.2.1.7 Hygrometric Method: The relationship between moisture content in porous materials and the

relative humidity of the immediate atmosphere is well known. Therefore, several relatively simple sensors for measuring relative humidity have been designed. Basically, these sensors can be classified into seven types of hygrometers: electrical resistance, capacitance, piezoelectric sorption, infra-red absorption and transmission, dimensionally varying element, dew point, and psychometric. The pluses of this technique include the simplicity of the apparatus, and low cost. Drawbacks include the deterioration of the sensing element through interactions with the soil components, and the special calibration required for each material that is tested (Schmugge et al, 1980).

4.2.1.8 Time Domain Reflectometry (TDR) Systems: The TDR system measures the travel time of the electronic pulse through the waveguides (two or more probes), which is surrounded with the soil. The water content of the soil is calculated by using the travel time readings. The TDR system consists of pulse generator that generates a square wave, and an oscillator that captures the reflected pulse, from many points along the probe. The probes are inserted into the soil; the travel time depends upon the complex permittivity of the soil (Kaur et al, 2016).The major advantages of TDR are high temporal resolution, no health risks, rapidity of acquisition (approximate 8s) and the repeatability of measurements. It can be operated up to 1 GHz frequency. This technique is independent of the soil texture, temperature, and salt content, helpful in performing long-term in situ measurements and can be automated (Susha Lekshmi et al, 2014). However, it is expensive, frequency dependent, involves complex electronic equipment, loss of reflection in highly saline soil and increase in conductivity with wetting of the soil mass.

4.2.1.9 Capacitive Technique and Frequency Domain Reflectometry (FDR): Here, capacitive probes are used and an oscillating circuit and a sensing part which is embedded in the soil. The operating frequency depends on the dielectric constant of soil. This technique determines the dielectric permittivity/dielectric constant of a medium by measuring the charge time of a capacitor which uses that medium as a dielectric. Despite the working principle of FDR is similar to that of capacitive technique, it uses swept frequency (collecting the data over a wide range of frequency) (Susha Lekshmi et al, 2014). Two electrodes are embedded into the soil and soil acts as dielectric medium. The electrodes are given voltage supply, due to presence of water the dielectric of soil changes. The accuracy and repeatability of the FDR are more as compared to TDR, gives high temporal resolution, no health risks, and instantaneous response time (Susha Lekshmi et al, 2014).The design of probe is flexible and robust, it is relatively inexpensive, and it is quite easy to interface FDR soil moisture sensor with a microcontroller. However, it requires individual calibration, fails in highly saline soils, frequency dependent, its installation requires extensive care, and being sensitive to air gaps between soil, access tube and probe which affect the accuracy (Kaur et al, 2016).

4.2.1.10 Gypsum Blocks: This is made of calcium sulfate dehydrates, and its ability to absorb water and to come into equilibrium with medium makes it an appropriate soil moisture sensor. Gypsum block can be cylindrical or rectangular in shape. In this technique, electrodes are embedded into the block which is inserted into the soil and small voltage is provided to the electrodes. The electric resistance between the electrodes measures the tension of the soil. If water is present in the soil, it is absorbed by the gypsum block, and comes in equilibrium with the soil water. Consequently, the electrical resistance is measured between the two electrodes will and this gives the information about the water content of soil using a meter attached to the cable. Gypsum blocks are cheap, and do not require much maintenance (Kaur et al, 2016). The weaknesses include its usefulness only in refill point of soil, very less response time, requirement of individual calibration, failure in saline soil and suited for fine textured soils and not with coarse textured soil since gypsum blocks are not generally sensitive below 1 atm (Susha Lekshmi et al, 2014).

4.2.1.11 Heat Flux Sensor Technique: The Dual Probe Heat Pulse (DPHP) sensor technique consists of two probes viz. heater and temperature sensor probes for measuring soil volumetric moisture content. The method is based on the application of an instantaneous pulse of heat to an infinite line source. The temperature increase that results from the heat pulse is measured (Susha Lekshmi et al, 2014). This technique considers the volumetric contributions of mineral and organic components. The downside is that, it is valid for non-swelling soil of known bulk density, and shallow depth and short radial distance is measured.

4.2.2 Soil Water Models

Soil – water simulation models (commonly based on infiltration, evaporation and transpiration) are based on column mass balance that provides an alternative to direct or indirect measurement of soil moisture in the field. Water balance is simply a statement of conservation of matter, i.e. matter can neither be created nor destroyed but can only change from one state or location to another. In its simplest form, the water balance equation states that, changes in volumetric water content of soil over a period of time are equal to the difference between the amount of water added and that withdrawn during the same period (Lascano, 1991). It is centered upon the conservation of mass, and the soil moisture in the system can be determined using the relationship below;

$$SM_t = SM_{t-1} + P - R - L - E - T + C - Q \qquad \text{(Sharma, 2006)}$$

Where; SM_t is the soil moisture volume at time t; SMt-1 is soil moisture volume at previous time; P is the precipitation; R is surface runoff; L is net lateral subsurface outflow; E is the evaporation or condensation; T is transpiration; C is capillary rise from lower levels; Q is the percolation. This model hence represents only a single column that is horizontally homogeneous at all levels. Contrary to this, actual systems are heterogeneous, and they can be represented by 21spatial averages or by linked columns that account for the spatial variability. Most of the models based on soil-water relationship developed for practical application to agricultural activities like crop yield estimation, irrigation planning, and runoff forecasting and use readily available meteorological data for inputs for one day time step (Sharma, 2006). The models can provide timely soil moisture information without the necessity of field visits. The main limitation of using such models is the error due to the several parameters, which can lead to significant deviations of their estimates.

4.2.3 Remote Sensing Techniques

Remote sensing of soil moisture content has been studied and developed over three decades. Soil moisture estimation by means of remote sensing depends upon the measurements of electromagnetic energy that has either been reflected or emitted from the soil surface. Water is near the extremes in its thermal and diurnal properties of the soil (Sharma, 2006). These properties are accessible to remote sensing through measurements at the thermal infrared and microwave wavelengths. Thermal infrared measurements depend on the diurnal range of surface temperature or measurement of the crop canopy-air temperature differential, whereas active and passive microwave considers the measurement of the radar backscatter coefficient and microwave emission or brightness temperature respectively. The variation in intensity of the microwave radiation with soil moisture depends on the dielectric properties, soil temperature, or a combination of both. Recent advances in remote sensing have shown that these techniques have the ability to measure soil moisture under a variety of topographic and vegetation cover conditions quantitatively. This has been demonstrated using aircraft and space platforms with physically based models. The high dielectric constant (k'= 80) of the free water compared to the dry soil (k'= 4) is attributed to the fact the water molecules are free to rotate at microwave frequencies (Jackson and Schmugge, 1986). Bound water has a lower constant because the water molecules are adsorbed to the surfaces of particles and the dipoles are immobilized (Sharma, 2006). Thus, as the soil moisture increases, the dielectric constant can increase to a value of 20 or more (Schmugge et al, 1980). This variation produces emissivity changes from 0.95 for dry soils to 0.6 or less for wet soils and changes in the radar backscatter coefficient of more than 10dB for this range of conditions. The advantages of remote sensing techniques over the in-situ methods is that the former allows the acquisition of global and synoptic view of the planet, offer rapid data collection over large areas on a repetitive basis within the top 2-3 cm of the soil (Sharma, 2006). On the other side, remote sensing measurements do not provide as accurate or as deep a measurements of the soil moisture as can be obtained by conventional insitu measurements at a point (Schmugge et al, 1980). Its estimation is also apparently affected by vegetation cover of an area.

5. CONCLUSIONS

Maintaining accurate and appropriate soil moisture and its use with utter care is required not just for proper development and yield of crops but also for survival of mankind who depends mainly on these crops. A comprehensive study of the reviewed literature betokens that researchers have employed various techniques. All the techniques have their own advantages, disadvantages and limitations. Generally, the selection of instrumentation or technique by an operator or a farmer depends on such factors as; soil type, economical, relative cost, reliability, accuracy, and energy-efficient means for collecting distributed data. Among all the methods, the thermo-gravimetric method remains the standard method.

The conclusive remark of this paper recommends that future research should be done on; determination of the influence zone within the soil mass for which the moisture content measurement is being made; with respect to this, automated FDR based (preferably wireless) system could be considered as regards to irrigation needs with time. Similarly, the authenticity of the commonly employed 'dielectric response' techniques-based for soils having organic matter, salinity and its overall physico-chemico-mineralogical parameters should be studied exhaustively; in considering a soil moisture system using microcontroller and embedded system, the FDR soil moisture sensor is easy to interface, which can also be used in implementing wireless sensor networks; carrying out detailed research work applying both remote sensing and field measurement for soil moisture content estimation; fabrication and utilization of nano-scale soil moisture sensors is also another relevant work to be carried out on the course of facilitating accurate soil moisture content measurements. Finally, in Nigeria, where electricity is a problem, methods that are not electric power dependent (example solar powered moisture meter) should be emphasized or developed to enhance research work.

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RURAL GROUNDWATER ASSESSMENT USING WQ INDEX: A CASE STUDY OF BOSSO LOCAL GOVERNMENT AREA, NIGER STATE, NIGERIA

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ABSTRACT

Due to the ever increasing need for water and food security, there is need for continuous assessment of water bodies in order to preserve the existing water resources and prevent further degradation. As such, it is of great importance to see that the water required for human need is made potable. This paper assessed the level of potability of groundwater in rural communities of Bosso LGA of Niger State, Nigeria. To achieve this aim, physicochemical analysis was carried out on thirty water samples from fifteen different locations(fifteenwater samples from boreholes and fifteen water samples from shallow wells). The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was applied on the analysed results of the parameters to obtain a single value that was used to rank the groundwater of the sampling stations. The results showed that 53%, 40% and 7% of water from the boreholes can be ranked as good, fair and marginal respectively while, 7%, 60% and 33% of water from the shallow wells can be ranked as good, fair and marginal respectively. The implication of this is that the groundwater in the area is good and fair for drinking purpose though water from the boreholes are more potable than water from the shallow well.

Keywords: CCME WQI, Assessment, Rural water supply, Groundwater, Groundwater Potability.

1. INTRODUCTION

Water is an essential resource to the life of all living organisms on earth. About 75% of the earth is filled with water (Ohimain and Angaye, 2014). As a result of rapid expansion of cities and subsequent population explosion, the development of groundwater resources for potable use has increased substantially over the last decade especially in developing countries. One means of establishing and assuring the purity and safety of water is to set a standard for the various contaminants. A standard therefore is a definite rule, principle or measurement which is established by government authority (Shelton, 1995).

Adekunle *et al*., (2007) reported that among various sources of water available, groundwater appeared to be the most reliable source due to its relative abundance and its unpolluted nature as a result of restricted movement of pollutant in the soil profile. Some compounding factors are responsible for the inadequacy of potable water: but two major factors include; rapid urbanization (Amadi*et al*., 2012), and increasing population, agricultural and industrial activities (Amangabara, and Ejenma, 2012) Inadequacy of potable water or poor water quality can result to substantial problems like, toxicity, poor agricultural productivity and health problems such as outbreak of diseases (Ohimain*et al*., 2013; Angaye*et al.*, 2015).

Potable water is defined as water that is free from microbial contaminants, low in compounds that are toxic to human health, which is clear, not saline and free from colour, odour and taste (Pritchard et al., 2008). Groundwater will possess all these attributes if the top surface through which the aquifer is recharged is protected from both natural and anthropogenic pollution. This will be achieved if the permeable soil stratum through which the water passes to water table is not polluted from lateral contaminant transferred from contaminated sites like poultry waste dumps (Lerner and Harris, 2009).Groundwater quality and availability is one of the most critical environmental and sustainability issues of the twenty-first century (UNEP,2006). It is widely used, for instance, for drinking and irrigation in food production (Zekster and Everett, 2004). However, groundwater is not only a valuable resource for water supply but also a vital component of global water cycle and the environment.

Shekwlo and Brisbe (1999) in their studies remarked that 50.8% of people living in Minna which is the State capital of Niger State rely on shallow dug wells, 23.3% on borehole, 16.3% on tap, 3.5% on river and 6% on springs.

Groundwater contamination occurs when pollutants released on the ground surface find their way down to the aquifer (Heath, 2004). The pollutants result majorly from improper disposal of waste on land; major sources which include industrial and household chemicals and garbage landfills, industrial lagoons and process waste water from mines, oil field, brine pit, leaking underground oil storage tanks and pipeline, sewage sludge and septic tank. Groundwater vulnerability is a measure of how easy or hard it is for contaminant at the land surface to reach a production aquifer or it is a measure of the degree of insulation that natural or man-made factors provide to keep pollution away from the aquifer (Morris, 2003).

Because of the ever increasing need for water and food security, there is need for continuous monitoring of the water body in order to preserve the existing water resources and prevent further degradation. Most importantly, it is of great importance to see that the water required for human need must be made potable. In this present study, the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was used, which is well-accepted and universally applicable for evaluating the water quality index. It can combine a variety of different measurement units in a single metric and is also effective as a communication tool. The index has the ability to convey relative differences in water quality between sites even when the same objectives and variables are used.(CCME, 1999).

1. MATERIALS AND METHODS

2.1 Study Area

The location used as a case study is Bosso local government area of Niger State, Nigeria. It has an area of 1,592km ^{2} and a population of 147,359 as at the 2006 census (NSG, 2007). It falls between longitude 6.200000^{0}E to 6.800000^{0}E and latitude 9.400000^{0}N to 9.800000^{0}N. The area has a special savannah climate with distinct rainy, dry and harmattan season respectively. The dry season usually occurs between October/November and ends around March/April while the rainy season starts around April/May through September/October and harmattan period starts around November through February. Temperature prevailing in the area is generally high with values ranging from 24^{0}C to 32^{0}Cwith an annual mean of about 27^{0}C. The average rainfall is about 250mm. Peasant farmers cultivate yam, rice, guinea corn, maize, pepper, vegetables and tomatoes, which thrive abundantly due to the availability of sandy soil from weathered rocks of the Minna batholiths (NSG, 2007).Figure 1 indicate location of the study area;

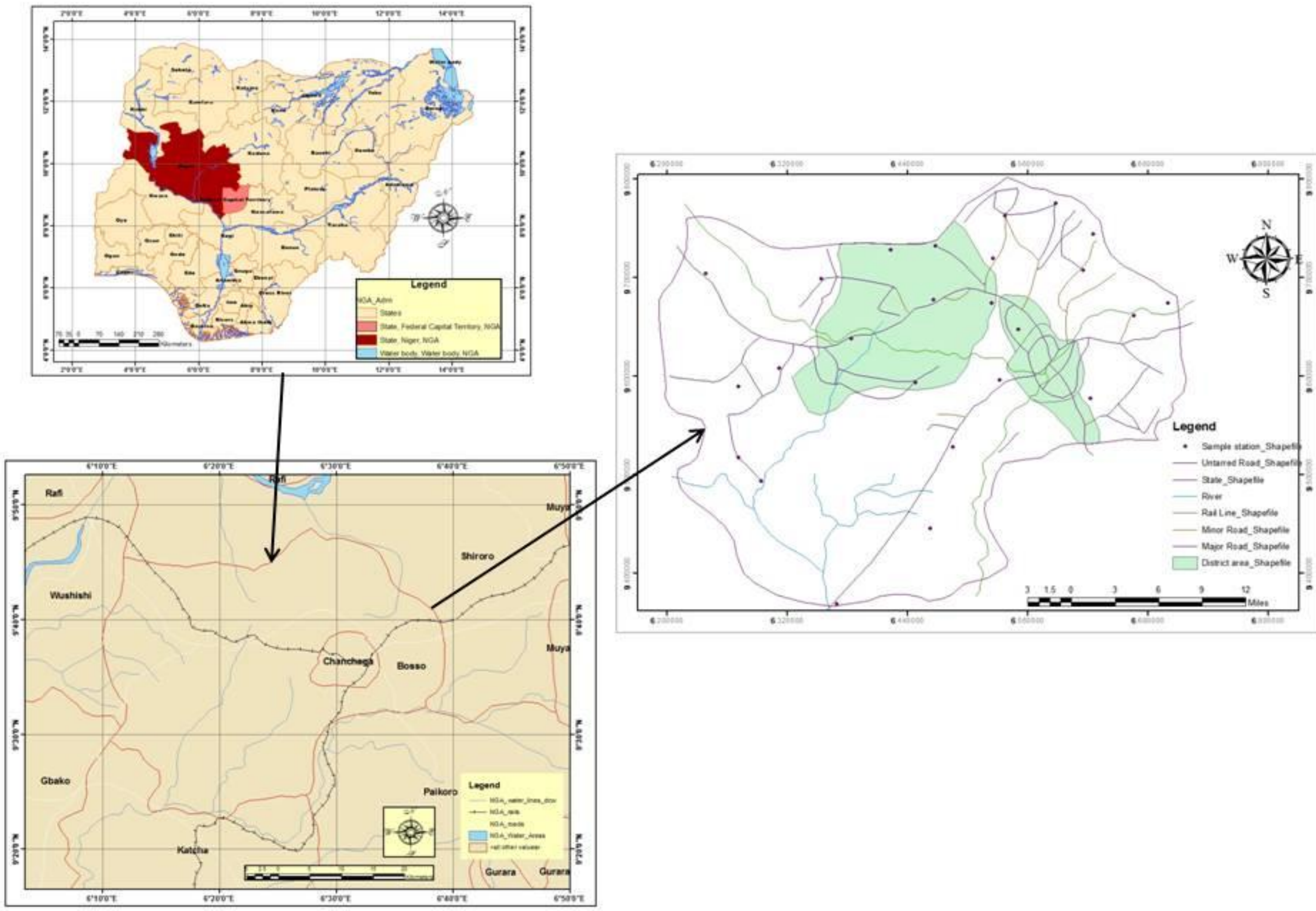

Figure 1: Study area indicating the sampling stations

1.2 Sampling Procedure and Analysis

1.3 Groundwater samples were collected from fifteen communities in Bosso Local Government Area of Niger State. The samples were collected at fifteen different locations. Four samples were taken from both boreholes and shallow wells at different locations. Each sampling location was recorded with global positioning system (GPS). The samples were collected using plastic bottles rinsed with trioxo-nitrate (V) acid and distilled water Lerner and Harris (2009) to avoid unpredicted change in the characteristics of the water samples. The bottles were marked and labeled in reference to the sampling points. Before the collection of water samples at the point of collection, each bottle was rinsed with the water source to be collected and firmly corked after sample collection to prevent contamination. The samples were then analyzed for ten physiochemical parameters namely: temperature, colour, turbidity, pH, electrical conductivity (EC), nitrates (NO_3^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), biochemical oxygen demand (BOD), dissolved oxygen (DO).The analysis was conducted according to the standard method for examination of water and waste water (APHA, 2005).

2.3 Water Quality Indices

2.3.1 General Description of the CCME WQI Index

The CCME WQI depends on measures of the scope; frequency and amplitude of excursions from guidelines. Once the CCME WQI value has been calculated, water quality can be converted into ranking by using the categorization scheme presented in Table 1.

Table 1. CCME WQI Categorization

Ranking	WQI	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; this implies that conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
Poor	0 – 44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

2.3.2 Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI)

The detailed formulation of the WQI, as documented by CCME (2001) and Amir *et al.* (2008) comprises three factors as follows:

Factor 1: $F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ numbers\ of\ variables}\right) \times 100$ (1)

The measure for **scope** is F_1. This represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables)

Factor 2: $F_2 = \left(\frac{Number of failed tests}{Total numbers of tests}\right) \times 100$ (2)

The measure for **frequency** is F_2. This represents the percentage of individual tests which do not meet objectives (failed tests).

Factor 3: (F_3) is the measure for **amplitude**. This represents the amount by which failed test values do not meet their objectives. This is calculated in three steps:

Step 1: Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.
When the test value must not exceed the objective:

$$excursion = \left(\frac{Failedtestvaluei}{Objectivej}\right) - 1 \qquad (3a)$$

When the test value must not fall below the objective:

$$excursion = \left(\frac{Objectivej}{Failedtestvaluei}\right) - 1 \qquad (3b)$$

Step 2: Calculation of Normalized Sum of Excursions. The normalized sum of excursions, (*nse*) is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} excursion}{NumberofTests} \qquad (4)$$

Step 3: Calculation
of F_3. F_3 ($Amplitude$) is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \qquad (5)$$

The CWQI is finally calculated as:

$$\mathrm{CWQ1} = 100 - \left(\frac{\sqrt{\mathrm{F}_1^2 + \mathrm{F}_2^2 + \mathrm{F}_3^2}}{1.732}\right) \qquad (6)$$

The constant, 1.732, is a scaling factor to ensure the index varies between 0 and 100. It normalizes the resultant values.

2. RESULTS AND DICUSSIONS

Water Quality index for each of the fifteen stations (for borehole water samples and shallow well water samples) in Bosso Local Government Area was determined using the physicochemical parameters listed in Table 2a, Table 2b, Table 3a and Table 3b, respectively. The values of the various scopes (F1), Frequency (F2) and amplitude (F3) with their respective water quality index are presented in Table 4. The bolden values are higher than the standard recommended by the WHO and CCME for drinking water.

In Table 4., The results of the CCME WQI ranking values shows that water quality for drinking purposes for Borehole water in the area can be ranked as good at Jikpan, Gidan Mangoro, Dogonruwa, Shatai, Saegbe, Kanakaka Bagu, Jikobe and Jigbe, and ranked as fair at Mangoro Hassan, Jikuchi, Popopi, Garatu, Tawo and She Station while only the borehole water at B Mugada can be ranked as marginal. Also from Table 4, the results of the CCME WQI ranking values shows that water quality for drinking purposes for shallow well waterin the area can be ranked as good only at Jikpan and as fair at Gidan Mangoro, Dogon Ruwa, Shatai, B Mugada, Saegbe, Kanakaka Bagu, Jikuchi, Jikobe and Jigbe and be ranked as marginal at Mangoro Hassan, Popopi, Garatu, Tawo and She station. Table 5 shows the percentage in ranking for groundwater in the area. From Table 5 and Figure 2, it can be shown that 53%, 40% and 7% of water from the boreholes can be ranked as good, fair and marginal respectively while 7%, 60% and 33% of water from the shallow wells can be ranked as good, fair and marginal respectively. The area with fair and marginal ranking shows the pollution status in those locations which might be due to proximity to domestic waste dump, well not properly covered or lined, use of too many fetchers thus introducing contaminants into the water etc.

Table 2a: Physicochemical parameters for borehole water samples for eight villages

Location	Temp (0C)	Col (Ptco)	Tur (NTU)	pH	EC (µs/cm	NO3 (mg/L)	SO4 (mg/L)	TDS (mg/L)	PO4 (mg/L)	DO (mg/L)
Jikpan	**27**	3	0.3	6.8	20.6	22	93.8	20.9	0.02	**3.6**
	28.1	2.5	0.1	8.1	22.3	34	100.1	25.1	0.05	**4**
	23	4	0.3	5.7	17.4	50	122	58.4	0.2	6.2
	25.3	3.6	0.2	7.4	19.1	**74.7**	154.8	22.9	0.18	5.1
G/mangoro	**27.7**	5.7	3.17	8.1	534.2	10.3	151.4	235.9	0.03	5.6
	29	6.1	3.3	7.8	416.1	10.3	161.3	100.8	0.01	5.9
	30	4.5	3.7	8.3	300.4	7.5	141.3	240.1	0.02	**4.2**
	28.9	5.8	3.4	8.5	333.1	7.8	155	238.8	0.1	5.2
Dongoruwa	**25.7**	3.6	1.4	**9.8**	343.4	24.2	79.9	39.8	0.08	6.3
	27.1	3.9	2	6.9	341.1	23	81.2	300.8	0.1	**4.2**
	23.5	3.2	1.7	7..0	343.2	29.1	85.3	69.3	0.06	6.1
	30	3.8	2	7.1	343.9	28.2	83.8	433.6	0.18	**4.6**
Shatai	**29.8**	5.3	4.9	6.9	747.6	22.9	80.1	113.4	0.13	8.7
	28.4	5	4.9	6.4	721.4	25	74.3	97.3	0.1	6
	31	6.2	5	7.5	760.1	30	91	114.3	0.12	5.2
	30.3	6.9	4.9	7	731.5	27.3	90.4	89.2	0.01	6.7
Bmugada	**29.2**	5.7	3.12	7	633.7	13.1	22.9	471.2	0.08	**4.8**
	31.1	4.5	3.2	8	410.6	10.3	20.8	420	0.06	**3.9**
	28.7	4	3.4	7.4	294.6	8.9	28.7	206.3	0.05	**4.6**
	31.6	3.8	3.39	7.6	234.3	4.9	27.6	467.2	0.06	5.2

Saegbe	**31.9**	2	**5.9**	7.2	449.4	2.1	36.4	306.8	0.02	6.3
	30.1	2.8	4.1	7.6	470.1	2.1	22.9	364.1	0.06	6.1
	27.9	3.1	2.9	7.4	497.3	2.4	19.1	240.3	0.04	**4.7**
	28.9	2.6	2.3	7	490.4	2.7	5	285.4	0.04	**4.8**
M/ Hasssan	**29**	8.9	3.4	6.8	757.3	6.4	7.1	158.1	0.03	6.4
	30	8.4	4	6.9	730.2	15.2	6.4	100.1	0.01	5
	28.9	8.1	**5.2**	8.1	741.3	20.6	6	140.5	0.04	**4.7**
	28.4	8.6	**6.5**	**8.7**	724.3	30.5	6.2	160.2	0.06	5.2
K/ Bagu	**27.3**	4.5	**5.3**	6.9	416.2	13.6	11.4	246.5	0.06	5.5
	26	4.9	4.1	6.8	400.9	15	11.5	205.5	0.04	5.9
	23.4	3.2	3	7	452.3	20.6	11.4	281	0.05	5.5
	22.7	3.8	2.1	7.2	437.4	19.4	11.9	235.9	0.06	5.8
WHO(objective)	25	15	5	6.5 - 8.5	1000	50	500	1000	0.5	_
CCME(objective)	15	_	5	6.5 - 8.5	_	48.2	500	500	_	5

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

Table 2b: Physicochemical parameters for borehole water samples for seven villages

Location	Temp (0C)	Col (Ptco)	Tur (NTU)	pH	EC (µs/cm	NO3 (mg/L)	SO4 (mg/L)	TDS (mg/L)	PO4 (mg/L)	DO (mg/L)
Jikuchi	**25.2**	1.7	1.9	7.3	9.4	83	11.1	476.4	0.29	6.1
	26	1.3	**5.6**	7.3	9.1	53	10.4	472.1	0.15	6.5
	28	1.9	**12**	7.4	9.6	42.5	8	500.2	0.17	**4.3**
	27	1.3	**11.3**	7.3	9.9	23.5	8.4	517	0.18	5
Jikobe	**27**	2.8	0.4	7.5	6.1	29.1	79.6	161.3	0.19	**1.5**
	26.5	2.4	0.2	7.3	6.9	25.4	80.3	164.3	0.17	**3**
	30	3.6	0.5	7.6	7.6	10.2	114.6	160.9	0.17	**3.4**
	28.9	3.1	0.1	7.4	7.2	13.1	129.3	171.2	0.18	**3.8**
Jigbe	**27.7**	3.3	1.45	7.3	88.3	16.02	199.5	328.6	0.1	**1.9**
	28.5	2.9	1.31	7.7	88.2	20.11	199.2	200.1	0.11	**3.4**
	30.1	4.2	2	6.5	90	12.17	199	180.7	0.08	**4.5**

	29	3.7	1.01	6.9	89.1	11.09	199.1	179.4	0.06	**4.1**
Popopi	**28.2**	1.7	**5.12**	6.2	392.3	9.68	211.1	175	0.07	**3.8**
	28.5	1.9	4.16	6	390.4	10.65	201.8	180.1	0.1	5.2
	27.9	1.5	**6.55**	7	392.6	20.14	200.8	329.7	0.09	5
	28.1	1.6	**9.42**	7.4	391	17.92	200.4	324	0.18	**4.5**
Garatu	**30.3**	6.8	4.09	6.3	413.4	18.57	12.7	657.7	0.23	6.5
	30	7	4.31	6.8	400.2	19.1	14.1	400.6	0.21	7.5
	29.5	6.7	**5.55**	6.9	514.8	18.57	120.6	648.6	0.12	**4**
	29.1	6.9	**5.32**	6.8	548.3	18.67	124.3	646.9	0.13	5
Tawo	**30.8**	3.8	3.39	**8.8**	538	19.06	186.6	708	0.04	5.3
	30.8	3.5	3.37	8.3	511.1	20.6	187.6	706.1	0.07	6.8
	30.7	2	2.31	**8.6**	7	**479.2**	61.47	141.3	0.36	**4.5**
	30.8	2.6	2.2	8.5	495.1	**62.37**	167.2	688.7	0.05	**4.8**
She Station	**31.7**	5.6	3.04	8.4	642.8	22.63	151.2	56.8	0.26	6.3
	32.9	5.8	4	8.3	622.1	25.01	155.4	59.7	0.24	**4.3**
	30.6	4.9	**7.6**	8.4	640	24.11	87.5	70.4	0.16	**2.9**
	30.5	5	**7.48**	8.4	637	26.23	87.1	69.2	0.18	5.1
WHO(objective)	25	15	5	6.5 - 8.5	1000	50	500	1000	0.5	_
CCME(objective)	15	_	5	6.5 - 8.5	_	48.2	500	500	_	5

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

Table 3a: Physicochemical parameters for shallow well water samples for eight villages

Location	Temp (0C)	Col (Ptco)	Tur (NTU)	pH	EC (µs/cm	NO3 (mg/L)	SO4 (mg/L)	TDS (mg/L)	PO4 (mg/L)	DO (mg/L)
Jikpan	**28.1**	7.6	0.61	6.5	46.9	0.67	249.6	53.6	0.06	16.4
	29	6.6	0.53	6.6	47.1	0.59	300.1	53.7	0.07	18.1
	25	9.9	0.59	7	44.4	14.3	413	58.6	**0.65**	24.5

	26.4	8.9	0.43	7.1	43.4	14.21	411.6	58.9	**0.61**	23
G/mangoro	**28.9**	14.3	**7.21**	7.8	**1214**	31.4	402.6	606.4	0.12	25
	29.5	12.7	**7.56**	7.5	**1213.1**	33.4	214.4	607.4	0.25	23.1
	31.6	13.9	**7.81**	8.4	**1209.1**	25.4	421.5	614.9	0.31	24.5
	30.1	14.5	**7.77**	8.2	**1211.6**	23.9	412.3	613.9	0.33	23.6
Dongoruwa	**26.8**	8.9	3.2	9.4	780.4	**73.9**	212.6	102.4	0.29	28.2
	25.4	10.3	4.2	9	782.3	**74.3**	221.4	110.3	0.23	27.4
	32.5	10.9	3.8	7.2	779.2	**88.1**	241.3	**1116.3**	0.43	20.71
	31.2	9.4	4.6	6.8	781.6	**86.2**	222.9	**1114.6**	**0.61**	2016
Shatai	**31**	13.3	**11.3**	6.6	**1699.2**	**70.1**	213	291.6	0.44	39.3
	32	14.5	**11**	6.5	**1673.2**	**75.1**	24.6	275.7	0.47	41.3
	30.7	**18.5**	**11.7**	6.8	**1666.4**	**84.1**	235.3	230.1	0.05	33.3
	31.6	**17.2**	**11.2**	6.7	**1662.4**	**83.6**	240.4	229.3	0.02	30
Bmugada	**30.4**	14.3	**7.1**	6.7	**1440.2**	40.1	60.8	**1211.3**	0.27	21.6
	31.2	10.2	**7.3**	5.2	**1441.3**	41.1	65.9	**1215.1**	0.3	22.5
	34	10.5	**7.7**	7.7	**1441.4**	13.9	80.5	**1213.6**	2.25	24.1
	32.9	9.6	**7.7**	7.3	**1441.6**	14.9	73.4	**1200.9**	0.22	23.6
Saegbe	**33.2**	4.9	**13.6**	6.9	**1021.4**	6.4	96.7	788.6	0.06	28.2

	30.1	6.4	**18.9**	6.7	**1114.6**	8.2	13.3	733.6	0.14	21.6
	31.1	3.4	**16**	6.8	**1022.3**	6.3	34.6	789.3	0.08	29.5
	30.5	7.9	**19.1**	6.6	**1114.3**	8	25.3	732.5	0.1	22.5
M/Hasssan	**30.2**	**22.3**	**7.7**	6.5	**1721.1**	19.7	18.9	406.4	0.11	28.9
	31.1	**20.9**	**8.7**	6.6	**1722.3**	20.1	18.2	409.2	0.13	29.1
	29	**22.1**	**12.7**	**9**	**1600**	**95.3**	17	415.7	**0.71**	22.5
	29.6	**21.6**	**14.8**	8.4	**1646.1**	**93.4**	16.6	411.9	0.21	23.6
K/Bagu	**28.4**	11.3	**12.1**	6.6	946	41.6	30.2	633.6	0.22	24.8
	27.8	11.4	**10.6**	6.8	929.4	42.5	30.5	640.1	0.23	21.4
	24.2	8.9	**5.3**	7.1	957.4	**55.4**	31.2	621.5	**0.99**	30.2
	23.6	9.6	4.8	6.9	994	**59.3**	31.6	606.4	0.21	26.1
WHO(objective)	25	15	5	6.5 - 8.5	1000	50	500	1000	0.5	_
CCME(objective)	15	_	5	6.5 - 8.5	_	48.2	500	500	_	5

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

Table 3b: Physicochemical parameters for shallow well water samples for seven villages

Location	Temp	Col (Ptc	Tur (NTU	pH	EC (µs/c	NO3 (mg/L	SO4 (mg/L	TDS (mg/L	PO4 (mg/	DO (mg/L)

	(0C)	o)	)		m	)	)	)	L)	
Jikuchi	**26.2**	4.3	4.3	7	21.4	**70.4**	29.6	**1224.6**	**0.99**	27.6
	27.6	4.5	4.5	7	20.9	**70.8**	30.8	**1214.7**	**0.93**	25.6
	27.9	3.5	0.9	7.1	21.7	**71.5**	22,5	**1330.3**	**0.65**	22.1
	28.1	3.2	0.7	7	22.6	**71.9**	22.4	**1329**	**0.61**	22.4
Jikobe	**27.6**	4.5	4.5	7	20.9	**70.8**	30.8	**1214.7**	**0.93**	25.6
	27.9	3.5	0.9	7.1	21.7	**71.5**	22,5	**1330.3**	**0.65**	22.1
	28.1	3.2	0.7	7	22.6	**71.9**	22.4	**1329**	**0.61**	22.4
Jigbe	**28.9**	8.3	3.3	7	200.7	49	**530.7**	330.5	0.33	8.4
	29.1	8.5	3.5	7.2	201.3	**50.3**	**540.5**	360.7	0.3	10.4
	30.4	9	2.6	6.2	202.5	35.7	**531.3**	450.1	0.25	16.4
	30.2	9.2	2.3	6.6	202.4	33.9	**529.4**	461.2	0.21	18.4
Popopi	**29.4**	4.2	**18.46**	6	891.6	29.6	**561.4**	449.9	0.24	16.9
	29.1	4.3	**22.1**	6.5	889.3	29.4	452.3	7.1	0.26	17
	29.5	4.4	**20.6**	7.4	893	**55**	**531.5**	800.2	**0.61**	21.4
	29.3	4.1	**21.4**	7.1	888.7	**54.8**	**533**	833	**0.61**	20.1
Garatu	**31.6**	**16.9**	**9.3**	6.1	939.6	**56.8**	33.9	**1690.8**	**0.79**	29.3

	31.6	**17.3**	**10.2**	6.3	940.3	**56.9**	33.7	**1671.2**	**0.77**	30.1
	30.7	**16.5**	**11.2**	6.9	**1248.2**	**57.3**	331.11	**1666.1**	0.45	25.1
	30.3	**17.3**	**12.1**	6.5	**1246.1**	**57.1**	330.6	**1662.9**	0.43	22.6
Tawo	**32.1**	9.4	**7.7**	8.5	**1222.8**	**58.3**	496.4	**1820**	0.14	23.8
	32.4	9.5	**6.8**	**8.9**	**1224.3**	**59.3**	498.4	**1810.3**	**0.8**	24.1
	32.1	7.6	**5.7**	8.1	**1127.3**	**68.9**	444.8	**1779.3**	0.21	20.7
	32.1	6.6	5	8.2	**1125.2**	**68.4**	444.6	**1770.5**	0.18	21.6
She Station	**33**	13.9	**6.9**	8.1	**1461**	**69.2**	402.1	145.9	**0.89**	28.4
	33.3	13.6	**6.8**	8.5	**1463.2**	**70.1**	300.2	150.4	**0.85**	28.5
	32.9	11.5	**18.4**	7.9	**1450.9**	**75.7**	241.2	176.7	**0.63**	24.4
	31.8	12.6	**17**	8.1	**1447.8**	**80.2**	231.6	177.9	**0.61**	22.8
WHO(objective)	**25**	**15**	**5**	**6.5 - 8.5**	**1000**	**50**	**500**	**1000**	**0.5**	**_**
CCME(objective)	**15**	**_**	**5**	**6.5 - 8.5**	**_**	**48.2**	**500**	**500**	**_**	**5**

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

Table 4: Quality of water according CCMEWQI

	BOREHOLE					SHALLOW WELL				
LOCATION	F1	F2	F3	WQI	RANKING	F1	F2	F3	WQI	RANKING
Jikpan	30	15	3	80	Good	20	13	2	86	Good
G/mangoro	20	13	6	85	Good	30	30	9	75	Fair
Dangoruwa	30	15	8	80	Good	40	28	8	71	Fair
Shatai	18	10	2	92	Good	40	35	14	68	Fair
B mugada	20	70	9	57	Marginal	40	40	11	67	Fair
Saegbe	30	17	3	80	Good	30	30	20	73	Fair
Mangoro Hassan	40	20	6	73	Fair	70	50	20	48	Marginal
KanakakaBagu	20	8	1	86	Good	40	20	9	74	Fair
Jikuchi	30	20	11	78	Fair	40	40	12	67	Fair
Jikogbe	20	20	10	83	Good	30	20	6	79	Fair
Jigbe	20	20	10	82	Good	30	23	3	78	Fair
Popopi	30	23	6	78	Fair	50	38	26	61	Marginal
Garatu	30	18	8	79	Fair	70	60	21	45	Marginal
Tawo	40	23	3	73	Fair	70	53	16	48	Marginal
She station	30	20	7	79	Fair	50	50	24	57	Marginal

Table 5: Percentage of Water Quality in the study area

Ranking	Borehole	Percentage (%)	Shallow well	Percentage (%)
Excellent	-	-	-	-
Good	8	53	1	7
Fair	6	40	9	60
Marginal	1	7	5	33
Poor	-	-	-	-

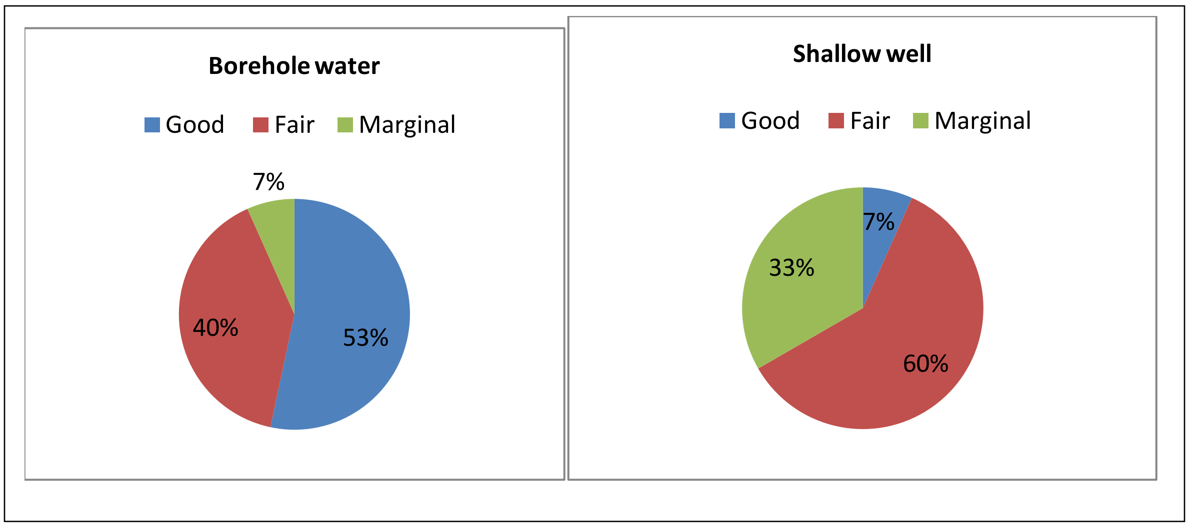

Figure 2: Percentages in ranking for both boreholes and shallow well

CONCLUSIONS

The water quality status of Bosso Local Government Area was evaluated using CCME water quality index. The results of the study revealed that groundwater in the area is good and fair for drinking purposes though water from the boreholes are more potable than water from the shallow well. The water can also be used for irrigation and drinking purposes. Furthermore, the application of water quality index is a reliable tool in assessing the overall quality of groundwater.

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DESIGN AND DEVELOPMENT OF A LOCALLY MADE RAINFALL SIMULATOR

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Abstract

Over the years, scientists have found the need for water erosion experiments to be undertaken in a controlled environment which has given rise to the different types and designs of rainfall simulators. The availability of such equipment is found to be rare in most universities in Nigeria especially due to its high cost of purchase and installation. This study discussed the design and fabrication of a small scale pressurized rainfall simulator. The rainfall simulator is 2.2m x 2.2m by size, resting on a wooden frame 2m x 2m by size, made using a 0.0508m x 0.0508m sized wood, at 1.65m in height and 2m by length and breadth, with 0.3m of each leg buried into the ground to stand firmly. The rainfall simulator has a main-pipe connection which receives water from the pump and supplies the laterals which in turn distributes water to the sub-lateral where the water is sprayed through the shower roses. Each of the shower roses is 90mm in diameter, made up of 105 holes with each of the holes have an approximate diameter of 2 mm and provides the simplest form of spray. The drop velocity (DV) was calculated to be 8.101m/s and 2.443 m/s when operated at maximum and at minimum intensity respectively. Performance test revealed the experimental coefficient of uniformity (CU) and rainfall intensity from the simulator to be 79.86% at 31.79mm/hr and 78.03% at 16.08mm/hr when run at maximum and minimum intensity respectively. The results of drop velocity (DV) and experiment coefficient of uniformity (CU) were within the acceptable range respectively. The intensity of water dropping from the simulator depends on the inflow rate of water which could be regulated by the control valve fixed at the main-pipe. Thus, this locally rainfall simulator meets the minimum requirements and can used for erosion studies.

Keyword: Erosion, rainfall simulator, terminal velocity, uniform coefficient

INTRODUCTION

In erosion studies, the need for more control over the experiments brought about the rise of rainfall simulators by researchers especially when natural rainfall is the primary agent of erosion. (Horne, 2017). Thus, the use of artificial rainfall simulation has been long used to study rainfall effects on erosion and over the years, it has become a very effective technique for assessing particle detachment, soil erosion, overland flow and chemical runoff (Tossell *et al.*, 1987).

Over the years, researchers have proposed several types and designs of rainfall simulators and the main types are the drop-forming rainfall simulators (non-pressurized simulators) and the pressurized nozzle simulators (spray type) (Yusuf *et al.*, 2016). Rainfall simulators, with drop-forming mechanisms such as hypodermic needles and string to generate drops were the earliest types (Mutchler and Hermsmeier, 1965). Such rainfall simulators operated with no pressure in them, hence, the raindrops had to be released at heights as high as 9metres (30 feet) to attain terminal velocity before reaching the ground, thus, these constraints limited its use to outdoor laboratory experiments. As cited by Wilson *et al*., (2014), the drop-forming rainfall simulators usually require high elevation, 10 to 12metres of range to attain terminal velocity and they are not portable in nature. On the other hand, the pressurized nozzle rainfall simulators, just as the name imply, operate under a pressurized system and rely on sprinkler heads or nozzles to produce rain-like drops which have the ability to attain terminal velocity quicker, thereby allowing for a more portable simulator (Horne, 2017). The pressurized nozzle rainfall simulators are pointed out to consume more water because of the wide area of coverage while discharging water when compared to the drop-forming rainfall simulators (Yusuf *et al.*, 2016).

Since 1930s, over a 100 rainfall simulators have been developed, with plot dimensions ranging less than 5m^2 with most of them less than 1m^2, with differences in rainfall intensities, spatial rainfall distribution, design, drop sizes and velocities and of all these designs, there isn't any standard to it. (Iserloh *et al*., 2013.). Thus, the fundamental requirement is the accuracy of test conditions, in which, it is essentially interpreted, combined and classified. Iserloh *et al*., (2013) further stated that the critical and most important properties of a simulated rainfall are the drop size distribution (DSD), the fall velocities of the drops (drop velocity) and the spatial distribution of the rainfall on the plot-area. As cited by Yusuf *et al.*,(2016), rainfall intensity is one of the many rainfall characteristics that influences drop size ditribution,, with median drop size distribution to be estimated at 2.25mm for high intensity storm. It was further stated that there is a strong correlation between the drop velocity of the rainfall drops and rainfall drop sizes as presented on Table 1.

Table 1: Relationship between rainfall drop diameter and terminal velocity

Diameter (mm)	1	2	2.4	3	3.4	4	4.4	5
Terminal velocity (m/s)	4.03	6.49	7.27	8.06	8.44	8.83	8.98	9.09

Source: Olaoke (2012)

Uniform drop distribution of a rainfall simulator can be difficult to achieve because the pressurized nozzles of the simulators sacrifice uniformity to produce higher intensities (Horne, 2017). It was further stated that uniformity of drop distribution is dependent upon spacing, nozzle pressure and oscillation with more concentration spray occuring directly under the nozzle. (Paige *et al.*, 2003). Thus nozzles are spaced so that areas of less coverage from the nozzles are overlapped. The objective of this study was to design and construct a locally made rainfall simulator capable of producing rainfall similar to natural rain at different intensities under an acceptable coeffient of uniformity and drop velocity.

MATERIALS AND METHODS

Design Consideration of the Rainfall Simulator

According to Bansal (2003) and Douglas *et al.*, (2008) as cited in Yusuf *et al.*, (2017), the capacity of the discharge pump determines the inflow/outflow discharge of the rainfall simulator, so it is necessary for the properties of the simulator to be determined which will in turn help in the pump selection. The pump selection was based on the pumps available in the local market so as to carefully choose the right pump for the simulator. In the design of rainfall simulators, the mass flow rates, area, velocity of water to the main pipe, lateral and sub-lateral were determined using Eq.1a, 1b, 2, 3, 4 and 5 respectively while losses through the main, lateral and sub-lateral pipes of the simulator were determined using Equations 6, 7 and 8 respectively (Bansal, 2003 and Douglas *et al.* 2008);

Mass flow rates, Area and Velocity of water

$$m = \rho \text{ x } Q. (1a)$$

$$m = \rho \text{ x } V \text{ x } A. (1b)$$

$$A = \frac{\pi D^2}{4} (2)$$

$$V_m = \frac{m}{\rho \text{ x } A_m} \quad (3)$$

$$V_L = \frac{m}{\rho \text{ x } A_L} \quad (4)$$

$$V_s = \frac{m}{\rho \text{ x } A_s} \quad (5)$$

Where;

m = mass flow rate (kg/s),

ρ = density of water (kg/m^3)

Q = discharge of water (m^3/s)

D = internal diameter of the pipe (m)

A_m = area of the main-pipe (m^2)

A_L = area of the lateral (m^2)

A_S = area of the sub–lateral (m^2)
V_m = velocity of flow of water in the main–pipe (m/s)
V_L = velocity of flow of water in the lateral–pipe (m/s) and
V_S = velocity of flow of water in the sub–lateral pipe (m/s)

Losses through the Main, Lateral and Sub-lateral pipes

$$h_m = \frac{k_e V_m^2}{2g} \quad (6)$$

$$h_L = \frac{k_T V_L^2}{2g} \quad (7)$$

$$h_S = \frac{k_T V_s^2}{2g} \quad (8)$$

$$H_t = h_m + h_l + h_s \quad (9)$$

$$V = \sqrt{\frac{2gH_t}{k_T}} \quad (10)$$

Where;
h_m = Frictional head loss in the main-pipe (m)
h_L = head loss in the lateral (m)
h_s = head loss in the sub-lateral (m)
V_m = velocity of flow of water in the main-pipe (m/s)
V_L = velocity of flow of water in the lateral (m/s)
V_s = velocity of flow of water in the sub-lateral (m/s)
H_t = head loss in the simulator network pipe due to T – joints (m)
V = mean velocity of water dropping from the rainfall simulator to the ground surface (m/s) and g = acceleration due to gravity (m/s^2)
k_e = entry loss constant
k_T = T – joint loss constant
The values of constant k_e and k_T were 0.5 and 1.8 as given by Douglas *et al.* (2008).

Coefficient of Uniformity and Rainfall Intensity

To verify uniformity of drop distribution, Christensen's coefficient of uniformity is adopted (Christiansen, 1942; Horne, 2017 and Yusuf *et al.*, 2017) which is expressed in Eq. 11 while the average intensity of rainfall over the entire plot is express in Eq.12;

$$CU = 100 * (1 - \frac{\sum /x - \bar{x}/}{\sum x}) \quad (11)$$

$$i = \frac{\bar{x}_h}{A_s} \quad (12)$$

Where;
n = number of observation (containers used)
x = volume of water in each bucket (Litre)

$\bar{x}$ = mean volume of water in the bucket (Litre)

|x - $\bar{x}$| = absolute deviation.

Σx = summation of x

S.D = standard deviation

CU = coefficient of the uniformity

i = intensity of rainfall (mm/hr)

$\bar{x}_h$ = average volume of water falling on the ground surface under the entire area of rainfall simulator in hour (Litre/hr)

A_s = area coverage of the rainfall simulator

Rainfall Simulator Design

The constructed simulator functioned as a continuous sprinkler system with pressurized water (Figure 1). PVC pipes, shower roses of and pipe fittings were the main components used in the fabrication of the simulator and they are readily available in the local markets in Nigeria. The simulator is made up of the main-line pipe, lateral pipes and the sub-lateral pipes. The main-line pipe receiving water from the pump has an internal diameter of 0.0381m (3.81cm) and it covers a horizontal distance of 8m while the section connecting to the pump covers a vertical distance of approximately 1.7m. Two sides of the horizontal main-line have 5 holes each, at interval of 0.3m of each other where the laterals were connected to the mainline pipe with the help of a T–joint pipe and 0.4m from both side of the main-pipes. Each of the laterals have a diameter of 0.0254 m (2.54cm) and 2.0m long, with each of them having 5 holes of diameter 0.019m at interval of 0.3 m where the sub–lateral (distribution pipe) was connected to the lateral and 0.5m to the end of each lateral pipe. The distribution pipe was 0.0195m in diameter (1.95cm) which was 0.08m long fitted to the lateral with help of T–joint. The shower roses were of galvanized metal material, 90cm in diameter, each having 105 holes period. With each hole having an approximate diameter of 2mm and they are known to provide the simplest form of sprays under pressurize (Yusuf *et al.*, 2017). In which, each of it was fixed to each sub–lateral using adaptor, for easy removal, when required.

Figure 1: Development of Rain Simulator in Progress

A wooden frame, was used as the support for the simulator, upon which the operation was carried out as shown in Figure 4. The frame was made using 0.0508m x 0.0508m sized wood at a height of 1.65m and length and breadth of 2m with 0.3m of each leg buried into the ground to stand firmly.

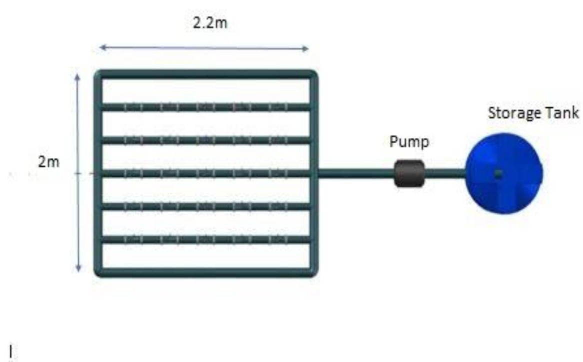

Figure 2: Aerial view of the rainfall simulator

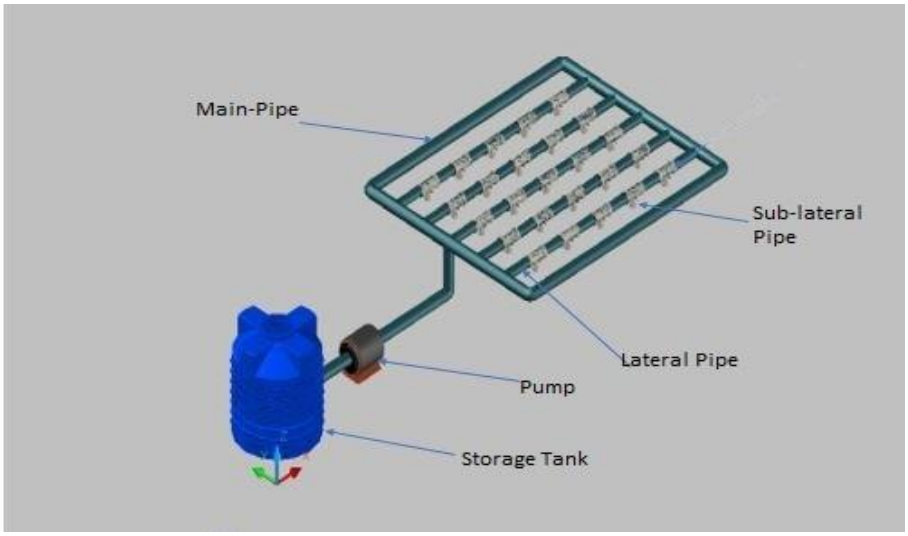

Figure 3: 3D View of the rainfall simulator

Figure 4: Rainfall simulator in operation

RESULTS AND DISCUSSIONS

Terminal Velocity and Head losses in the Pipes

Equations 3, 4 and 5 were used to determine the flow rate velocities in the main-line, laterals and sub-laterals respectively while equations 6, 7 and 8were used to determine the head losses of the respective pipes stated above. The Total head loss due to friction and the mean velocity (terminal velocity of discharge from the rainfall simulator to the ground) were determined using equations 9 and 10. Table 2 below presents the velocities, cross-sectional area and head losses of the various sections of the pipes.

Table 2: Estimated Total Head Loss and Terminal Velocity using a 60L/min Pump

Parameter	**Area (m^2)**	**Velocity (m/s)**	**Head loss (m)**
Main-Pipe	0.00114	0.877	0.022
Lateral	0.00051	1.973	0.181
Sub-lateral	0.00029	3.507	0.322
Total Head loss			0.525
Terminal Velocity		2.392	

The design results as presented in Table 2 shows that the rainfall simulator when connected to the pump with a 60L/min (use standard unit for this pls) maximum discharge would exhibit a total head loss of 0.525m and a terminal velocity of 2.392m/s which is far below the required terminal velocity for high intensity rainfall (Parsakhoo *et al.,* 2012; Gunn and Kinzer, 1987). This is as a result of the low capacity of the pump which also means that a bigger pump with higher discharge would be needed if the required terminal velocity is to be attained. Table 3 shows the estimated total head loss and terminal velocity for the rainfall simulator in connection to a 116.7L/min pump;

Table 3: Estimated Terminal Velocity and Total Head Loss using a 116.67L/min Pump (Fully opened)

Parameter	**Area (m2)**	**Velocity (m/s)**	**Head loss (m)**
Main-Pipe	0.00114	1.754	0.078
Lateral	0.00051	3.945	1.428
Sub-lateral	0.00029	7.014	4.514
Total Head loss			6.020
Mean Velocity		8.101	

Table 3 presents the result of the rainfall simulator when connected to a pump with a 116.7L/min maximum discharge rate. A total head loss of 6.02m and a terminal velocity of 8.101m/s which slightly surpasses the required terminal velocity for high intensity rainfall was observed (Parsakhoo *et al*. 2012; Gunn and Kinzer, 1989). This is as a result of the high capacity of the pump to apply adequate pressure to attain the required terminal velocity needed. It was also noted that the total head loss of the rainfall simulator using a 116.7L/min pump in Table 3 increased more than ten times that of the total head loss in Table 2, this shows the high sensitivity of the rainfall simulator to change in flow rate of the system. In view of all analysis, the 116.7L/min capacity pump was selected to be used with the rainfall simulator.

The rainfall simulator was designed with a control valve close to the pump for throttling, so as to be able to control the inflow of water into the rainfall simulator and in turn control the spray water from the shower roses. That way, the varying of the rainfall intensity from rainfall simulator can be achieved. For the sake of this experiment, the rainfall simulator was calibrated for two distinct rainfall intensities, and they were achieved by;

a) Fully opening the control valve for maximum intensity.
b) Partially opening the valve (half way) for minimum intensity.

Table 4: Estimated Terminal Velocity and Total Head Loss for 116.67L/min Pump when partially opened valve (half way)

Parameter	**Area (m2)**	**Velocity (m/s)**	**Head loss (m)**
Main-Pipe	0.00114	1.754	0.045
Lateral	0.00051	1.973	0.181
Sub-lateral	0.00029	3.507	0.322
Total Head loss			1.564
Mean Velocity		2.443	

The results in Table 4 reveals that the rainfall simulator, when operated with the valve partially opened (half way) would have a total head loss of 1.564m and a terminal velocity of 2.443m/s. This correlates to drop size of light stratiform rain type between 0.5mm – 2.0mm as seen in Table 5below.

Table 5. Tabular relationship showing rain types, drop sizes and their respective terminal velocity

Rain Type	**Sizes of drop**		**Terminal Velocity**	
	mm	*in*	*m/s*	*miles/hr*
Light Stratiform Rain (.04" per hour)				
Smaill Drop	0.5	0.02	2.06	4.06
Large Drop	2	0.08	6.49	14.4
Moderate Stratiform Rain (.25" per hour)				
Small Drop	1	0.04	4.03	8.9
Large Drop	2.6	0.1	7.57	16.1
Heavy Thundershower (1.0" per hour)				
Small Drop	1.2	0.05	4.64	10.3
Large Drop	4	0.16	8.83	19.6

Largest Possible Drop	5	0.2	9.09	20.2
Hailstone	10	0.4	10	22.2
Hailstone	40	1.6	20	44.4

Source: (Horstmeyer, 2008)

Experimental Coefficient Uniformity and Rainfall Intensity

In the determination of coefficient of uniformity, five buckets (3Litres capacity each) were randomly placed under the rainfall simulator and the rainfall simulator was activated for 60 seconds as shown in Fig 5. The volume from each bucket were measured using a measuring cylinder and recorded. After each successful experiment, the buckets were randomly rotated before the next experiment. This experiment was repeated fifty times at maximum and minimum intensity each and the coefficient of uniformity and rainfall intensity was estimated as shown in Table 6a and 6b below;

Figure 5: Buckets randomly placed under the simulator for determination of uniformity coefficient

Table 6a: Volume of water in each tagged bucket after each experimental run at maximum intensity

RUNS	Bucket Tags	Vol (litre)	$\bar{x}$	$x - \bar{x}$	$/x - \bar{x}/$	$(x - \bar{x})^2$
1	B1	2.50	2.12	0.38	0.38	0.14
	B2	2.15	2.12	0.03	0.03	0.00
	B3	2.61	2.12	0.49	0.49	0.24
	B4	1.98	2.12	-0.14	0.14	0.02
	B5	2.06	2.12	-0.06	0.06	0.00
2	B1	2.95	2.12	0.83	0.83	0.70

	B2	1.25	2.12	-0.87	0.87	0.76
	B3	1.12	2.12	-1.00	1.00	1.00
	B4	3.01	2.12	0.89	0.89	0.79
	B5	1.80	2.12	-0.32	0.32	0.10
3	B1	1.98	2.12	-0.14	0.14	0.02
	B2	2.90	2.12	0.78	0.78	0.61
	B3	2.40	2.12	0.28	0.28	0.08
	B4	1.36	2.12	-0.76	0.76	0.58
	B5	2.37	2.12	0.25	0.25	0.06
4	B1	2.07	2.12	-0.05	0.05	0.00
	B2	2.26	2.12	0.14	0.14	0.02
	B3	3.10	2.12	0.98	0.98	0.96
	B4	2.99	2.12	0.87	0.87	0.76
	B5	1.73	2.12	-0.39	0.39	0.16
5	B1	2.06	2.12	-0.06	0.06	0.00
	B2	1.41	2.12	-0.71	0.71	0.50
	B3	2.75	2.12	0.63	0.63	0.40
	B4	1.58	2.12	-0.54	0.54	0.29
	B5	2.77	2.12	0.65	0.65	0.42
6	B1	2.00	2.12	-0.12	0.12	0.01
	B2	1.58	2.12	-0.54	0.54	0.29
	B3	1.88	2.12	-0.24	0.24	0.06
	B4	2.46	2.12	0.34	0.34	0.12
	B5	2.48	2.12	0.36	0.36	0.13
7	B1	1.87	2.12	-0.25	0.25	0.06
	B2	2.57	2.12	0.45	0.45	0.20
	B3	1.60	2.12	-0.52	0.52	0.27
	B4	1.52	2.12	-0.60	0.60	0.36
	B5	2.25	2.12	0.13	0.13	0.02
8	B1	2.46	2.12	0.34	0.34	0.12
	B2	1.76	2.12	-0.36	0.36	0.13
	B3	1.89	2.12	-0.23	0.23	0.05
	B4	1.67	2.12	-0.45	0.45	0.20
	B5	1.27	2.12	-0.85	0.85	0.73
9	B1	3.27	2.12	1.15	1.15	1.31

	B2	2.07	2.12	-0.05	0.05	0.00
	B3	2.53	2.12	0.41	0.41	0.17
	B4	1.89	2.12	-0.23	0.23	0.05
	B5	1.71	2.12	-0.41	0.41	0.17
10	B1	1.73	2.12	-0.39	0.39	0.16
	B2	1.76	2.12	-0.36	0.36	0.13
	B3	2.15	2.12	0.03	0.03	0.00
	B4	2.09	2.12	-0.03	0.03	0.00
	B5	2.37	2.12	0.25	0.25	0.06
	Total	105.96			21.34	13.43
	Mean	2.12			0.43	

Table 6b: Volume of water in each tagged bucket after each experimental run at minimum intensity

RUNS	Bucket Tags	Vol (litre)	$\bar{x}$	$x - \bar{x}$	$/x - \bar{x}/$	$(x - \bar{x})^2$
1	B1	1.23	1.072	0.16	0.16	0.02
	B2	1.03	1.072	-0.04	0.04	0.00
	B3	1.36	1.072	0.29	0.29	0.08
	B4	1.05	1.072	-0.03	0.03	0.00
	B5	0.99	1.072	-0.08	0.08	0.01
2	B1	1.39	1.072	0.32	0.32	0.10
	B2	0.61	1.072	-0.47	0.47	0.22
	B3	0.59	1.072	-0.48	0.48	0.23
	B4	1.49	1.072	0.41	0.41	0.17
	B5	0.92	1.072	-0.15	0.15	0.02
3	B1	1.03	1.072	-0.04	0.04	0.00
	B2	1.50	1.072	0.43	0.43	0.19
	B3	1.17	1.072	0.10	0.10	0.01
	B4	0.68	1.072	-0.39	0.39	0.15
	B5	1.25	1.072	0.18	0.18	0.03
4	B1	1.05	1.072	-0.03	0.03	0.00
	B2	1.16	1.072	0.08	0.08	0.01

	B3	1.47	1.072	0.40	0.40	0.16
	B4	1.52	1.072	0.45	0.45	0.20
	B5	0.77	1.072	-0.30	0.30	0.09
5	B1	1.00	1.072	-0.07	0.07	0.00
	B2	0.57	1.072	-0.51	0.51	0.26
	B3	1.31	1.072	0.23	0.23	0.05
	B4	0.84	1.072	-0.23	0.23	0.05
	B5	1.49	1.072	0.42	0.42	0.18
6	B1	1.25	1.072	0.18	0.18	0.03
	B2	0.66	1.072	-0.41	0.41	0.17
	B3	1.12	1.072	0.05	0.05	0.00
	B4	1.24	1.072	0.17	0.17	0.03
	B5	1.28	1.072	0.21	0.21	0.04
7	B1	0.87	1.072	-0.20	0.20	0.04
	B2	1.42	1.072	0.35	0.35	0.12
	B3	0.81	1.072	-0.26	0.26	0.07
	B4	0.82	1.072	-0.25	0.25	0.06
	B5	1.22	1.072	0.15	0.15	0.02
8	B1	1.35	1.072	0.27	0.27	0.07
	B2	1.00	1.072	-0.07	0.07	0.00
	B3	0.87	1.072	-0.20	0.20	0.04
	B4	0.82	1.072	-0.25	0.25	0.06
	B5	0.55	1.072	-0.53	0.53	0.28
9	B1	1.63	1.072	0.56	0.56	0.31
	B2	1.11	1.072	0.04	0.04	0.00
	B3	1.18	1.072	0.11	0.11	0.01
	B4	1.16	1.072	0.09	0.09	0.01
	B5	0.76	1.072	-0.31	0.31	0.10
10	B1	0.91	1.072	-0.17	0.17	0.03
	B2	0.77	1.072	-0.30	0.30	0.09
	B3	1.19	1.072	0.12	0.12	0.01
	B4	0.97	1.072	-0.10	0.10	0.01
	B5	1.21	1.072	0.14	0.14	0.02
	Total	53.61			11.78	3.90

Mean	1.072	0.24

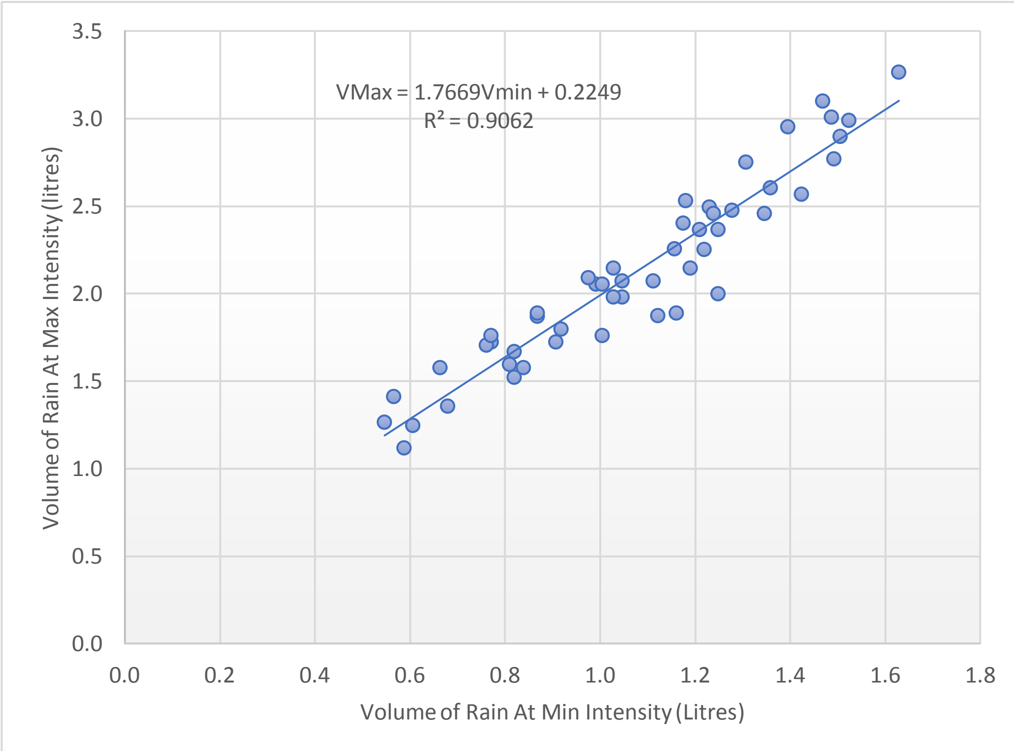

Figure 6: Volume of Rainfall (Maximum Intensity Vs Minimum Intensity)

Table 7: Characteristics of the Rain Simulator at Both Maximum and Minimum Intensity

Flowrate	**At Max. Intensity**	**At Min. Intensity**
Coefficient of Uniformity CU (%)	79.86	78.03
Standard Deviation	0.82	0.44
Area (m^2)	4.00	4.00
Average Intensity (mm/hr)	31.79	16.08
Kinetic Energy ($J/m^2/mm$)	26.07	22.23
Erosivity Index R (MJ mm ha^{-1} h^{-1})	1278.63	543.46

The coefficient of uniformity at maximum intensity was found to be 79.86% and that at minimum intensity was found to be 78.03% as seen in Table 7, with both values within the accepted range of 68.3 to 82.2% for a rainfall simulator as stated by Junior and Siqueira (2011). This confirms that the shower roses, sprinkles water at good spacing between themselves, providing a good coverage on the ground. The coefficient of uniformity (CU) when the rainfall simulator was operated at maximum intensity was seen to be higher than when it was operated at minimum intensity but with little variation between the two values, this can also be confirmed in Fig 6, where the correlation coefficient between rainfall volume, maximum and minimum intensity were found to be $R^2 = 0.9062$ and a linear relationship of $V_{max} = 1.7669V_{min} + 0.2249$ was obtained. This means that the rainfall simulation at both maximum and minimum intensity satisfy the required coefficient of uniformity (CU) needed for operation.

CONCLUSIONS

The locally made rainfall simulator described in this work was able to attain the desired rainfall intensities with the help of the control valve. With its simplicity and cost effectiveness, it can be said that, this rainfall simulator is suitable for erosion studies within the environment of study.

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EFFECT OF LAND MANAGEMENT USE ON SOIL HYDRAULIC CONDUCTIVITY IN GIDAN KWANO, NIGER STATE

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ABSTRACT

Hydraulic conductivity is one of the most important parameters for flow and transport related phenomena in soil and also a criterion for measuring soil ability to transfer water. There is concern arising from the suitability, efficiency and ease of the different measuring methods use under different land management practices. The purpose of this paper is to determine and evaluate soil hydraulic conductivity under different land management practices which include forest land (teak and Melina plantation), grass land and maize cultivated land using constant head method. The measurement is at different depth of 0-15cm, 15-25cm, 25-50cm, 50-75cm. The marginal means of each land use were used to compare the result obtained through statistical means. All tests were carried out using SPSS at significance level of 0.05. An ANOVA test was conducted to check if each of the land use is significantly different. The soil in forest zone (Teak plantation and Gmalina plantation) had significantly high bulk density as 1.7533cm^{-3} and 1.6967cm^{-3} respectively at depth 50-75cm compared to the low bulk density in grass, maize cultivated land as 1.5000cm^{-3} and 1.4833cm^{-3} respectively at depth 50-75cm. However, soil hydraulic conductivity was significantly high in the grass site or soil at the surface with 2.8833cmh^{-1}. Results obtained from the different land use serve as Knowledge of variability of soil that can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects.

Keyword: soil hydraulic conductivity, bulk density, porosity and land management practices

1.0 INTRODUCTION

1.1 Background to the study

The hydraulic conductivity of soil is an important hydraulic property frequently used in hydrological modeling and water flow related studies in soils, such as irrigation and drainage system design and infiltration modeling, it is also a key parameters for the monitoring of soil and water management (Tayfun, 2005). Knowledge of the rate of water permeability through various soil types is essential for determining the type of plants to be grown, spacing, yield, managing soil

– water systems and erosion control. Many methods have been developed over time for field and laboratory measurement for hydraulic conductivity unfortunately, these methods often yield substantially dissimilar results, as hydraulic conductivity is extremely sensitive to sample size, flow geometry and soil characteristics (Sarki *et al*, 2014). Research has shown that regardless of the land management practices, a small portion of soil can be transported by a large portion of water flow, indicating that the spatial hydraulic characteristics of soils are highly variable (Ibrahim and Aliyu, 2016). Knowledge of variability of soil physical properties can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects (Bagarello and Sgroi, 2004).

Several studies have been conducted on soil hydraulic properties in relation to tillage and the results were contradictory. Depending on cultivation history, climate zone, and soil management practices, saturated and unsaturated hydraulic conductivity under no-till or minimum tillage can either be greater or lower (Miller *et al*., 1998) than that under continuously tilled treatments, or not significantly different from that under continuously tilled treatments (Bodhinayake, 2003). Change in land use from natural forest to crop cultivation modified the hydraulic properties of the surface soil resulting in an increased runoff/infiltration ratio (Leduc *et al*., 2001). Land use change is a complex process shaped by human activity affected by ecological, economic, and social drivers, and capable of influencing a wide range of environmental and economic conditions (MacDonald, *et al*., 2000).

Understanding of soil hydraulic conductivity is also essential for sound land management. Therefore, there are no single value that represent soil hydraulic conductivity because it varies in a wide range of circumstances and for all soil types and some of the specific problems that instigate the need of this kind of study which may be due to lack of suitability of the soil hydraulic conductivity and their acceptability in the study locations. Information relating to hydraulic conductivity of the studied sites is dearth.

Based on the above statement, the major objective of this study is to determine hydraulic conductivity of soil under different land management practices and also compare various results obtained from the study areas.

MATERIALS AND METHODS

2.1 Materials

2.1.1 Study Region

The host community of Federal University of Technology Minna Gidan Kwano is located along Minna - Bida road and is approximately 12 km from the state capital, Minna. Gidan Kwano lies between Latitudes 9°31'N and Longitudes 6°26'E with an estimated land mass of about eighteen thousand nine hundred hectares (18,900 ha). Teak plantation and Gmelina land is at latitudes and longitudes 9°31'1"N, 6°27'30"E and 9°30'55"N, 6°27'28"E respectively while Grass land and Maize cultivated land is at 9°31'55"N, 6°27'23"E, 9°31'55"N, 6°27'39"E respectively. The site is bounded Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga (Musa, *et al.,* 2013). Four locations were selected to perform the experiment, which include forest sites (Teak and Gmelina plantations), grass land (fallow) and maize cultivated land. Measurement of soil hydraulic conductivity was determined at four depths of 0-15cm, 15-25cm, 25-50cm and 50-75cm for each of the study locations.

2.1.2 Laboratory Analysis

Particle size analyses were determined by hydrometer method according to the procedure of Gee and Or, 2002) using sodium hexameta phosphate (calgon) as dispersant. Soil bulk densities were determined using core method described by (Fasinmirin and Adesigbin, 2011). Soil samples were taken from soil core at depths 0-15cm, 15-25cm, 25-50cm and 50-75cm on each location of the land use using ring cylinders with height 5.1cm and diameter 5cm (Gabriel and Cornelis, 2008). Porosity was determined for each sample collected from the study area (Knutsson and Morfeldt, 2002). Porosity of the soil was calculated from bulk density and particle density was assumed to be 2.65 mg/m^3(Suzuki *et al.,*2004). The hydraulic conductivity of soil was carryout according to the guideline of Akanegbu, (2013).

2.2.3 Statistical analysis

To compare various results obtained from different land management practices for the study areas, statistical test was carried out using SPSS and tests are conducted at significance level of 0.05. For each of the location or different land management practices, the mean and standard deviation were calculated. Statistical test was conducted to check if each of the locations is significantly different. Marginal means of hydraulic conductivity, bulk density and porosity was use to compare the land use through multiple comparison.

3.0 RESULTS AND DISCUSSIONS

3.1 Results of soil aggregate

The soil aggregate for the various study locations were determined and the result presented in Table 1. It was observed that there was a gradual increment of sand particle for 0-15cm depth to 50-75cm depth which could be as a result of the decaying plant properties as this is within the root zone of crops.

Sandy soil is the most predominant soil in the study areas and these are easily detached but hard to transport while clayey soil is hard to detach but easily transported if finally detached. This reveals that the actual percentage of sand in any soil sample determines to a great extent the saturated hydraulic conductivity of that particular soil (Odumeke, 2014).

Table 1: soil textural classification of the forest (Teak and Gmalinaplantation) land, Grass land and Maize cultivated land

Study location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	USDA Textural class
Teak plantation					
	0-15	60	12	28	sandy clay loam
	15-25	50	8	42	sandy clay
	25-50	65	10	25	sandy clay loam
	50-75	68	12	20	sandy loam
Gmalina plantation	0-15	72	10	18	sandy loam
	15-25	62	18	20	sandy clay loam
	25-50	72	8	20	sandy clay loam
	50-75	65	17	18	sandy clay
Grass land	0-15	65	15	20	sandy clay loam
	15-25	60	22	18	sandy loam
	25-50	58	20	22	sandy loam
	50-75	55	23	22	sandy clay loam
Maize cultivated land	0-15	72	17	11	sandy loam
	15-25	70	17	13	sandy loam
	25-50	65	22	13	sandy loam
	50-75	60	18	22	sandy clay loam

Table 1 above shows the result of particle size composition of the collected soil samples. Teak plantation land shows a little variation in the percentages of sand, silt, and clay among the collected soil samples. According to the USDA classification system, the soil samples collected at the 0-15cm, 25-50cm depth of teak plantation land are predominantly Sandy clay loam while those of 15-25cm and 50-75cm depth are sandy clay and sandy loam. The highest value of sand is 68% at depth 50-75cm it also have the lowest percentage of clay at the same depth of 50-75cm and this is in line with research work on manure teak plantation by Fernández-Moya *et al*., (2013). Results from table 1 was observed also from gmalina plantation that at depth 0-15cm and 25cm-50cm there is same percentage of sand content which was also observed in the studying of Fernández-Moya *et al*., (2013). From the results obtained from grass land it shows that sand contents has the highest value of 65% of sand at depth 0-15cm and it has the lowest value of silt content as 15% in the study area of grass plantation. At depth 25-50cm and 50-75cm of grass land the clay content remain the same. The results obtained from maize cultivated land shows that at depth 0-15cm, 15-25cm, and 25-50 the soil samples collected are predominantly sandy loam while that of depth 50-75cm are sandy clay loam. The results obtained from soil textural classification throughout the land use are predominantly having high percentage of sand particles which is similar to the works of Olorunfemi and Fasinmirin, (2011) and also recorded a high percentage of sand particles throughout their study but the values obtained from their study were observed to be lower when compare with values from this study location. This could be linked to the fact that there study location is in the forest zone where they experience high amount of rainfall compared to this study location.

3.2 Statistical results of bulk density, porosity and soil hydraulic conductivity

From the table 2 it shows that soil bulk density value for teak plantation land was observed to be highest at depth 50-75cm with little porosity of 22.96% which means the soil is too compacted and there is no record of soil hydraulic conductivity at the depth. Also the lowest soil bulk density is at the surface i.e depth 0-15cm which is almost in line with Ajibola *et al.*, (2018) and it has the highest hydraulic conductivity at same depth. It was also observed that soil hydraulic conductivity decreases from the surface to the bottom i.e from 0-15cm to 50-75cm. These values from teak plantation site in table were much lower than those found by Rubio *et al.*, (2005).

Table: 2 selected physical properties of the various study locations with their mean and deviation

Location		ρ_b **(gcm^{-3})**	P **(%)**	K_{sat} **(cmh^{-1})**
Teak plantation				
	0-15	1.4067±0.01528	46.92±0.576	0.0006±0.00003
	15-25	1.5000±0.02000	43.40±0.755	0.0001±0.00002
	25-50	1.6200±0.02646	38.87±0.996	0.0005±0.00004
	50-75	1.7533±0.02517	33.84±0.951	0.000±0.00000
Gmalina plantation				
	0-15	1.5667±0.06658	42.39±0.785	0.0014±0.00040
	15-25	1.5867±0.10693	42.01±0.433	0.0014±0.00010
	25-50	1.6067±0.06658	39.24±1.000	0.0003±0.00004
	50-75	1.6967±0.06506	36.48±0.951	0.0000±0.00000
Grass land				
	0-15	1.3000±0.01732	50.94±0.652	2.8833±0.02082

	15-25	1.3533±0.02082	48.93±0.785	1.4767±0.03215
	25-50	1.3533±0.03055	48.93±1.155	1.5033±0.01528
	50-75	1.5000±0.02000	43.40±0.755	1.3833±0.02082
Maize cultivated land				
	0-15	1.2967±0.03786	51.07±1.433	1.2200±0.02000
	15-25	1.3533±0.01155	48.93±0.433	1.1533±0.02887
	25-50	1.3533±0.03055	48.93±1.155	1.1133±0.02517
	50-75	1.4833±0.02082	44.03±0.787	0.9767±0.07767

Where ρ_b = soil bulk density, P = porosity, K_{sat} = soil hydraulic conductivity.

Gmelina plantation shows that soil bulk density increases from the surface to the bottom i.e from 0-15cm to 50-75cm. This is an indication that the soil is compacted down the soil profile for the study area. At 0-15 and 15-25cm depth the bulk density is almost the same with a recorded porosity of 42.26 and 41.87% respectively. This is almost in line with Ajibola *et al.,* (2018). The bulk density value obtained almost same with one found by Uloma *et al.,* (2013). The grass land in table 2 shows that the bulk density at 50-75cm depth was 1.50gcm^{-3} and it's in line with a research work carried out by Uloma *et al.,* (2013). The result obtained from the grass land show some variation down the profile and these changes down the profile is also in line with the work of Rubio *et al.,* (2005) due to these variations of soil bulk density, It can stated that soil bulk density is one of the major soil property that affect soil hydraulic conductivity. Soil hydraulic conductivity at 0-15cm record the highest value due to low soil bulk density at the profile. The results from maize cultivated land in table 2 indicates that the soil bulk density at 15-25cm and 25-50cm is same and the soil hydraulic conductivity at that depth varies by small value. At depth 50-75cm the soil hydraulic conductivity was lowest this could be as a result of high bulk density at the region. The highest value of soil hydraulic conductivity from maize cultivated land in table 2 was recorded at 0-15cm depth.

The saturated hydraulic conductivity varied at different locations. This confirms spatial variation of hydraulic conductivity as reported by other researchers (Rubio *et al.,* 2005). This variation was also further confirmed by the statistical difference shown by other properties of soil determined which include porosity and bulk density. It was also noted that locations with same soil textural class had different values of soil hydraulic conductivity. This is in line with report of Ritzema, (2006) that soils of identical texture may have different soil hydraulic conductivity values due to differences in structure.

Table 3 shows the comparative levels of significance of the various physical properties for the various study location

Location		Mean bulk density	Mean hydraulic conductivity	Mean porosity
TP				
	GP	-0.0192ns	-0.0005ns	0.73ns
	GS	0.1933*	-0.0192*	-7.29*
	MS	0.1983*	-1.1155*	-0.748*
GP				
	TP	0.0192ns	0.0005ns	0.73ns
	GS	0.2125*	-1.8109*	-8.02*
	MS	0.2175*	-1.1151*	-8.21*
GS				
	TP	-0.1933*	1.8114*	7.29*
	GP	-0.2125*	1.8109*	8.02*
	MS	0.005ns	0.6958*	-0.19ns
MS				
	TP	-0.1983*	1.1155*	7.48*
	GP	-0.2175*	1.1151*	8.21*
	GS	-0.005ns	-0.6958*	0.19ns

* = The mean difference is significant at the .05 level, ns = the mean difference not significant at the 0.05 level

Where TP = Teak plantation site, GP = Gmelina plantation site, GS = Grass site, MS = cultivated land

The subjected result to statistical analysis test in table 3 shows that the hydraulic conductivity, bulk density and porosity of teak plantation site shows that there is no significant difference between the teak plantation site and gmelina plantation site at 0.05 level but there is significant difference between teak plantation site and (grass, maize site), which means that bulk density, porosity and hydraulic conductivity has no effect on teak plantation and gmelina plantation site. Table 3 also shows that there is no significant difference between grass and maize cultivated land for bulk density and porosity but has significant difference on teak and gmelina plantation site.

4.0 CONCLUSIONS

The results obtained have shown that saturated hydraulic conductivity varied at different locations. This variation was also further confirmed by the statistical difference shown by other properties of soil determined which include porosity and bulk density. It was also noted that locations with same soil textural class had different values of soil hydraulic conductivity.

The study further reveals the significant differences in the soil of four land uses in Gidan Kwono, Minna Nigeria. The soil hydraulic conductivity is strongly compared to bulk density and porosity. The soil in forest zone (Teak plantation and Gmalina plantation) had significantly high bulk density as compared to the low bulk density in grass, maize, beans and yam sites. However, soil hydraulic conductivity was significantly high in the grass site or soil. Soil hydraulic conductivity is highly dependent on soil texture, soil bulk density and porosity. Results shows that soil bulk density and porosity, affect soil hydraulic conductivity of soils of the study areas. Results obtained from the different land use serve as Knowledge of variability of soil that can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects. Finally, results of the experiment revealed that soil hydraulic conductivity vary considerably among land uses. Saturated hydraulic conductivity was higher in grasslands than other land use. Improvement on this study could be done through expansion of area of studied and increasing the number of samples and measurements since a soil are highly heterogeneous and tends to vary from point to point even at the same layer.

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PERFORMANCE ASSESSMENT OF SELECTED IRRIGATION SCHEMES IN NIGER STATE USING COMPARATIVE INDICATORS

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Abstract

The study was carried out to evaluate the performance of selected irrigation Scheme in Niger State using various indicators such as output per unit cropped area and water consumed, related to production with land and water, relative irrigation supply (RIS) related to water supply from the system with crop water demand and financial self-sufficiency (FSS) related with collection of fees from water users in the command area. In this study, the performance indicators for the schemes were determined for year 2013-17. The analysis of agricultural performance indicators showed that the production value of different crops grown in command area were fluctuating upwards and downwards signifying inconsistency in management of the schemes. The analysis of water use indicators showed that not all water released from the reservoir get to the command area due to damage of the distribution canals and some of the canals have been overgrown by weeds thereby making the canal capacity insufficient to meet the peak consumptive requirement. The analysis of economic or financial indicators showed that the scheme had a serious problem about the collection of water fees i.e. revenue or irrigation charges collected from scheme were less than that of total operation and maintenance expenditures.

Keywords: command area, irrigation project, performance indicators, relative irrigation supply.

Introduction

Water resources are renewable but are limited in supply are limited. In order to therefore acquire highest efficiency from existing resources, it is necessary to make use of the resources concerned. Efficient use of limited water resources, especially for agricultural irrigation, will both enhance producer’s yield per unit of water and will protect environment from problems of excess water like flash flood and bilharzia. Many developing nations may face insufficient water resources to satisfy their agricultural, domestic, industrial and environmental water demands within the next two decades (Asfaw and Admassie, 2004). The world population is forecasted to grow by about 30% by the year 2024, reaching 8 billion people (Cakmak*et al*., 2004). This means competition among the agricultural, industrial, domestic and other users will increase in unprecedented levels. Therefore, water management in irrigated agriculture is important in meeting the food requirement of the increasing world population (Takeshi and Abdelhadi, 2003).

Irrigation is important in terms of agricultural production and food supply, the incomes of rural people and public investment for rural development. Yet dissatisfaction with the performance of irrigation projects in developing countries is widespread. Despite their promise as engines of agricultural growth, irrigation projects typically perform far below their potential (Small and Svendsen, 1992). A large part of low performance may be due to inadequate water management at system and field level, poor structural maintenance and failure to stick to design specifications during construction. (Cakmak*et al*., 2004).

To complement a rain-dependent farming system, irrigated agriculture was thought to be one of the solutions to enhance food security in the country. Since its initial promotion, irrigated agriculture in Nigeria still comprises a small fraction of total cultivated area; water development by constructing small earthen dams in the country is believed to bring changes in the way of life of the local communities in the area. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource-water if they are mismanaged. Performance evaluation of irrigation projects is not common in the country.

Niger State has made tremendous progress in development of its irrigation potential. However, only about two-third of the created irrigation system is actually being utilized and overall project irrigation efficiencies are very poor. Though, applying water to crop through irrigation increases yield and production in agriculture, inappropriate management of irrigation schemes might lead to environmental problems such as a high water table and poor drainage and thus salinization and pollution in addition to low quality of water. The performance of many agriculture systems is significantly below their potential due to number of shortcomings, such as poor design, construction, operation and maintenance. The system performance, agricultural productivity and financial aspects are the domain provides an idea about performance indicators. The system performance providing facility of water for irrigation and other purposes. The water distribution system is influenced by physical, climatic, economic and other factors. The prevailing climatic condition largely determines both, the available water resources and the crop water requirements in any season.

The agricultural productivity shows that, in Niger State, more than 85 percent population depends on agriculture, thus production per unit area as well as per unit water is vital for state's economy. Government has intervened by coming up with irrigation schemes through construction of about ten earth dams across the state but record has shown that none of the schemes has been utilized to maximum capacity. Adequate records are however lacking to ascertain the optimum and current performance of these irrigation schemes. Also, Lack of knowledge and tools used to assess the performance of projects adds to the problem. There is therefore a need to conduct a holistic performance assessment of these irrigation schemes using standard indicators with a view to recommending appropriate measures to improve their performance. This study is therefore carried out to evaluate the performance of three, Tungan-kawo, Kontagora and Lapai/Agaiesmall scale irrigation schemes in Niger State.

Materials and Methods

There are ten irrigation schemes in Niger state (Figure 1). However, this study will be limited to carrying out performance evaluation of three of them. These include Wushishi, Lapai, and Kontagora local government areas.

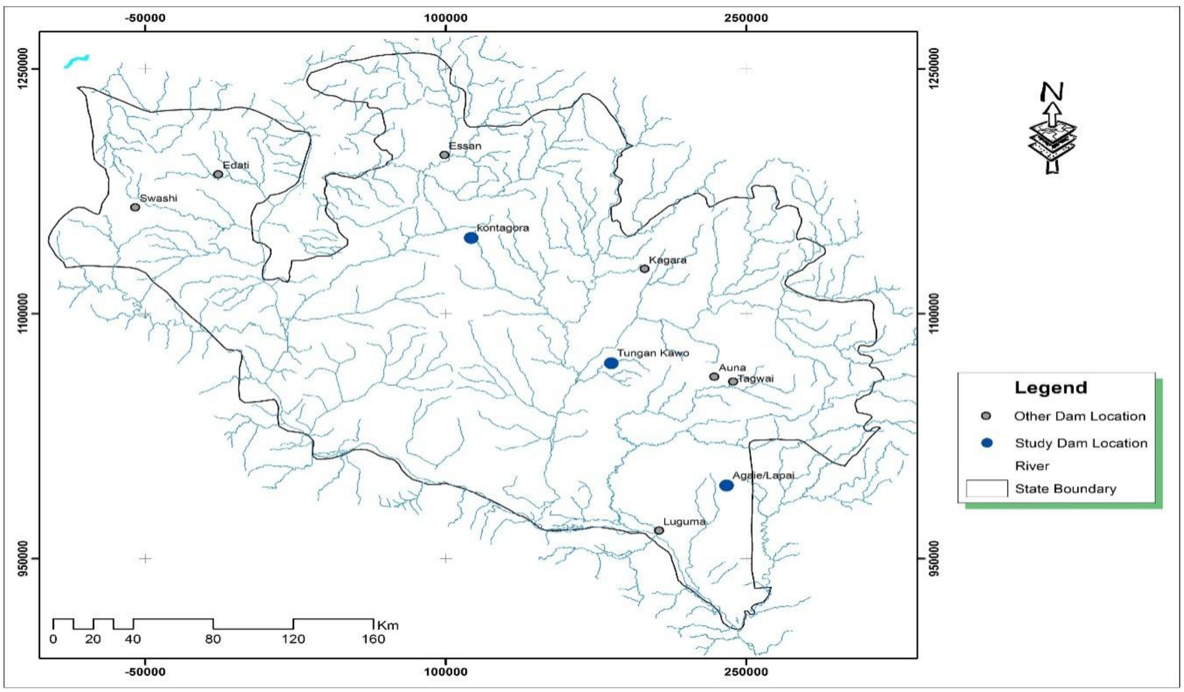

Figure 1: Existing Agricultural Dams in Niger State and the Study Area.

These dams have contributed to national income, and to the communities involved. The main aim of these dams is for crop irrigation and fishing. TungaKawo Irrigation dam was constructed in 1988 and located about 7.5 km from Wushishi town. It has a dam height of 11.75m, width of 6 m with a length of 3.3km. It has a design capacity of $23x10^6m^3$covering a land area of average of $900m^2$. It has presently employed a total of 264 people. Kontagora Irrigation dam was constructed in 1991 and located about 4.5 km along Kontagora – Yahuri road in Kontagora Local Government of Niger state. It has a dam height of 20m, width of 4 m with a length of 1km. It has a design capacity of $1.77x10^6m^3$covering a land area of average of $105m^2$ and has presently employed a total of 105 people. Lapai/ Agaie Irrigation dam was constructed in 2004 and located at about 6 km from Paiko town along Paiko – Lapai road in Paikoro Local Government of Niger State. It has a dam height of 16 m, width of 6.9 m with a length of 1.2 km. It has a design capacity of 2.8 $x10^6 m^3$covering a land area of average of $600m^2$. It has presently employed a total of 495 people.

Data collection

For the study some necessary data were collected from Upper Niger River Basin Development Authority office. Sites of the Dams were visited and discussions also made with farmers to affirm the secondary data obtained. Data collected includes production, price of crops, area irrigated, cropping pattern, amount of water harvested and climatic data. The same data were also collected using questionnaire surveys from the water users (10% of the total water users). The questionnaires also were made to get the perception of the farmers about the water distribution within the project. The Secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production cost per season or per year, and cropping pattern. Climatic data of each irrigation projects were collected from the nearby weather stations established by National meteorological agency for the purpose of monitoring weather for the dams.

Water use performance- Two types of indicators, relative water supply (RWS) and relative irrigation supply (RIS) were used for evaluation of water use performance:

$$\mathrm{Re}\,lative\,water\,\mathrm{sup}\,ply = \frac{total\,water\,\mathrm{sup}\,lied}{crop\,water\,demand} \qquad \text{(i)}$$

$$\mathrm{Re}\,lative\,irrigation\,\mathrm{sup}\,ply = \frac{irrigation\,\mathrm{sup}\,lied}{irrigation\,demand} \qquad \text{(ii)}$$

where, total water apply (m^3) is diverted water for irrigation plus rainfall, crop water demand (m^3) is the potential crop evapotranspiration (ETp), or the real evapotranspiration (ETc) when full crop water requirement is satisfied. Irrigation supply (m^3) is surface diversions and net groundwater drafts for irrigation, irrigation demand (m^3) is the crop ET minus effective rainfall. Irrigation requirement and net crop water requirement calculated by Cropwat 8 program (FAO, 1992). The reference evapotranspiration (ETo) is calculated on a monthly basis using the Penman-Monteith (Allen et al., 1998). The monthly value of effective rainfall (Pe) was calculated using the US Bureau of Reclamation's method (Smith, 1992). RWS and RIS values indicate whether there is an adequate supply done or not to cover the demand.

Physical performance- Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. It was calculated using the following parameters:

Cropping intensity- is an indicator used to assess the degree to which irrigated crops are grown in the command area. It is determined as:

$$Cropping\,intensity = \frac{annually\,cropped\,area}{cultivable\,area} \quad \text{(iii)}$$

$$Irrigation\,ratio = \frac{irrigated\,land}{irrigable\,land} \quad \text{(iv)}$$

$$Sustainabilty\,of\,irrigable\,land = \frac{irrigated\,land}{initial\,irrigated\,land} \quad \text{(v)}$$

Where, irrigated land (ha) refers to the portion of the actually irrigated land (ha) in any given irrigation season. Irrigable land (ha) is the potential scheme command area.

Economic performance- Economic indicators deal with how much fee collected from water user, yearly maintenance and operation expenditure and whether system self–sufficient or not. The economic performance indicators used in the evaluation were calculated using the following equation:

$$Effectiveness\,of\,fee\,collection = \frac{Collected\,fee}{Total\,fee} \quad \text{(vi)}$$

$$Financial\,self\,sufficiency = \frac{Annual\,fee\,revenue}{Total\,annual\,Expenditure} \quad \text{(vii)}$$

Where, effectiveness of fee collection represents how portion of fee collected from water users whereas financial self-sufficiency represents the collected fee from water users either sufficient or not sufficient for operation-maintenance (O-M) cost in each year.

Results and Discussions

The results of relative irrigation supply (RIS), irrigation ratio (IR), sustainability of irrigable land (SIL) and financial self-sufficiency (FSS) are as shown in figures 2 and 3 while five years maize and rice output are as shown in figure 4.

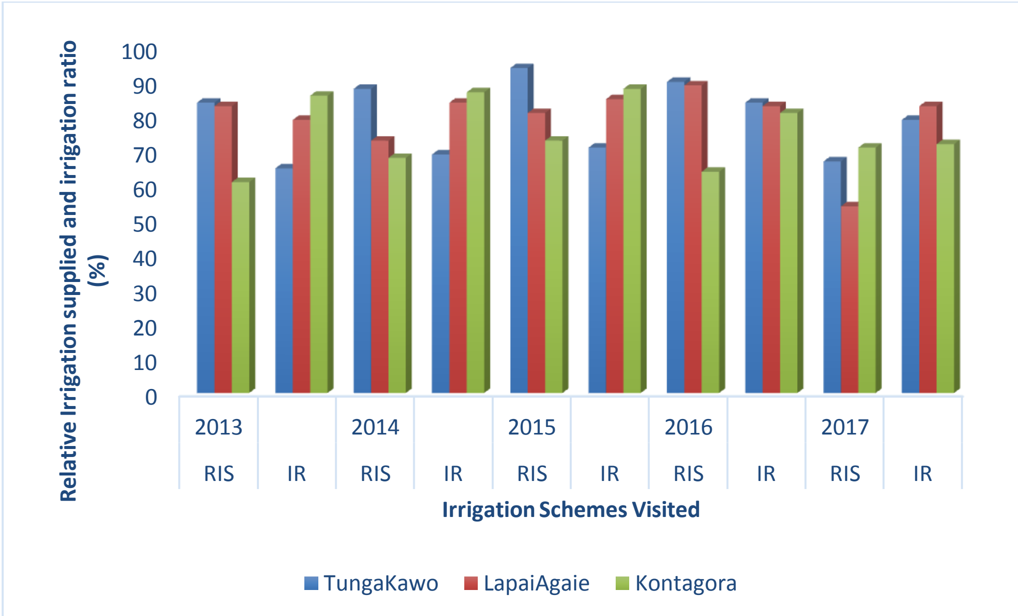

Fig. 2: Five Years Percentage performance of Relative Irrigation Supply and Irrigation Ratio

From figures two, RIS was increasing for Tungakawo scheme until 2016 when there was a slight reduction. However, there was a sharp reduction in 2017 for both Tungakawo and LapaiAgaie schemes. The only year a decrease in RIS was noticed for Kontagora dam was 2016. This may not be unconnected with failure of some sections of distribution canals which was noticed in all the schemes, siltation of the reservoir and fluctuations of weather during the period under study. There were also cases in Lapai, Agaie and Tungakawo where some section of the distribution canals have been overgrown by weeds (Figure 3). These narrowed down the width of the channels.

RIS was calculated from the ratio of irrigation supplied to the irrigation demand. It was gathered from oral interview that at times more water is released than irrigation demand but much of the water released are wasted whenever there is a canal breakage like the one noticed for Kontagora dam (Figure 4).This leads at times to localized flood and waterlogging in some places and inadequate water supply at the far downstream end of the scheme. Irrigation Ratio (IR) calculated from ratio of irrigated land to irrigable land keeps increasing for the three schemes until 2017 when much was not achieved (Figure 2). From 2013 to 2016, it was reported that farmers were requesting for more lands allocation but the reason for that reduction in 2017 could not be explained by both the farmers and the managers. The water users give less attention to water saving issues and waste significantly large amount of water resources. Farmers feel that excess irrigation water application would result in increased yield, and divert the water to the schemes as long as it is available. Lack of sound irrigation scheduling, lack of knowhow on actual crop water requirements are some of the factors contributing to wastage of water. Similar results were also obtained from many researches around the world (Ray *et al*., 2002; Bandara, 2003). These values also imply relationship between the water supply and crop water demand was poor from the point of water distribution in the schemes (Şener, *et al*., 2007).

Figure 3: Some section of distribution channel overgrown by weeds.

Figure 4: Distribution canal Failure in Kontagora scheme.

From figure 5, sustainability ratio is decreasing yearly in Tungakawo and Lapai/agaie schemes possibly due to farmers' attitude to maintenance. However, in the year 2016, sustainable ration for Kontagora scheme witnessed an increase possibly due to farmers' associations' participatory attitude in maintaining the canals and laterals. The SIL was calculated from ratio of irrigable land to initial irrigated one. The decline has made the farmers to depend more on rain fed agriculture and has made production output to be reduced in dry season. This by extension has also affected the financial self-sufficiency (FSS) of the project (Figure 5) which was also reducing from 2013 -

2016. However, in FSS in the three schemes witnessed a slight increase possibly due to farmers change in attitude to payment of water fee or due to introduction of penalties for farmers who refuse to pay the stipulated fee. Sustainability of irrigation is indicative of whether the area under irrigation is contracting or expanding with reference to the nominal area initially developed. Financial self-sufficiency indicates the revenue from the irrigation over the expenditure for operation and maintenance. The government covers the operation and maintenance of the irrigation scheme and it is considered as subsidy; and currently, attitude of farmers to water fee is poor.

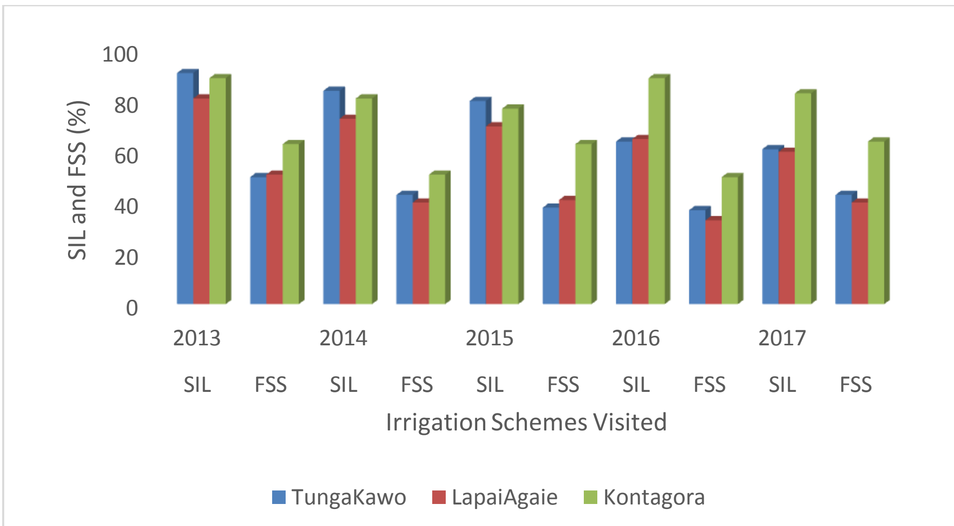

Fig. 5: Five Years sustainability of irrigable land and financial self Sufficiency

Overall output of grains in the three schemes are as presented in figure 6. Maize and rice are evaluated here because they are the two major crops being planted on the schemes and the evaluation is done with the assumption that other agronomical practices that could affect the yield are kept constant. Other crops being cultivated are cassava, pepper, okra, spinach, jute mallow etc. However, proper records were not being kept for these crops as the money realized from their sales are used to buy inputs for rice and maize. The expectation from the schemes was increase in output, however, there are fluctuations in the may be attributed to some structural failure that has been mentioned. If the schemes are completely well maintained, output can be doubled and will guarantee food security in the state.

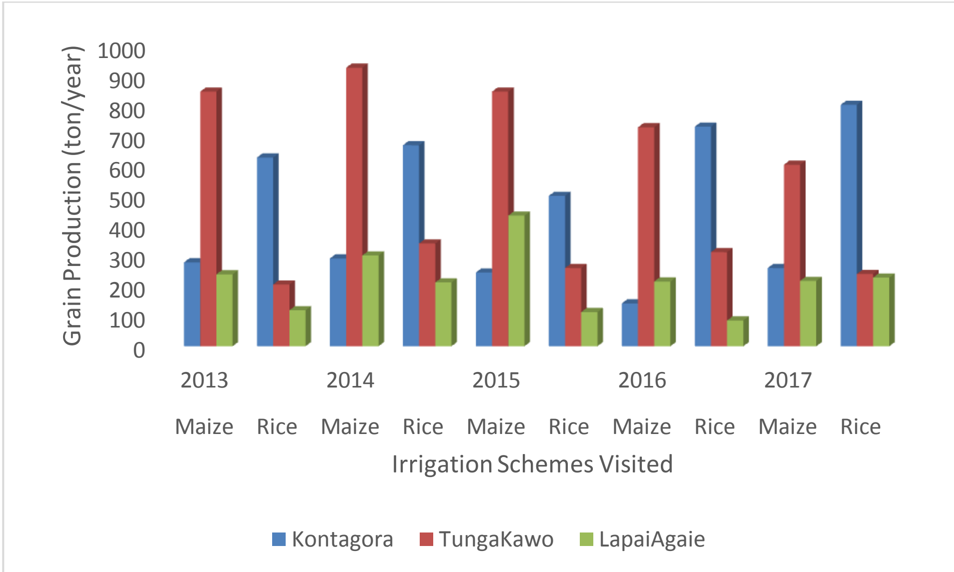

Fig. 6: Five Years Output of Maize and Rice from the irrigation Schemes

Conclusions

In this study, the performances of three irrigation were assessed using comparative indicators. This indicators used are useful to evaluate the degree of utilization of resources such as land and water in producing agricultural outputs. The RIS results indicated that excess irrigation water is supplied from the reservoir, but the water supply and crop water demand was poor from the point of water distribution in the schemes. Water users are responsible for the overall water management including maintenance of the main diversion and this has made them not to be paying irrigation water fee since. The reasons for this may be because; water fee is not collecting according to the used water amount by farmers, weak committee and delay of payments by the farmers.

Therefore for the successful fee collection the suggested solutions maybe institutional reforms for water management, install of volumetric measurement, collection of fee before irrigation and investment in infrastructure. Generally, institutional reforms for water management at the scheme are essential. The water users association (WUA) would have to be strengthened and capacitated through training for efficient water management and government should be enforce pricing policies. Comparative indicators are very good estimator and indicator of performance of irrigation projects as a whole but full, reliable and consistent documentation system is a must. And this type of study has to be adopted and practiced on some other small-scale irrigation projects in the country.

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YIELD RESPONSE OF ONION (*ALLIUM CEPA*) TO DEFICIT IRRIGATION IN THE SAHEL SAVANNAH REGION OF NIGERIA

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Abstract

The objectives of this research is to understand water requirement needs, predetermine yield expected from irrigation scheduling under limited supply or water scarcity and the relationship between yield and water deficit by onion plant daily. The irrigation interval observed were; control on the first block of regular seven days irrigation interval, second and the third were irrigated at3days and seven days in excess of the regular seven days irrigation schedule. The three stages of growth were identified as vegetative, flowering and fruiting/ ripening stages. Water was applied at depth of 25cm on each plot. The growing season lasted for four months. Highest yield of 31.5kg/plot (12t/ha) was obtained from 7 days normal irrigation, followed by 10 days,25.0kg/plot, and lowest yield of 18.3kg/plot (1.8t/ha) was obtained from 14 days irrigation. The result of this research shows that irrigating at interval of seven days has the highest significant yield and under critical condition farmer can irrigated at interval of ten days because up to 65-70% yield was obtained compared with treatment A and irrigation should not be schedule at interval of fourteen days because up to 57.6% of yield were lost. It was concluded that deficit irrigation will enhance good water management, reduce soil erosion, reduce cost and energy needed than to irrigate frequently.

Key words: Deficit Irrigation, Irrigation Schedule, Water

Introduction.

The concept of irrigation involves the artificial application of water to the soil for the purpose of supplying moisture essential for plant growth (Michael and Ojha, 2005). However, in a broader sense, irrigation is the application of water to the soil, to improve soil moisture, dilute salts, soften tillage pans and clods and to provide crop insurance against short duration droughts. (Sharma and Sharma, 2006). Deficit irrigation is being known globally as an efficient way of water management whereby there is a balance between minimum water applied to a crop and the maximum crop yield per unit of water applied (Arora, 2004). Thus, in arid and semi-arid regions where water is scares and food must be produced, water must be carefully managed by using optimum approach to the application and use of limited water supply, considering the fact that many farmers involve in crop production do not pay attention to efficient water management. Water requirement of crop varies and that at some certain growth stages crops are more sensitive to water deficit than others. The need therefore for the knowledge of when to apply water and how much of it to apply for optimum production comes into play. (Shock *et al.*,2010). Thus, the knowledge of the marginal productivity of water allocated to each crop at different growth stage is required in order to arrive at an optimal set of decision. According to Jensen (1968) and Stewart *et al.*, (1977), two key parameters commonly required in determining crop water requirement and predictions of yield water response to deficit irrigation are; crop coefficient (kc) and yield response factor (ky). The yield reduction to relative evapotranspiration deficit. It is the factor that integrates the weather, crop, and soil conditions that make crop yield less than its potential yield in the case of deficit evapotranspiration. The yield response factor ky is commonly required as input data in some empirical water production function.

Onion (*Allium cepa*) is a monocot and vegetable crop believed to have originated in the Near East and is grown almost all over the world. It is mainly grown for its bulb, which is used in almost in every home, on daily basis (Gohil and Kaul,2016;FAOSTAT,2001). Its main use include in flavouring and seasoning of a wide variety of dishes. It`s popularity is due to its aromatic, volatile oil, the allyl-prophl sulphide which imports a cherished flavour to food. Onion takes 100 to 140 days before it complete its life cycle. And high humidity leads to greater incidences of pest and disease and bulb rotting. (Steve, 2012, and Igbadun,et,al.2012).

Materials and Methods.

Study Area

The experiment was carried out at Kaduna Polytechnic demonstration farm, Nariya which is on latitude 10^{o} 16'N and longitude 7^{o} 21'E at an attitude of 600 – 800m above mean sea level, during dry season (cold harmattan to dry hot) November 2017 to April 2018. See table 1 for meteorological parameter during the study period. The region falls within the guinea savannah with severe deficit in rainfall from November to April sometime and a surplus of rainfall from May to September, with an average range of 1500mm the average incoming solar radiation range from 15.6MJ/m2/day in August to 21.0MJ/m2/day in March. The range in solar radiation implies that light temperature greatly limit potential crop production at any time of November to February.

Experimental Plot

The experimental plot was laid out using chain surveying method. The instruments used were measuring tape, ranging poles and pegs. The layout was 3m x 2.5m for each plot and 18 plots of experimental unit was used the total area of $45m^{2}$ (0.045ha).

In order to ensure as much homogeneous soil conditions as possible within the treatment. Each treatment was divided into six (6) basins. The basins were spaced 0.5m (furrow) apart between each treatment, to allowed for easy supply of water and reduce possible seepage water from one experimental unit to another

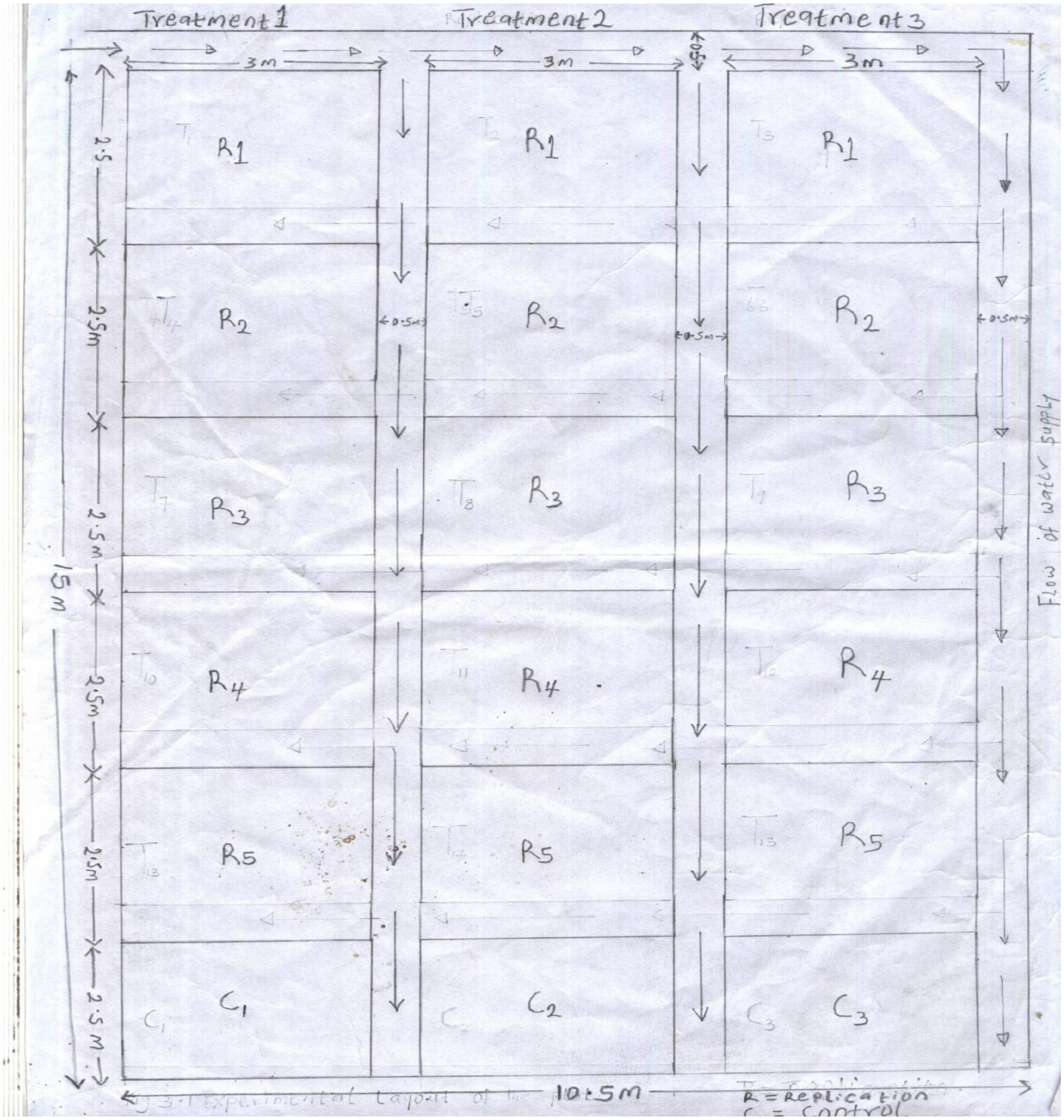

Plate 1: Experimental Treatments and Replication

Experimental Design.

The Randomized Complete Block Design (RCBD) was used in the study of the effect of water stress (Deficit irrigation) on onions yield during the growing stages of vegetative, flowering and bulb formation. The experimental designs were used since, there is no restriction in the randomization.

ANOVA was employed for the analysis of the results such as degree of freedom (df), sum of square (ss), mean square (ms) and F calculated were analysed. The f calculated was compared with table value of F to analyzed it level of significance. The level of experimental errors was determined using Latin square design (LSD) to compared with the result obtained from the treatments of the yield.

Surface irrigation method (check basin type) was used in which basin were irrigated through a break in the embankment and water allowed in until the basin is pounded to a level of about 50mm.The first weeding, application of fertilizer and spraying of chemical was done at Week 4 after transplanting. Second weeding done at Week 8 after transplanting and irrigation was stopped two weeks before harvesting, immediately after the falling of some leaves. Soil texture (percentage of sand, silt and clay), soil structure, bulk density, and soil moisture before and after irrigation were determined to have idea if there are any changes in the soil characteristics. Harvesting and measuring the weight of the harvested onion was done using weighing balance from various replications of treatments.

Results.

The results obtained from the experiment are summarized in the tables and figures below.

Table 1 Average meteorological data recorded during the growing period (late November-early April)

h	nd(km/hr)	Rainfall(mm)	nshine(hr)	temperature(o^c)	
Jan.					
.					

Table 2 ANOVA TABLE

Source of variation	Degree of freedom (DF)	Sum of square (SS)	Mean Squares (MS)
Replication	r – 1 6 – 1 = 5	SSR 96.95	MSR = 16.16
Treatment	t – 1 3 – 1 = 2	SST = 9.92	MST = 4.96
Total	rt – 1 3 x 6 1 = 17	SST = 232.90	
Error	(r-1) (t – 1) 5 x 2 = 10	SSE = 126.03	MSE = 12.60

Table 3. below show evapotranspiration as measured from the experimental plot (mm) using the meteorological data obtained on the field.

Stages/stress level	Treatment 1 (mm)	Treatment 2 (mm)	Treatment 3 (mm)	Seasonal ET (mm)
R_1	85.40	78.60	79.00	243.00
R_2	75.20	72.60	79.40	227.20
R_3	79.00	80.00	73.30	232.30
R_4	79.40	75.20	71.20	225.80
R_5	73.20	75.30	74.10	220. 60
R_6	72.30	79.00	76.60	227.90

Table3. Physical properties of soil in the experimental plot.

Depth (cm)	Moisture content (%)	Bulk Density (g/cm^3)	Textural Class
0-15	20.7	1.29	Silt loam
15-30	21.9	1.29	Clay loam
30-45	22.5	1.46	Clay loam
45-60	25.2	1.31	Clay

Table 4. Yield obtained from the experimental plot.

Plot	Treatment			Average(kg)	Total(kg)
	1	2	3		
R_1	5.3	4.3	3.1	4.2	12.7
R_2	4.9	4.1	2.9	4.0	11.9
R_3	5.6	4.5	3.3	4.5	13.4
R_4	5.4	3.8	2.9	4.0	12.1
R_5	4.8	3.9	2.8	3.8	11.5
R_6 (control)	5.5	4.4	3.3	4.4	13.2
Total	31.5	25.0	18.3	4.2	74.8

Total yield obtained for the control(seven days irrigation interval was 31.5kg/plot.25.0kg/plot was the obtained for 3days water stress and 18.3kg/plot was obtained when the crop was stressed for seven extra days in excess of the seven days irrigation interval.

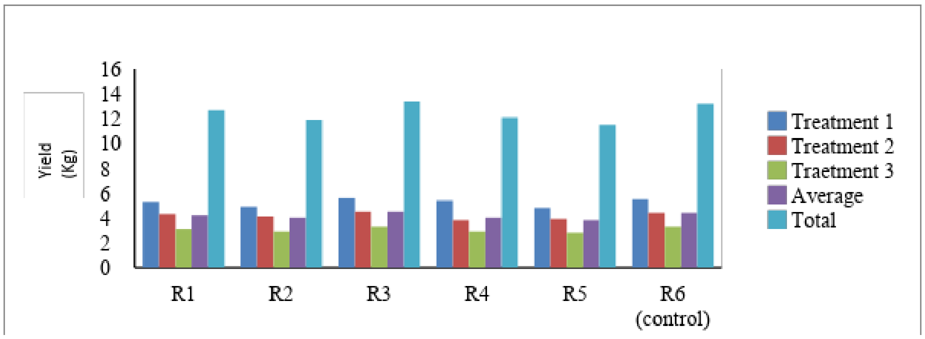

Fig 1: Yield (kg) obtained per plot(m^2)

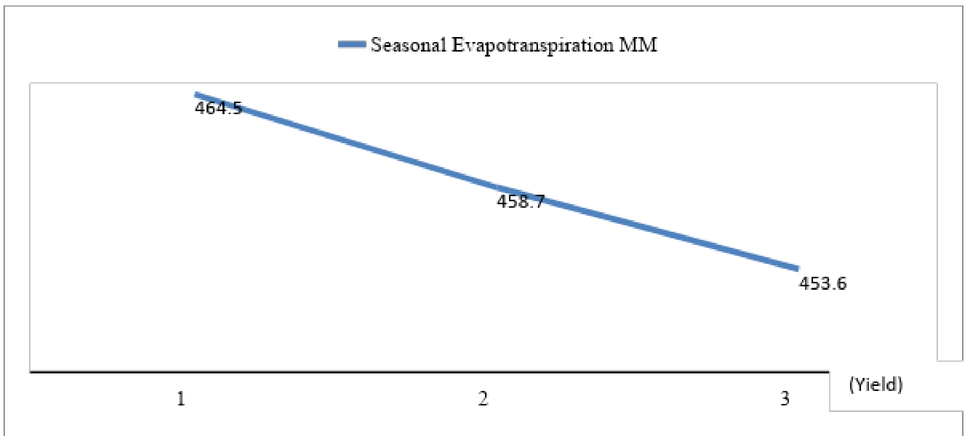

Fig 2. Relationship between water stress and seasonal evaporation.

Discussions

Deficit irrigation promotes good water management, reduce soil erosion, reduce cost and energy needed than to irrigate frequently. In this study, irrigation ceases when bulbs have attained the desired marketable size and falling of the leaves. Computing the level of significance fromThere was on the yield from the result obtained, at the three stages of water stress (see fig 1). The maximum yield of 31.5kg/plot(17.03ton/ha) was obtained from treatment 1 (control) where no stress was observed during the growth stage. Treatment($T_{2)}$ which was stressed for an additional 3 days (10days) show little difference in yield of 25.0kg/plot (13.51ton/ha) and Treatment ($T_{3)}$ which was stressed for an additional 7 days (14days) shows about 57.6% reduction in yield,18.3kg/plot (9.81ton/ha). In table 1,F calculated value (11.28) for treatment is less than the table value at 5% (2.57) and 1% (4.03) level of significance different in crop yield which shows that the higher the seasonal evaporation the more the crop required water.(Table 3).

The ranking of the means treatment using LSD of 1.65 value indicated that T_1 31.5kg, T_2 25.0kg, T_3 18.3kg. Treatment T_1 was found to be significant than treatment T_2 and is highly significant than Treatment T_3. It can be deduce therefore that a farmer under critical condition can irrigate with the interval of 10days (figure 2).

Finally, the yield water use relationship shows that yield of onion crop increases with increase in the rate of seasonal evapotranspiration. The evapotranspiration during the cropping season (ie November 2017- April 2018 was 456.5mm and a highest yield value of 31.5kg/plot was recorded.

Conclusions

It was concluded that deficit irrigation will enhance good water management, reduce soil erosion, reduce cost and energy needed than to irrigate frequently. In this study, irrigation treatments significantly affected yield, bulb height, bulb diameter and bulb weight. There was significant difference on the yield from the result obtained, at the three growth stages of onion when it was stressed with an additional days from the normal interval of 7days regular irrigation schedule. The maximum yield of 31.5kg/plot(17.03ton/ha) was obtained from treatment 1 (control) where no stress was observed during the growth stage. Treatment($T_{2)}$ which was stressed for an additional 3 days (10days) show little difference in yield of 25.0kg/plot (13.51ton/ha) and Treatment ($T_{3)}$ which was stressed for an additional 7 days (14days) shows about 45% reduction in yield,18.3kg/plot (9.81ton/ha).

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EFFECT OF COMPACTION ON SOIL BULK DENSITY: A REVIEW

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Abstract
Compaction of agricultural soil is a major concern for many agricultural soil scientists and farmers. Soil compaction, due to heavy field traffic, has resulted in the uneasy flow of water into the soil for crop use which has led to yield reduction of most agronomic crops throughout the world. Soil compaction is a physical form of soil degradation that alters soil structure, limits water and air infiltration, and thus reduces root penetration in the soil. The review shows the tentative approach in the understanding and quantification of the effects of soil compaction. We found the following major points: (1) Exposure of the soil to vehicular traffic load, soil water contents, soil texture and structure, and soil organic matter are the three main factors which determine the degree of compactness of that soil. (2) Soil compaction has direct effects on soil physical properties such as bulk density, strength, and porosity; therefore, these parameters can be used to quantify soil compactness. (3) Modified soil physical properties due to soil compaction can alter elements mobility and change nitrogen and carbon cycles in favour of more emissions of greenhouse gases under wet conditions. (4) Severe soil compaction induces root deformation, stunted shoot growth, late germination, low germination rate, and high mortality rate.

1.0 INTRODUCTION

Soil has been described to be complex mixtures of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. It forms the surface of land thus it is said to be the skin of the earth (NRCS, 2006). Soil is known to support plant life and is vital to life on earth. The unconsolidated mineral and organic matter on the surface of the earth has been subjected to several genetic and environmental factors such as climate (including water and temperature effects), macro and microorganisms, conditioned by relief, and weather action on parent material over time (NRCS, 2006)

Soil bulk density (ρ_b) is defined as the ratio of dry soil mass to bulk soil volume (including pore spaces) The SI unit for density is mega grams per cubic meter (Mgm^{-3}), which is numerically equivalent to grams per cubic centimetre (McKenzie, 2002). It is also an indicator of soil compaction. DOA (1970) stated that bulk density (ρ_b) is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and pores among soil particles. Just as soil is a combination of soil minerals, organic matter, and air- or water-filled pores, so soil bulk density is a weighted average of the densities of these components. According to McKenzie, (2002). Thus soil bulk density is generally expressed as

$$\rho_b = f_a\rho_a + f_p\rho_p + f_o\rho_o + \cdots \ldots \ldots \ldots \ldots .. + f_n\rho_n \qquad 1$$

Where:

f =is the volume fraction of a component,

a = is the air pore space

p = is the soil mineral particles

o = is the organic matter while

n = is the infinite value.

High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil, bulk density is primarily a function of relative pore space and OM content (Arshad, 1996)

$$\% \text{ pore space} = (1 - \frac{\rho_b}{\rho_p}) \times 100 \qquad 2$$

ρ_b = Bulk density

ρ_p = Particle density

Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration (Arshad, 1996). Bulk densities in table 1 thresholds indicate impaired function. Conversion between the weight and volume of the soil is also determined using soil bulk density.

Table 1: General relationship of soil bulk density to root growth based on soil texture

Soil Texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

Table 1 shows the relationship of three different types of soils (sandy, silty, and clayey soils) with relation to their bulk densities ideal for plant growth and bulk densities that restrict the proper development of the root systems. The sandy soil shows its bulk density at about 1.60 g/cm^3 which is much ideal for plant growth, but its bulk density above 1.80 g/cm^3 hinders the development of the root systems. Silty soils also show that its bulk density at 1.40 g/cm^3 is favourable for plant growth and its bulk density at 1.65 g/cm^3 is also not favourable for root growth. And clayey soils show that at bulk density even at 1.10 g/cm^3 is ideal for plant growth, but bulk densities at 1.47 g/cm^3bulk density is not favourable for root growth development.

1.1 DETERMINATION OF SOIL BULK DENSITY

There are basically four methods used in determining soil bulk density (Zhao, 2010):

- Core method
- Excavation method
- Clod method
- Radiation method

A. Core method

The core sampler is pushed or driven into the soil to the desired depth and then removed. Many samplers are available which are provided with a metal casing to hold the core and permit easy removal and handling of the sample during weighing, wetting and drying. If the soil sampler is assumed to be full its volume may be used as the volume of soil.The intact core is removed, dried in an oven at 105°C, and weighed.

A larger diameter core diminishes all disadvantages of small sampling area, compression of soilinside the core and stones present except when rocks are large but closely spaced.

Plate 1: A three inch diameter ring is hammered into the soil to collect bulk density samples
Source: (Arshad, 1996)

Advantages - It's fairly quick and it's easy to use

- Does not require expensive instrumentation or skill labour
- The coring tool does not rust, and
- It is also light weight and requires no lubrication
- The cutting head can also be removed by hand and also removing samples from tube is quick and simple

Disadvantages - compression of soil inside the core

- Presence of coarse particles (may be skeletal material) inside the core and small sampling volume (Monoj, 2013)

- Only small sampling area of core can be covered, the coring tool does not function well in muddy soils or over irrigated agricultural land and also stony soils. (Yoav, 2006).

A larger diameter core diminishes all these disadvantages, except when rocks are large but closely spaced.

B. Excavation method

In this method, level soil surface is dug to a desired depth. A hole is lined with a plastic, then it is filled with a measured volume of water. Excavated soil is then dried and weighed. The major advantage of excavation method is that it can be done in stony or gravelly soils. While it's major disadvantages are that water gets heavy to lug around and excavated soil is no longer undisturbed. If done properly, this method will usually give you more accurate numbers than core methods (Blake, 1986).

Plate 2: Excavated soil, ready to be oven dried.

Source: (McKenzie*et al*, 2002)

Advantages - It gives more accurate results in deeper soil depths, larger sample sizes can be fetched and it can also be done in stony or gravelly soils

Disadvantages - Water gets heavy to lug around

Also there are problems associated with the use of plastic, weather conditions, and transport of large amounts of water.

If done properly, this method will usually give you more accurate numbers than core methods.

C. Clod method

The bulk density of clods, or coarse peds, is calculated from their mass and volume (Blake,*et al.*, 1986).The volume is determined by coating the clod with a water-repellent substance and by weighing it first in air, then again while immersed in a liquid of known density, making use of Archimedes' principle.

Advantages - This method can be used only if other methods are not visible.

Disadvantages - Giving higher bulk density values than do other methods and it does not take the inter-clod spaces into account

D. Radiation methods

The radiation method involves measurement of radiation transmitted through the soil using a detector mostly in the laboratory. In the field, the backscatter of rays from the soil can be recorded by a detector (Manoj k. Shukla, 2014).

Advantages -it is quicker to use, especially where measurement at depth are required.

- It also has added advantages of being non-destructive and therefore allows repeated measurement at the same location.

Disadvantages - It is more expensive and requires skilled labour and careful adherence to the nuclear safety protocols.

2.0 QUANTIFYING THE EFFECTS OF THE SOIL BULK DENSITY

To show the peculiarities of soil compaction, physical parameters such as the bulk density and porosity, soil strength, water infiltration rate and reduction of aeration have been used. Indeed, under natural conditions, due to steady state aggregation and biological processes, the soil contains large proportions of macro pores. Macro pores are relatively more affected during the soil compaction than the micro pores.

2.1 Bulk density and porosity

Direct methods for determining bulk density and water content involve the sampling of a known volume of soil which is then weighed in both wet and dry states (Hakasson and Lipiee, 2000). Typical resistant indicators used now are days are highly precise, as the soil density measures up to the soil depth of 20cm. while for deep stratum, the stress state transducers with six earth pressure gauges that measure three dimensional stresses can be useful (Eguchi and Muro, 2007). For an accurate measurement of the effects of the soil compaction on all types of the soil, the soil bulk density alone is not adequate but other soil properties such as the soil strength, soil aeration, and soil moisture should be measured (Lipiee and Hatano, 2003). It was reported that an increase in contact pressure of 100 kilo Pascal (kpa) caused a decrease of 5.7% in the soil porosity at 10-15 cm depth after 24 passes in the sandy humus rich forest soil (Sakai et al. 2008).

2.2 Soil strength

The soil strength is measured by a penetrometer and further more cone penetrometer is widely employed to measure the soil strength in terms of cone resistance in mega Pascal (Uzowiez and Lipiee 2009).

3.3 Water infiltration rate

Soil water infiltration rate can also be used to monitor the soil compaction status, because the soil compaction reduces the total porosity of the soil (Silva *et al*. 2008). These mainly involves the number of macro pores, as water infiltrates faster in non-compacted soil than in a massively compacted soil of the same type (Hamza and Anderson 2003). These are not directly related to the changes in porosity but rather to the changes in both the number of macro pores and in connectivity between macro pores. Such changes in the ratio of the convoluted pathway of the fluid diffusion through porous media can influence the soil electrical conductivity (Selaji*et al*. 2010).

3.4 Reduction of aeration

Air permeability varies largely according to the soil physical properties for the same level of compaction, while the measurement of oxygen diffusion rate (ODR) by electrode needs a lot of care. Redox potential measurements can be a good tool to characterize the compacted soils as these measurements can be carried out in situ for the long periods, but this method is only applicable to the very wet soils close to or at saturation (Feder*et al*. 2005; Lipiee and Hatano 2003; Nawaz 2010). Among different method discussed, the soil bulk density and the soil strength are more commonly employed to quantify the soil compaction but the use of other indicators like water infiltration rate, oxygen diffusion rate (ODR), redox potential, etc. in combination with them can largely increase our understanding and results precisions. Sensors have also been developed to detect the location and depth of the hard pans in real time that are equipped with four horizontal operating penetrometers, for on-the-go sensing and mapping of the location and intensity of hard pan (Loghavi and Khadem 2006). Sensory systems have been also developed to measure the soil compaction that has already been reviewed (Hemmat and Adamchuk, 2008).

4.0 Effects of compaction on the soil chemical properties and biogeochemical cycles

4.0.1 Reductive conditions

Chemical properties are influenced by modified soil physical properties due to soil compaction such as the reduced water infiltration rate and reduced soil air permeability (Nawaz *et* al., 2013). The soil compaction causes decrease in oxygen diffusion and can lead to anoxic conditions in compacted soils if consumption of oxygen is faster than diffusion (Schnurr–putz*et al*.2006).Selective extraction techniques using citrate– bicarbonate and citrate–bicarbonate–

dithionite showed that the soil compaction under forest resulted in an increase of readily extractable iron oxides after two years, before mineralogical transformations were detectable by XRD (Nawaz *et* al., 2013).

4.2 Carbon and nitrogen cycles

In a laboratory experiment, when silt loam (acid forest soil) was compacted artificially to a bulk density of 1.5 from 1.1 Mg/m^3, a significant reduction in the carbon mineralization and net nitrification rates was observed after 9 months (Tan and Chang, 2007). The soil compaction, directly, results in the lower efflux of carbon dioxide CO_2 from compacted soils (Silveira*et al.* 2010).

4.3 Environmental impacts of the soil compaction

The soil compaction reduces the available Nitrogen (Tan *et al.*, 2008) and efficiency of Nitrogen use by the crops decreases, which can increase the fertilizer requirements.

Anaerobic conditions in the soil due to the soil compaction can result in reduced decomposition of pesticide and ultimately increased leaching of pesticide in groundwater and aquifers (Alletto *et al*. 2010). Similarly, decreased hydraulic conductivities can result in slow downward movement of water and, ultimately, more nitrate contents in ground waters.

If the soil compaction is carried out in steep slopes, this can result in increased runoff and ultimately increase soil erosion and sediment transport which could be a serious problem for the landscape. Increased runoff in slurry applied fields can result in the entrance of slurry in surface waters and ultimate threat to the aquatic life as degradation of slurry can reduce the oxygen levels in surface waters (Nawaz*et al*., 2013). However in some soils (sandy soils), soil compaction increases the soil strength, erodibility, and consequently the soil erosion for the same amount of runoff is reduced.

4.4 Effect of the soil compaction on plants

Overall effect of the soil compaction on the plant yield is negative (Ishaq *et al*. 2001; Saqib *et al.* 2004). If a soil is already suffering from other types of degradation such as the salinity, drastic effects of the soil compaction on the plant growth and crop yield are reported to be doubled (Saqib *et al*. 2004).

4.5 Roots

Generally, compaction results in a decrease in the root length, root penetration, and rooting depth (Riley 2005). Top soil compaction is a more limiting factor for the root growth than the subsoil compaction. Botta *et al*. (2006) and Saqib*et al*, (2004) found that the compaction of a sandy clay loam soil to a bulk density of 1.65 from 1.21 Mg/m^3 reduced root length density of wheat plants while the presence of salinity (15 dS/m) was more drastic than the soil compaction alone. In the same experiment, they observed greater reductions in potassium K^+ concentrations and the potassium and sodium K^+/Na^+ ratio in leaves due to interaction of salinity and compaction.

Conclusions

Since soil bulk density is a reflection of being an important function of the soil, there is need for the soil to provide good structural support, water and solute movement, and aeration for the plants. The review paper tends to show how important determination soil bulk density is, as the knowledge of various soil bulk densities helps the farmer have good idea of an ideal soil bulk density that will boost plant growth and development. And also knowledge of unfavourable soil bulk densities that restrict the proper development of the root systems and the plant in general.

The review shows the various methods of soil bulk density determination. Thus, core sampling method is generally taken to be the standard method, but it is somewhat unsatisfactory for stony or non-coherent samples out of the three other methods (clod, radiation and excavation methods). But it shows that the core method is the most favourable and flexible due to its affordability, running cost, easy maintenance and overall accuracy during field operations.

The review tends to show that knowledge of the effect of compaction on the soil chemical properties and biogeochemical cycles leads reduction of fertilizer requirement by the farmer. Also knowledge of the anaerobic conditions in the soil due to the soil compaction can help reduce leaching of pesticide into ground water and aquifers.

The review also shows more understanding and achievement of results precisions when quantifying soil bulk density if physical parameters are used.

Compaction of the soil cannot be avoided as it occurs due to different factors beyond control, but it effects can only be limited by adopting healthy farming practices.

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DETERMINATION OF ELEMENTAL CONCENTRATION OF SOME NIGERIAN COAL SAMPLES USING INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA)

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ABSTRACT
The issue of irregular power supply and the unharnessed large deposits of coal in Nigeria (which can be a source of remedy) prompted the analysis of coal by Instrumental Neutron activation analysis (INAA). Nigerian Nuclear Research Reactor – 1 (NRR – 1) was used to irradiate the coal samples to determine the elemental concentrations. 0.15 g – 0.20 g of the samples were fed into the reactor by means of pneumatic transfer with the aid of rabbit capsule. The investigation revealed seven elements (Mg, Al, Ca, Ti, V, Mn and Dy) in various concentrations. It also showed that these coal samples generally have very low trace elements (Ti, V, Mn and Dy) in part per million (ppm) which implies that the large scale use of these coal samples will not cause serious environmental pollution.

Key words: Coal samples, Irradiation, Instrumental Neutron activation analysis, Elemental concentration

1.0 INTRODUCTION

Coal is essentially made up of coal matter, mineral matter and moisture. Coal matter consists of carbon, hydrogen, oxygen and nitrogen while the mineral include aluminum and other silicates iron sulphide and oxide of several metals of varying compositions. Thus, when coal is subjected to combustion for extracting heat energy the byproduct is the oxidized incombustible residue in form of ash having concentration that is closely correlated with the mineral matter content (Omeje, *et al.*, 2011).

Prior to the discovery of petroleum in Nigeria in the 1950s, coal was the country's main mineral export and major source of revenue. Today, coal is still abundant in Nigeria has practically an unlimited domestic supply for any purpose. In 1905 an ordinance establishing the Nigeria coal corporation was enacted and solely charged with the responsibility of developing the coal resources of Nigeria (Godwin, 2008).

The coal resources discovered so far in Nigeria occur within geological units known as the coal measures. The coal measure are concentrated within the Anambra basin, but coal measure occur in other rocks within Nigeria, such as Lafia-Obi in Nasarawa State, Lamja Gombe in Gombe State and Afikpo in Ebonyi State to mention but a few.

Since coal is low cost and reliable source of energy, it is used for the generation of thermal electricity. Presently, Nigeria's most exploited coal mine located at Enugu State is no longer in operation leading to the loss of electricity generation from the Oji thermal power plant for decades now. Coal contains many major and minor trace elements and hence its combustion either for industrial or domestic purposes can be a potential sources of environmental pollution. It is therefore important to ascertain the concentration of such elements in Nigeria coal samples, in order to asses any hazard it's use/uses could cause to the environment. Hence, coal mining operations are sometimes associated with the distribution of various hazardous substances particularly in connection with surface water contamination. Various analytical techniques such as instrumental neutron activation analysis (INAA), x-ray fluorescence, and atomic absorption spectrometry have been applied by some researchers for the determination of various elements in coal and other samples. This work applied INAA to measure the elemental concentrations in six coal samples from five states in Nigeria and bring to the bare the human/health and ecological effects (if any) in using coal with high toxic or trace elemental contents.

2.0 MATERIAL AND METHOD

2.1 Instrumentation

The Nigeria Research Reactor - 1 (NIRR-1) is a miniature neutron source Reactor and has in pool structural configuration with a nominal thermal power rating of 31kw. NIRR-1 was acquired for an extensive soil fertility-mapping project of the different arable land in Nigeria and is specifically designed for neutron activation analysis (NAA). Therefore, the capabilities for the analysis of trace, minor and major elements in different sample matrices have been enhanced greatly (Jonah *et al.*, 2006). The samples used in this project work were irradiated using NIRR-1.

2.2 Theory of NAA Measurement

In Neutron Activation Analysis a source of neutron is required. In this work, NIRR-1 was used to provide the source of neutrons. The sample is exposed to a flux of activating particle, (Neutrons) from a nuclear reactor. The sample is bombarded with neutrons, causing the elements to form radioactive isotopes. As many elements have high cross-section for neutron capture in (n, γ) -type nuclear reactions, which are thus the most analytically significant of the activation process. The radiation intensity from the radionuclide produced by activation is proportional to the amount of the corresponding element present in the sample. Irradiation of the sample will produce a heart variety of radionuclide which needs to be separated so that the amount of the individual element originally present can be calculated. Since the radioactive emissions and radioactive decay paths for each element are well known, using this information it is possible to study spectra of the emissions of the radioactive sample and determine the concentration of the elements within it (Kogo *et al.*, 2009).

The instrumentation used to measure the gamma rays from the radioactive sample generally consist of a semiconductor (Hyper pure germanium detector (HPGe) and a computer based, multi-channel analyzer (MCA).

In Neutron Activation Analysis, samples could be short, intermediately or long-irradiated depending on the element of interest. However, in this work only short irradiation were employed due to time and other constraints.

2*.2.1 Short Lived Irradiation*

In short-lived irradiation, each of the samples was parceled. Sealed in $7cm^3$ rabbit capsules and sent for irradiation one after the other in one of the outer irradiation channels of NIRR-1. The neutron spectrum in the outer channel is soft having a flux of $2.5x10ncm\text{-}^2s^{-1}$ and irradiation period of 600s. the outer irradiation channels was chosen so as to eradicate corrections, which arise from nuclear interference caused by threshold reactions notably Mg in the presence of Al; Al in the presence of Sl; and Na in the presence of P. all these are as a result of the closeness of the inner channels of the MNS reactors to the core leading to the relatively higher ratio of fast to thermal neutrons. The short irradiation is only capable of identifying the elements of interest with short half-life (Jonah *et al.*, 2006).

2.3 *Sample Collection and Preparation*

2.3.1 *Sample collection*

The samples used in this work where collected from Nigerian coal cooperation Enugu, these includes coal samples from: Ogwashi/Azagba in Delta State, Owukpa in Benue State, Inyi in Enugu State, Okpara in Anambra State, Ogboyoga in Kogi State and Okaba in Kogi State.

2.3.2 Sample preparation

This consists primarily of weighing and packaging. The sample aliquots of the standard approximately 0.15g - 0.20g were weighed and wrapped in polyethylene films. The polyethylene films and rabbit capsule (vial) were cleaned by soaking in 1:1 KNO_3 (nitric acid) for 2 days and washed with de-ionized water. The polyethylene film containing the sample is then heat sealed and put into vial, the vial is then covered with cotton wool and sealed, then stored prior to sample irradiation.

2.4 Sample Analysis

After the short irradiation there is a waiting time of 2 to 15 minutes, followed by the first bit of counting which was carried out for ten minutes. The samples were placed on a plexi-glass sample holder designated, H_2 which refers to the source detector geometry of 5cm which is depicted as S_1. The second lap of counting was also carried out for 10 minutes after irradiation and depicted as S_2. The waiting period in this case is as long as 3-4 hours. Samples are counted on plexi-glass sample holder denoted, H_1 which refers to source detector geometry of 1cm.

After the irradiation for the long-lived, the first lap of counting was carried out after a waiting period of 4-5 days for duration of 30 minutes. This long irradiation is termed L_1 and is carried out using the H_1 holder. The second lap of counting is carried out after a cooling period of 10-15 days for duration of 60 minutes. This is termed as L_2 and samples counted using plexi-glass holder H_1. With the aid of gamma ray spectrum software known as WINSPAN 2004, the gamma ray of sample radionuclides can be identified by their energies as well as quantitative analysis of their concentrations are obtained as reported by Jonah *et al.*, (2006). However, only short irradiation was considered for the six coal samples used in this work as pointed out earlier.

3.0 RESULTS AND DISCUSSIONS

3.1 Results

The analytical result of INAA of six (6) coal samples are presented in the Table 1 below. Seven elements were found from the coal samples presented. These include Mg, Al, Ca, Ti, V, Mn and Dy, which was obtained by short-lived irradiation.

Table 1: Concentration of Element for Six (6) Coal Samples Analyzed

ELEMENT	Ogwashi	Ogboyoga	Inyi	Owukpa	Okpara	Okaba	feedcoal(*)	coal ash (*)
Mg (%)	BDL	BDL	BDL	0.04±0.01	BDL	BDL	0.05±0.00	2.70±0.01
Al (%)	0.20±0.01	0.60±0.02	0.30±0.01	0.40±0.01	0.75±0.02	0.05±0.02	1.45±0.01	9.85±0.49
Ca (%)	0.03±0.01	BDL	BDL	BDL	BDL	0.04±0.01	-	-
Ti (%)	BDL	0.10±0.01	0.03±0.01	0.03±0.01	0.10±0.01	0.11±0.01	0.09±0.00	0.95±0.04
V (ppm)	7.5±0.3	6.1±0.6	3.80±0.01	5.3±0.05	10.3±0.6	11.5±0.8	92.76±0.40	127.67±0.01
Mn (ppm)	1.62±0.06	2.0 ± 0.1	2.6±0.1	17.0±0.3	2.4±0.1	45±1	2.77±0.57	232.24±0.01
Dy (ppm)	1.6±0.1	0.33± 0.04	0.11±0.03	0.35±0.04	2.26±0.04	0.42±0.05	6.41±0.05	8.37±0.41

Key BDL: Below Detection Limit **(*): Ewa *et. al.*, (1996)**

Other trace elements of interest were not determined because of fact that the samples were not exposed to long-lived irradiation. However, comparing this work to Ewa *et al.*, (1996) some significant relationship exists for some of the trace elements and other elemental concentrations obtained for feed coal and coal ash as presented in columns 8 and 9 respectively.

3.2 Discussions

Seven elements were obtained from the short-lived irradiation for all six (6) coal samples that were analyzed. From table 1, it can be observed that Ogwashi coal has five elements with two below detection limit (BDL). Element such as V, Mn and Dy constitutes elements with higher concentrations while, Ti was found to be BDL.

The Ogboyoga coal is also enriched in V and Mn, with higher concentrations compared to other elements found, while Al, Dy and Ti have low elemental concentrations, with Mg and Ca being below detection limit.

The Inyi coal has V and Mn as its major elements with higher concentrations while Al, Dy and Ti are minor elements with lower concentrations. Mg and Ca were below detection limit.

The result also showed that six elements are present in Owukpa coal and one element below detection limit. Ma and V having higher concentrations than Al, Dy, Mg and Ti, with Ca to be below detection limit.

The Okpara coal has V and Mn also as its major element with higher concentrations as compared to others. Al, Dy and Ti are minor element with lower concentrations while Mg and Ca are found to be below detection limit.

The Okaba coal is enriched in V and Mn with higher concentrations compared to other elements found while Al, Dy, Ti and Ca have lower elemental concentrations with Mg found to be below detection limit.

However, element such as Mn and V are present in high concentration in all the coal samples analyzed and as such constitute the major elements present, other element such as Al, Ca, Mg, Ti and Dy are presented as minor element or are found to be below detection limit in some samples. The fact that element such as Al, Ca, Mg, Ti and Dy are present in the sample shows an even distribution of the element in the coal samples analysed.

It was observed from the Table 1 that the quantity of Mn in the sample is greatest in Okaba and Owukpa coals compared to other coal samples, indicating that the coal in those regions might have negative effect on its users and miners. It was also observed that the concentration of Mg is strongly below detection limit for six coal samples except for Owukpa coal which is present at moderate concentration level. However, the result obtained was compared with that of Ewa *et al.*, (1996) and it was observed that element such as Mg and Ti are found to be below trace concentration level and Mn was noted to be above trace concentration level. Mn having the greatest hazard potential had concentration of about (45 ± 1) in Okaba and (17.9 ± 0.3) at Owukpa.

4.0 CONCLUSIONS

The instrumental neutron activation analysis is an effective method of analyzing elemental concentration in coal samples. More importantly, it is useful for the purpose of monitoring trace element level around Nigerian Coal mines and Nigeria coal plants by the Environmental protection Agency. However, most elements identified were also found to be in moderate quantities, which shows that most coals found in Nigeria have low trace element concentration level. Based on the findings of this work, it is recommended that detailed study on elemental concentration level in coal samples using INAA and other techniques be investigated in order to ascertain properly the environmental impact of coal, and samples exposed to long irradiation in order to identify other elements.

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HYDROGEOPHYSICAL AND GEOTECHNICAL INVESTIGATION IN UFUMA AND ITS ENVIRONS, ANAMBRA STATE, NIGERIA

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ABSTRACT

Both hydogeophysical and geotechnical investigations have been carried out in some parts of Orumba axis in Anambra State, Nigeria in order to determine the depth to the subsurface water and the geotechnical properties of soil. Fifteen vertical electrical soundings were carried out during the geophysical survey using the Schlumberger Array. The data was interpreted using the conventional curve matching and computer iteration method. Tests were carried out on soil samples which include Particle Size Distribution Analysis and Atterberg Limits tests. The geo-electric results revealed five different curve types namely; K, HK, AK, KQ and QK-curve types. 80% of all the sounding curves belong to HK and AK-types whereas the remaining 20% belongs to other three curve types within the study area. The results also revealed that depths to the water saturated sandstones (aquifer) within the study area range from 42.28m at Ufuma area to 132.99m at Ndiokpalaeze with an average resistivity 2016.93 Ohm-m. The thickness map reveals high aquifer thickness in the northeastern part than the other parts with an average of 95.65m across the area. The water table map indicates NW-SE flow direction and correlates favourably with the topography of the area. The result of the aquifer parameters revealed that the hydraulic conductivity ranges from 7.0×10^{-2} m/day at Umuogem community (VES 6) to 7.35×10^{-1} m/day at Ufuma Community (VES 3) with an average of 2.78×10^{-1} m/day; while the transmissivity ranges from 7.95m^2/day at Umuogem community (VES 6) to 50.32 m^2/day at Ogboji community (VES 12) with an average of 22.26 m^2/day within the study area. The result of sieve analysis reveals medium to coarse grained sand of 85% (by weight) of the soils, while the remaining 14% and 1% are fine grained sand and coarse silt. The Atterberg Limit Tests of the samples collected shows 63.45% liquid limit (LL), 19.13% plastic limit (PL), and 44.33% plasticity index (PI) indicates that the soil samples have good intergranular cohesive force. Based on the hydrogeophysical and geotechnical results, the aquifers are capable of yielding enough water that would serve the immediate environs as well as the soil nature, highly plastic.

Keywords: Hydrogeophysical; lithologic unit; Aquifer; Resistivity; Transmissivity; Erodibility

INTRODUCTION

Potable water is the water which is used for drinking and sanitary purposes. The availability of potable water is an essential matter all over the world and Anambra State is no exception. Groundwater constitutes the only reliable water supply for drinking and irrigation purposes. It is exceptionally important as a source of relatively low-cost and high-quality municipal and domestic water supply in urban centres of the developing world (Okoro *et al*., 2010 and Chinwuko *et al.*, 2015). Nevertheless, current researches have shown that special care and skill are needed for its exploration and exploitation.

Consequently, electrical resistivity method, which is one of the geophysical methods, can now contribute substantially towards this initiative and can greatly reduce the number of necessary pumping tests, which are both, expensive and time consuming. The subsurface information inferred from this survey gives a better knowledge of the aquifer systems and a more realistic picture of groundwater potential of any area (Chinwuko *et al.,* 2015 and Anakwuba *et al.*, 2014,). This method has been successfully used in investigating groundwater potential in different geological settings including sedimentary environment (Emenike, 2000).

However, the geotechnical properties of lateritic soils are influenced by climate, drainage, geology, the nature of the parent rock and the degree of weathering or linearization of the parent rock (Aginam *et al.*, 2015). These factors also differentiate laterite from other soils that are developed in the temperate or cold regions (Aginam *et al.*, 2015). Lateritic soils contribute to the general economy of the tropical and subtropical regions where they are in abundance because, they are widely utilized in civil engineering works as construction materials for roads, houses, landfill for foundations, embankment dams, etc. Lateritic soils are less expensive and useful in road construction, such that they are cheaper than other materials that can achieve comparable strength with them and they are more available than those materials. In Anambra State, laterite is a major road construction material that is used for the sub-grade and, occasionally, the sub-base and base courses of the roads.

This research describes the geo-electric investigation of groundwater potential and geotechnical properties of lateritic soil undertaken in some parts of Orumba Axis of Anambra State. The primary objective of this investigation is to obtain from the geophysical characteristics of the study area, a meaningful delineation of the aquiferous units of the area as well as obtain adequate information on geotechnical properties of the lateritic soils of the area.

GEOLOGY OF THE AREA

The study area falls within Anambra State, Nigeria and it is located between latitude 07^o09^l N to 07^o15^l N and longitude 006^o00^l E to 006^o06^l E (Fig. 1). The formations encountered in the study area were deposited in the Anambra Basin as a result of marine transgression that occurred during the Campanian-Maestrichtian sub-stages of second sedimentary cycle (Nwajide, 1979; Anakwuba *et al.*, 2014; Chinwuko *et al.*, 2015). The formations that outcropped in the study area are Ameki Group (precisely Nanka Sandstone) and Imo Formation (Imo Shale and Ebenebe Sandstone) (Fig. 2).

Nanka Sands (Eocene) forms the dominant geologic formation in the study area. The Nanka Sands is approximately 305m at its type locality (Nwajide, 1979 ; Nfor *et al.*, 2007; Okoro *et al.*, 2010; Chinwuko *et al.*, 2015). It is a lateral equivalent (the same origin) of Ameki Formation. The Nanka Sands consist of fine to coarse grained sands with abundant intercalations of calcareous shale and thin shaly limestone below, and of loose cross–bedded white or yellow sands, with bands of fine-grained sands and sandy clay above (Okoro *et al*., 2010; Anakwuba *et al.*, 2014). The sand member of the formation constitutes the aquifer system.

Afterwards, Nanka Sands are underlain by thick Imo Shale (Paleocene), which is characterized by thick clayey shale with occasional admixture of clay ironstone and thin sandstone bands (Okoro *et al.*, 2010; Anakwuba *et al.*, 2014). The formation is fine textured and dark grey to bluish grey in colour. Its major lithology is the Shale which is impermeable to water and also is generally described as an aquitard however; the sand member of the formation constitutes the aquifer system. The Ogwashi-Asaba Formation was deposited on top of the Ameki Formation in the Oligocene-Miocene. The Ogwashi-Asaba Formation is composed of alternating bands of sandstone and shale (Obiabunmo *et al.*, 2014). The sandstone unit exhibits colours that range from yellow, whitish, red, to reddish brown. It is also mainly ferruginized and indurated, although sometimes friable. The base of the sandstone consists of poorly sorted pebbly to very coarse grained sandy particles with mixture of some fine sand (Reyment, 1965).

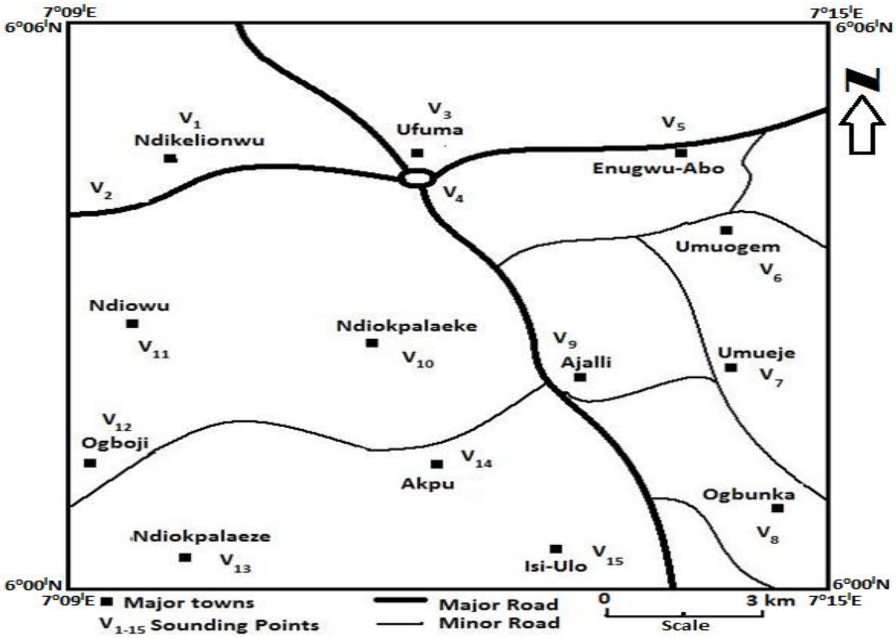

Fig.1: Map of the study area showing towns and VES locations (NGSA, 2010)

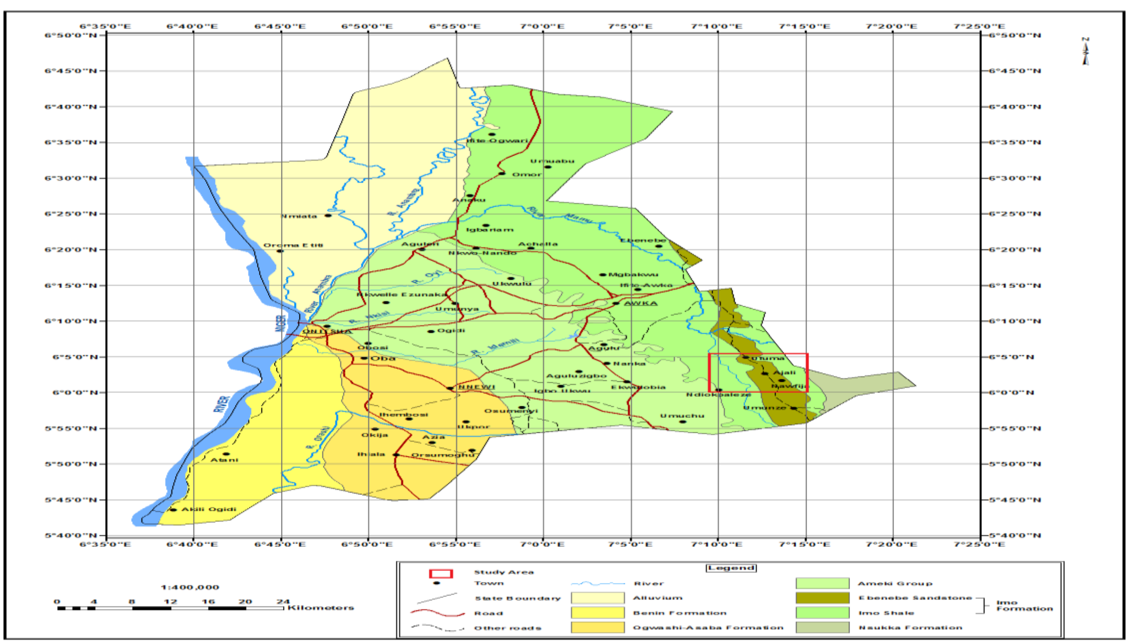

Fig. 2: Geologic map of Anambra State showing the study area (NGSA, 2010)

METHODOLOGY

The vertical electrical sounding (VES) was carried out at fifteen VES locations within the study area (Fig. 1) using ABEM Terrameter SAS 1000 model for groundwater investigation purposes. The Schlumberger electrode configuration having a maximum current electrode spread of 300 m was used. The apparent resistivity values obtained from the measurement were plotted against half the current electrode spacing on a bi-logarithmic graph in order to determine the apparent resistivities and thicknesses of various layers penetrated. This technique has been utilized in groundwater exploration by various researchers such as Onwuemesi and Egboka (2006), Nfor, *et al.*(2007), Oseji and Ujuanbi (2009), Okoro *et al.* (2010), Ezeh (2011), Obiabunmo *et al.* (2014), Anakwuba *et al.*, 2014; Chinwuko *et al.*, 2015, Anizoba *et al.* (2015), Osele *et al.* (2016) and others. The resistivity curves were interpreted quantitatively by matching small segments of the field curves using two-layer model curves and the corresponding auxiliary curves. The resistivity data were interpreted manually using partial curve matching method as well as using Interpex one dimensional (IXID) that was developed by Interpex Limited (http://www.interpex.com/ix1dv3/ix1dv3_version.htm).

Meanwhile, six soil samples were obtained from borrow pits in Ufuma, Enugwu-Abo, Ajalli, Ndiowu, Isi-ulo and Ndikelionwu. The choice of these sites and soil is justified by the fact that it is a borrow pit from where various construction companies get their material for road construction in this parts of Anambra state. The natural moisture content was determined by the oven drying method. Specific gravity of soils, particle size distribution, plasticity characteristics were determined in accordance with procedures outlined in BS 1377 (1990).

RESULTS AND DISCUSSIONS

Qualitative Interpretation of VES Curves

Fifteen geo-electrical sounding curves obtained from the study area (Fig. 3) were interpreted qualitatively. The result revealed five different curve types within the area. Four-layer case of type-K (6.67%) and five layer cases: HK- type (40%); AK-type (40%); type-KQ (6.67%) as well as type-QK (6.67%) were mostly recorded. According to Worthington, (1977) and Chinwuko *et al.*, (2015), each curve types aid in identifying the nature of the successive lithologic sequence in a place and hence can be used, in qualitative sense, to assess the groundwater prospect of an area, including the study area. Curve types present in this study area are often associated with groundwater possibilities.

Quantitative Interpretation of VES

Depth to Aquifer

Four to five geo-electrical units with their corresponding thicknesses and resistivities were interpreted in the area (Fig. 3 and Table 1). The units from top to bottom include the top soil, shaly-sand, shale, sandstone, water saturated sandstone and shale. The results also revealed that depths to the water saturated sandstones (aquifer) within the study area range from 42.28m at

Ufuma area to 132.99m at Ndiokpalaeze with an average resistivity and aquifer's thickness as 2016.93 Ohm-m and 95.65m respectively (Table 1).

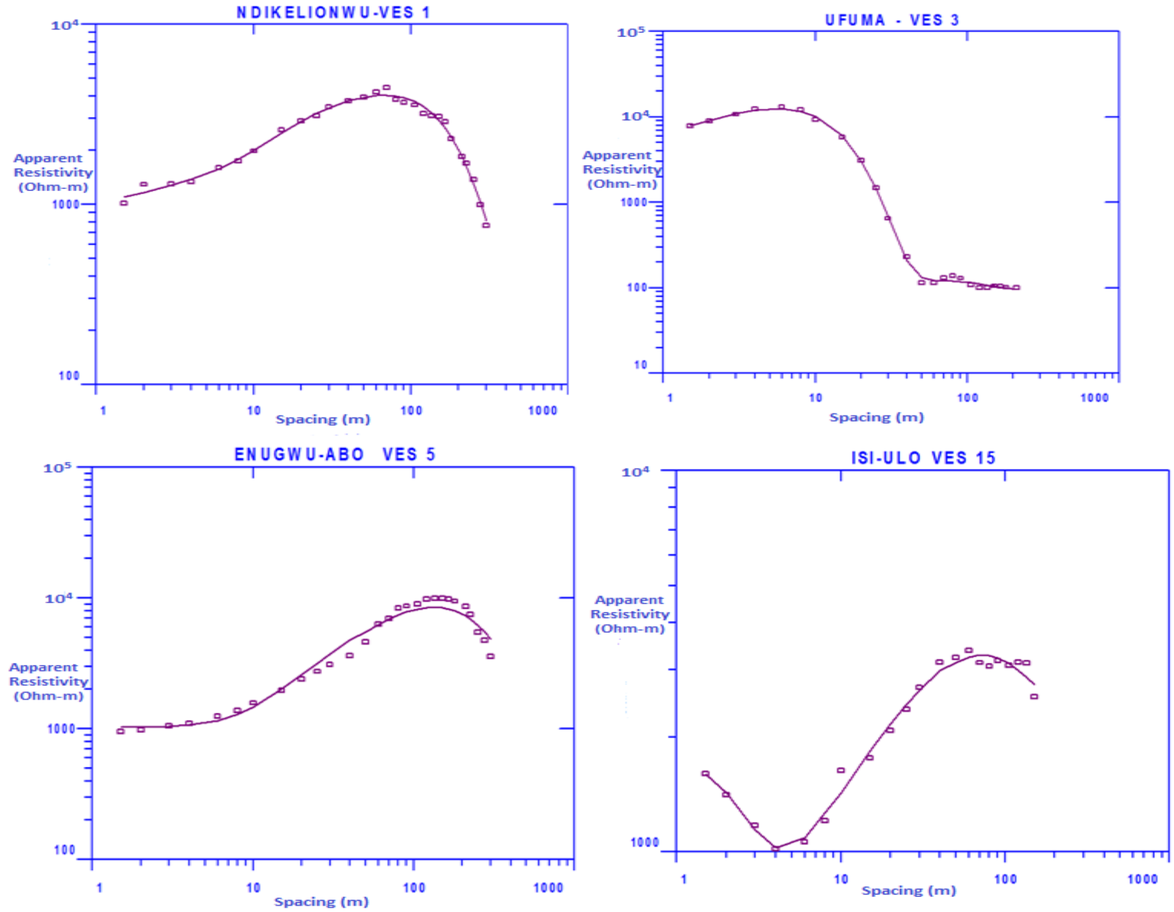

Fig. 3: Representative geo-electric curves within the study area

Table 1: Summary of VES Interpretation with respect to Aquifer

VES No	Curve Type	b (m)	h (m)	ρ (ohm)	R (Ohm-m)	S (Ohm-1)	K_c (m/day)	T_c (m^2/day)
1	AK	75.78	99.54	1472	146522.900	0.0676	0.2449	24.3742
2	AK	78.02	70.21	503.66	35361.970	0.1394	0.7156	50.2423
3	KQ	63.17	18.73	490.60	9188.938	0.0382	0.7347	13.7610
4	HK	42.28	54.91	1994.02	109491.600	0.0275	0.1808	9.9277
5	QK	88.72	136.28	2446.00	333340.900	0.0557	0.1474	20.0877
6	HK	97.16	113.39	5144.15	583295.200	0.0220	0.0701	7.9486
7	HK	73.32	135.43	3711.90	502702.600	0.0364	0.0971	13.1503

8	AK	48.08	80.39	1870.30	150353.400	0.0430	0.1927	15.4912
9	HK	48.52	70.63	937.08	66185.960	0.0754	0.3846	27.1643
10	K	43.67	76.97	1656.40	127493.100	0.0465	0.2176	16.7487
11	AK	56.23	157.64	4281.70	674967.200	0.0368	0.0842	13.2733
12	AK	45.31	165.66	1186.73	196593.700	0.1396	0.3037	50.3109
13	HK	132.99	117.5	1064.90	125125.800	0.1103	0.3385	39.7738
14	AK	38.69	66.52	1158.75	77080.050	0.0574	0.3111	20.6944
15	HK	58.01	70.94	2335.70	165694.600	0.0303	0.1543	10.9460
Average		65.997	95.65	2016.93	220226.500	0.0618	0.278485	22.2596

Key: $\boldsymbol{\rho}$ = *Aquifer resistivity;* $\boldsymbol{h}$= *Aquifer thickness;* $\boldsymbol{S}$=*Longitudinal Conductance;* $\boldsymbol{R}$= *Transverse Resistance;* $\boldsymbol{K_C}$= *Hydraulic Conductivity of Aquifer;* $\boldsymbol{T_c}$= *Transmissivity of Aquifer*

Aquifer Thickness map

The aquifer thickness map was produced using various aquifer thickness obtained within the study area (Fig.4 and Table1). The thickness map reveals high aquifer thickness in the northeastern part than the other parts. The distribution of aquifer thickness values at contour interval of 1m indicates that two distinct zones can be identified within the area. The whitish colour which occurs at the northeastern parts of the map reveals the existence of relatively high thickness of the aquiferous unit (100m to 170m), while the brownish colour at other parts corresponds to relatively moderate thickness of the saturated unit (20m to 90m). The area is generally characterized by a thick and prolific aquiferous unit.

Aquifer Characteristics

The result of aquifer characteristics (Table 1) revealed that the hydraulic conductivity obtained ranges from 7.0 x 10^{-2} m/day at Umuogem community (VES 6) to 7.35 x 10^{-1} m/day at Ufuma Community (VES 3) with an average of 2.78 x 10^{-1} m/day. Meanwhile, the transmissivity ranges from 7.95m^2/day at Umuogem community (VES 6) to 50.31 m^2/day at Ogboji community (VES 12) with an average of 22.26 m^2/day within the study area (Table 1). More so, the result also revealed that the transverse resistance obtained ranges from 9.19 x 10^3 Ohm-m at Ufuma (VES 3) to 6.75 x 10^5 Ohm-m at Ndiowu (VES 11) with an average of 2.20 x 10^5 Ohm-m; whereas the longitudinal conductance ranges from 2.20 x 10^{-2} Ohm-l at Umuogem community (VES 6) to 1.40 x 10^{-1} Ohm-l at Ogboji community (VES 12) within the study area (Table 1). These values of the aquifer characteristic conform to those obtained by Anakwuba *et al.* 2014 and Chinwuko *et al.* 2015.

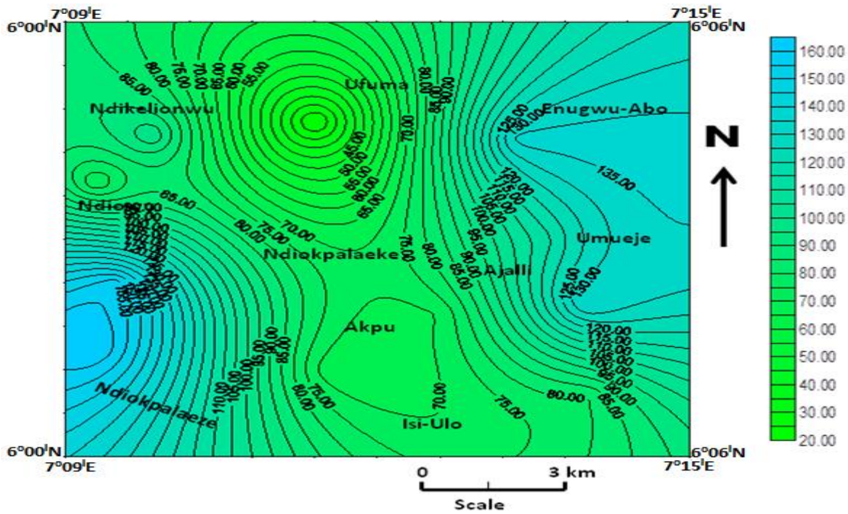

Fig. 4: Aquifer thickness map in the study area (Contour Interval~5m)

Geo-electric correlations within the study area

Cross sections along W-E and N-S directions carried out on interpreted resistivity data from the study area (Fig. 5) show four to five geo-electric layers: the topsoil, siltstone layer, dry sandstone, water saturate sandstone and shale. In the topsoil, resistivity values range from 347.58 to 2057.5 Ohm-m, with thickness varying between 1.09m and 3.08m. The topsoil is relatively thin in most places, with resistivity values characteristically of clayey to sand or lateritic soil. The siltstone layer has resistivity in the range of 25.00 Ohm-m to 1341.30 Ohm-m. The thickness of the Layer ranges from 1.75m to 5.90m. In Ndiokpalaeke area however, this layer was not delineated. Underlying siltstone layer is dry sandstone which has high resistivity values ranging from 1656.4 Ohm-m to 20895.0 Ohm-m. The thickness of this layer ranges from 41.64m to 120.64m. The next layer is the water saturated sandstone which is observed to be characterized by resistivity varying between 713.00 Ohm-m and 5144.15 Ohm–m with considerable thickness range of about 57.51m to 135.43m. Generally, the water saturated sandstones (aquiferous units) in these areas are continuous. Underlying this prospective layer is a conductive material described as shale. Its resistivity is low ranging from 14.02Ohm-m to 713 Ohm–m.

Comparison of Geo-electric section and Borehole section

The comparison of lithologic section from the borehole located near one of the sounding stations at Ufuma and its interpreted geo-electric units (Fig.6), showed that the overburden thickness in the lithologic section is 4.57m (15.0ft) while in geo-electric section, it is 2.57m (8.44ft). In the underlying layers, the geo-electric units show suppression and merging of some lithologic units from the borehole. This is due to the fact that geo-electric units are not the same as lithologic units. A given lithologic unit with variations in resistivity will give rise to so many geo-electric units.

Also, different lithologic units with similar resistivities would be merged as one geo-electric unit. Hence, the water table varies a little from the geo-electric unit with value of depth being 42.91m (140.79ft) in the geo-electric section and 48.77m (160ft) in lithologic unit. There is a high correlation with the borehole section at Ufuma (Fig. 6). This study showed a clear support or proof of the depth to aquifer in the study area.

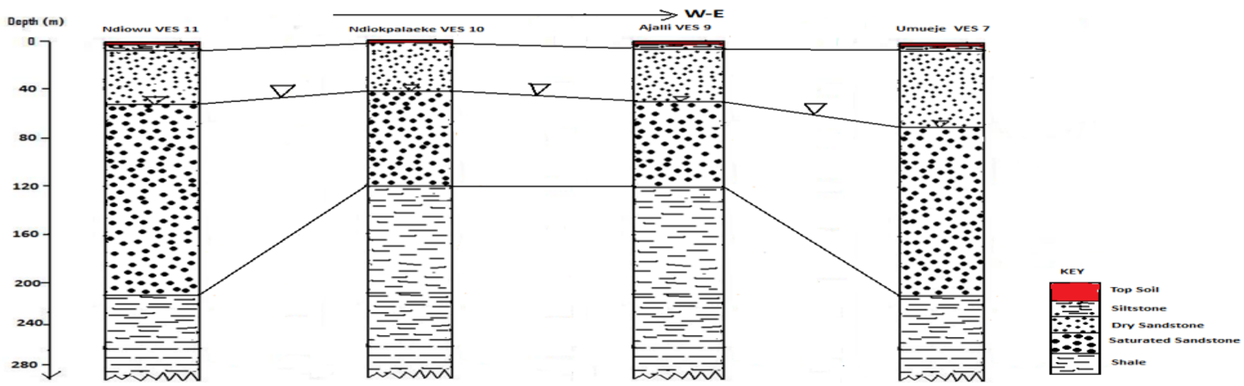

Fig.5a: Geo-electric correlation along W-E

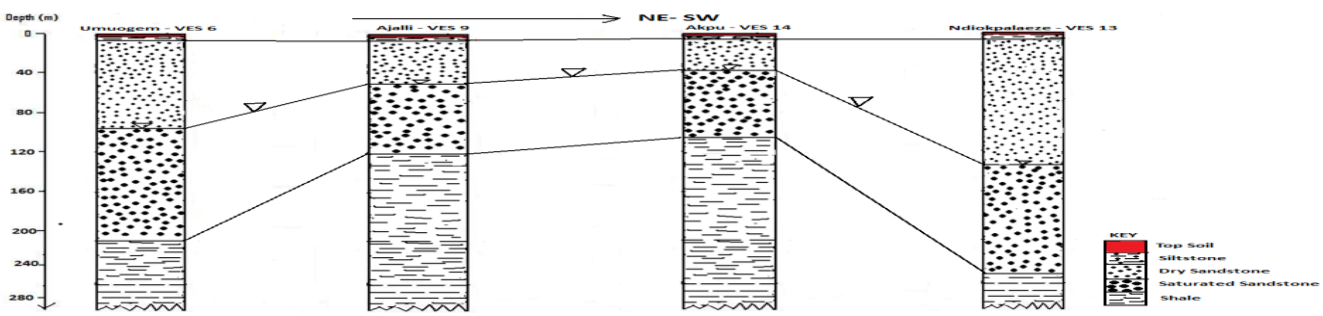

Fig.5b: Geo-electric correlation along NE-SW

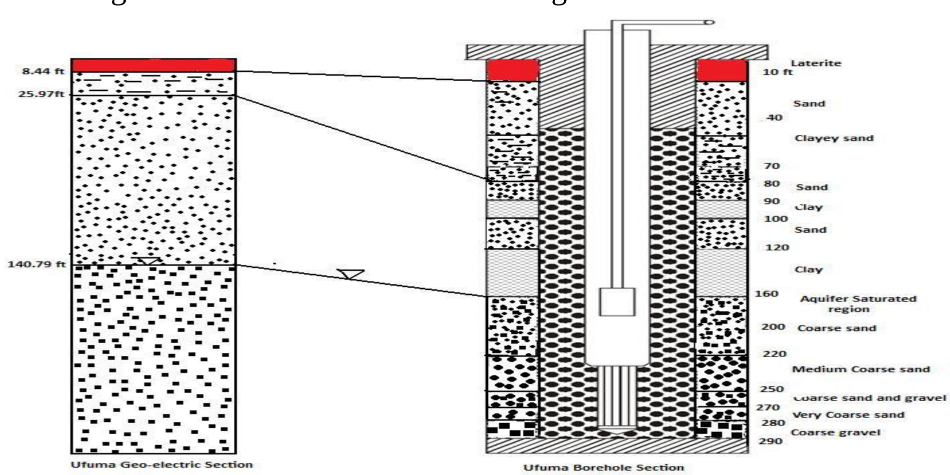

Fig.6: Correlation of geo-electric and borehole sections at Ufuma

Water-table Map

Water-table is the plane, which forms the upper surface of the groundwater-saturated zone in an unconfined aquifer. The level of water table is jointly controlled by the topography, local climatic condition and the nature of the near surface rock of the area. The water-table values were produced by subtracting the depth to aquifer from surface elevation measured from the mean sea level (Table 2). A water-table map was produced (Fig. 7). The relationship between the water-table and topography was studied by drawing cross sections A- B on the topography map and water-table map respectively which was superimposed (Fig.8).The red curve outlined the surface elevation, while the blue curve traced the water-table. The water-table curve follows topography and groundwater flows in NW-SE direction. It was also observed that the hydraulic flow is higher at Ogbunka area because of high intensity of the water-table contour than at Ndikelionwu and Ndiowu areas were the intensity of the water-table contour is less.

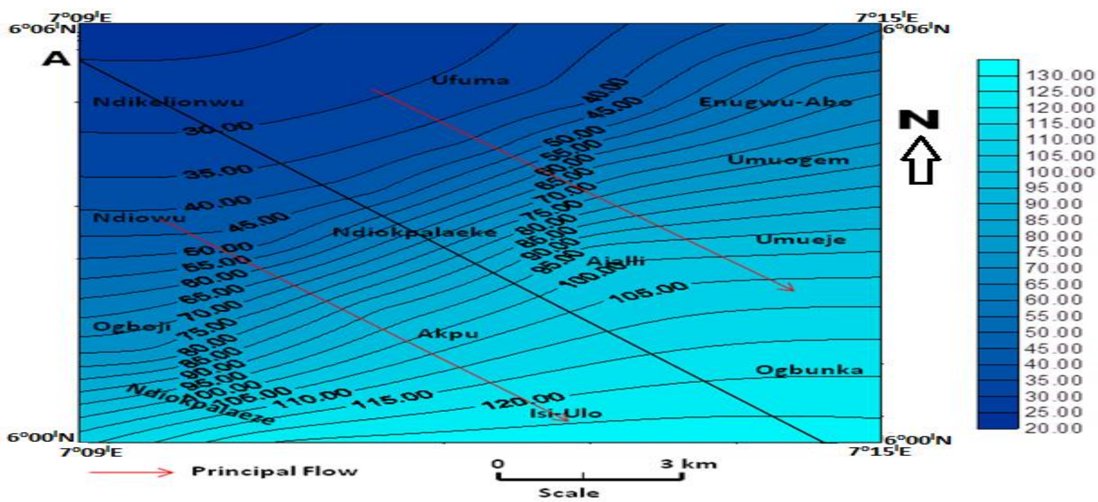

Fig. 7: The water-table map with reference to mean sea level (Contour Interval~5m)

Table 2: Watertable with reference to MSL

VES No	Town Names	Elevation (m)	Depth to water (m)	Watertable w.r.t MSL (m)
1	Ndikelionwu	60.06006006	75.778	-15.71793994
2	Ndikelionwu	75.07507508	78.023	-2.947924925
3	Ufuma	120.1201201	63.174	56.94612012
4	Ufuma	105.1051051	42.28	62.82510511
5	Enugwu-Abo	90.09009009	88.72	1.37009009
6	Umuogem	120.1201201	97.156	22.96412012

7	Umueje	75.07507508	73.315	1.760075075
8	Ogbunka	75.07507508	48.081	26.99407508
9	Ajalli	90.09009009	48.523	41.56709009
10	Ndiokpalaeke	90.09009009	43.668	46.42209009
11	Ndiowu	90.09009009	56.23	33.86009009
12	Ogboji	150.1501502	45.312	104.8381502
13	Ndiokpalaeze	75.07507508	132.986	-57.91092492
14	Akpu	120.1201201	38.686	81.43412012
15	Isi-ulo	150.1501502	58.014	92.13615015

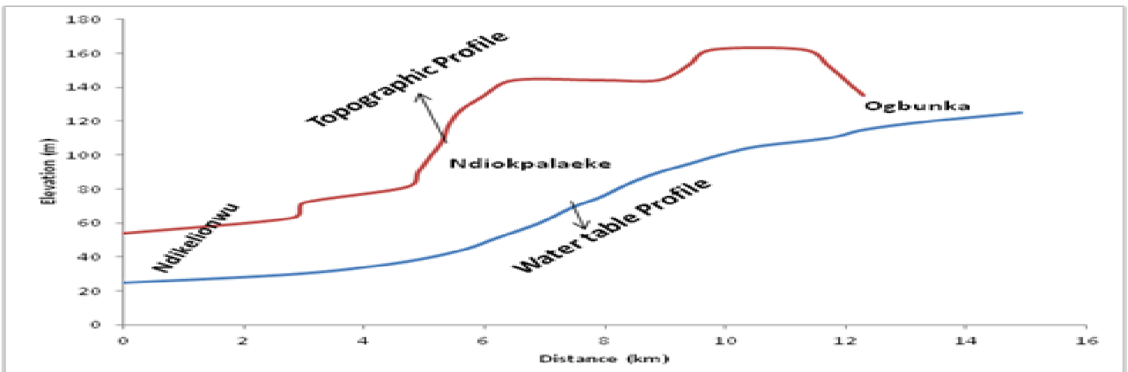

Fig. 8: Composite cross- section of water table and topography

Geotechnical Results and analysis

Grain size analysis

The grain size distribution analysis was carried out (using mechanical shaker) on six soil samples. The result of sieve analysis reveals medium to coarse grained sand of 85% (by weight) of the soils, while the remaining 14% and 1% are fine grained sand and coarse silt respectively. The sorting indicates that the samples range from very poorly sorted at Ufuma to moderately sorted at Ajalli (Table 3 and Fig. 9). Based on the grain size analysis results, removal and transportation of the soil grains by runoff water is easier according to Usman *et al.*, 2014. Smaller particles are easily carried away by water since the transporting medium requires relatively small amount of energy. This is why erodibility potential of the soil units is high.

Table 3: Index properties of collected soil samples within the study area

Property	Sample Description						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average (%)
Specific Gravity	2.67	2.64	2.69	2.61	2.71	2.68	2.67
% gravel (> 2mm)	0	0	0	0	0	0	0
% Coarse grained sand (<2mm to 0.15mm)	86.43	78.02	85.88	87.43	86.89	87.06	85.29
% fine Sand (<0.15mm to 0.018mm)	12.55	21.53	12.81	11.7	12.13	12.856	13.93
% silt (<0.018mm)	1.02	0.45	1.31	0.87	0.98	0.084	0.79
Liquid limit (%)	64.62	60.74	67.71	64.21	63.42	60.00	63.45
Plastic limit (%)	21.04	21.02	17.04	18.05	19.10	18.50	19.13
Plasticity Index (%)	43.58	39.72	50.67	46.16	44.32	41.50	44.33

Result of Atterberg Limits Tests

The Atterberg Limits Tests of the samples collected (Table 3) shows 63.45% liquid limit (LL), 19.13% plastic limit (PL), and 44.33% plasticity index (PI) indicates that the soil samples have good intergranular cohesive force (Fig. 9 and Table 3) and the result also correlate with that obtained by Aginam *et al.*, 2015. The moderate clay content of the soil units observed in parts of the study area minimizes devastation caused by gullies.

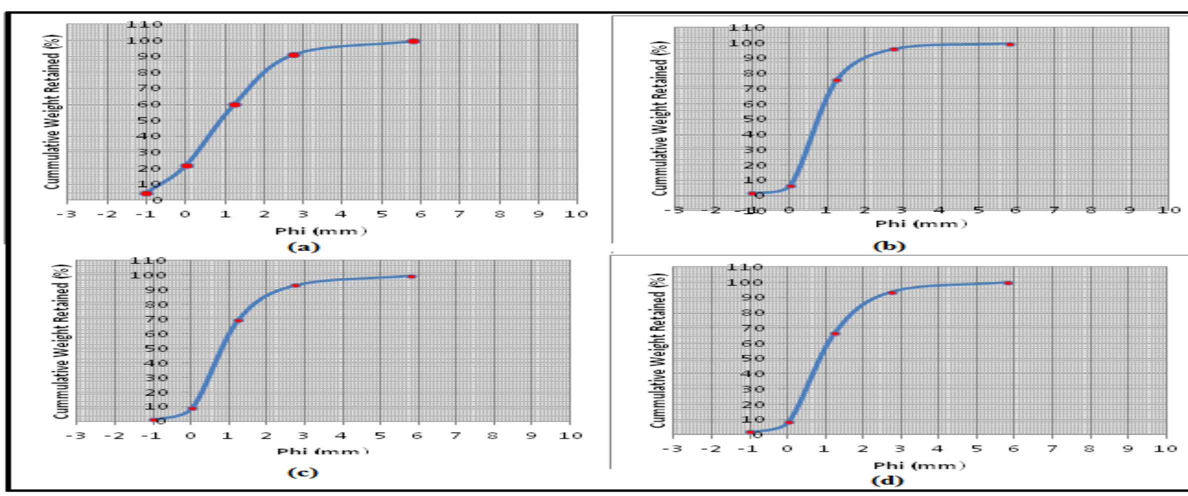

Fig. 9: A Cummulative frequency graph of sample 1-4 from the study area

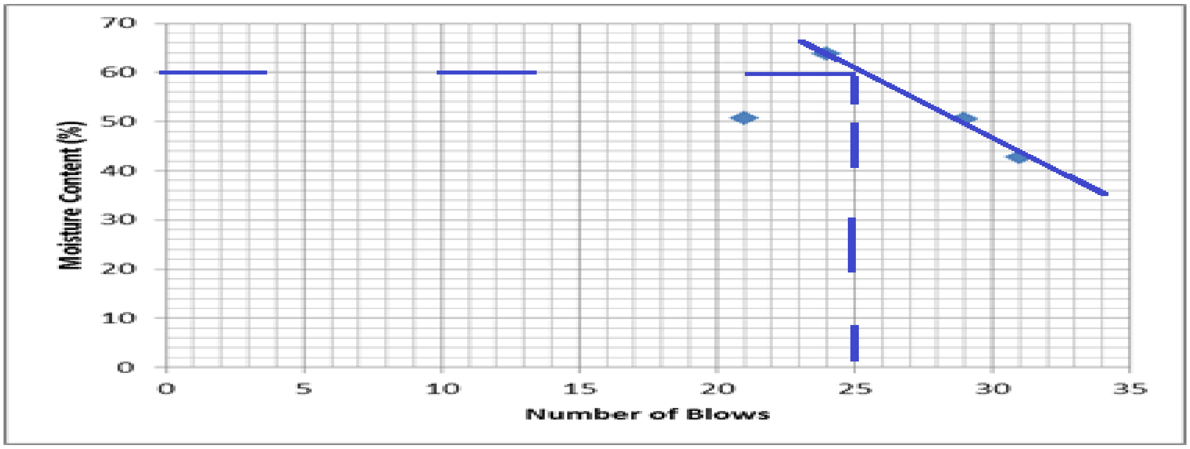

Fig. 10: A plot of moisture content against number of blows

Conclusions

Hydrogeophysical and Geotechnical Assessment in Ufuma and its Environs of Anambra State, Nigeria were carried out and the conclusions are as follows:

1. The geo-electric results revealed five different curve types namely; K, HA, AK, KQ, and KQ-curve types. 80% of all the sounding curves belong to HK and AK-types whereas the remaining 20% belongs to other three curve types within the study area.
2. The results also revealed that depths to the water saturated sandstones (aquifer) within the study area range from 42.28m at Ufuma area to 132.99m at Ndiokpalaeze with an average resistivity 2016.93 Ohm-m. The thickness map reveals high aquifer thickness in the northeastern part than the other parts with an average of 95.65m across the area.
3. The water table map indicates NW-SE flow direction and correlates favourably with the topography of the area.
4. The result of the aquifer parameters revealed that the hydraulic conductivity ranges from 7.0 x 10^{-2} m/day at Umuogem community (VES 6) to 7.35 x 10^{-1} m/day at Ufuma Community (VES 3) with an average of 2.78 x 10^{-1} m/day; while the transmissivity ranges from 7.95m^2/day at Umuogem community (VES 6) to 50.31 m^2/day at Ogboji community (VES 12) with an average of 22.26 m^2/day within the study area
5. The result of sieve analysis reveals medium to coarse grained sand of 85% (by weight) of the soils, while the remaining 14% and 1% are fine grained sand and coarse silt respectively. The Atterberg Limits Tests of the samples collected shows 63.45% liquid limit (LL), 19.13% plastic limit (PL), and 44.33% plasticity index (PI) indicates that the soil samples have good intergranular cohesive force.

6. Based on the hydrogeophysical and geotechnical results, the aquifers are capable of yielding enough water that would serve the immediate environs as well as the soil nature, highly plastic.

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GROUNDWATER QUALITY MAPPING USING GEOGRAPHIC INFORMATION SYSTEM (GIS): A CASE STUDY OF BOSSO LGA, NIGER STATE, NIGERIA

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Abstract
Spatial variations in ground water quality in Bosso Local Government Area located in the north-Central part of, Niger State, Minna Nigeria, have been studied using geographic information system (GIS) technique. GIS, a tool which is used for storing, analyzing and displaying spatial data is also used for investigating ground water quality information. For this study, water samples were collected in Bosso LGA. The water samples were analyzed for some parameters: These include very important physical tests like Ph; temperature, dissolved oxygen, Total dissolved oxygen, Phosphate ion, Sulphate and Nitrate, and compared with the standards. The ground water quality information maps of the entire study area have been prepared using point interpolation for all the above parameters. The results obtained in this study and the spatial database established in GIS will be helpful for monitoring and managing ground water pollution in the study area.
Key words: Groundwater pollution, spatial interpolation. GIS, Water quality.

INTRODUCTION

Groundwater is one of earth's most vital renewable and widely distributed resources as well as an important source of water supply throughout the world. The quality of water is a vital concern for mankind since it is directly linked with human welfare. In Nigeria, most of the population is dependent on groundwater as the only source of drinking water supply (NIUA, 2005; Mahmood and *Kundu, 2005; Phansalkart a 2005).* The groundwater is believed to be comparatively much clean and free from pollution than surface water. Groundwater can become contaminated naturally or because of numerous types of human activities; residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality (U.S. EPA, 1993; Jalali, 2005a; Rivers et al., 1996; Kim et al., 2004:

Srinivasamoorthy et al., 2009; Goulding, 2000; Pacheco and Cabrera, 1997). contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies, and potential health problems. A wide variety of materials have been identified as contaminants found in groundwater. These include synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radionuclides (Fetter, 1999). The importance of water quality in human health has recently attracted a great deal of interest. In developing countries like India around 80% of all diseases are directly related to poor drinking water quality and unhygienic conditions (Olajire and Imeokparia, 2001; Prasad, 1984).

Groundwater is a valuable natural resource that is essential for human health, socio-economic development, and functioning of ecosystems (Zektser, 2000; Humphreys, 2009; Steube et al., 2009). In Niger state, severe water scarcity is becoming common in several parts of the Bosso communities. The exploitation of groundwater to meet demands of domestic, agriculture, and industry sectors has resulted in overexploitation of groundwater resources. Geographic information system (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields (Stafford, 1991; Goodchild, 1993; Burrough and McDonnell, 1998; Lo and Yeung, 2003).

GIS has been used in the map classification of groundwater quality, based on correlating total dissolved solids (TDS) values with some aquifer characteristics (Butler et al., 2002) or land use and land cover (Asadi et al., 2007). Other studies have used GIS as a database system in order to prepare maps of water quality according to concentration values of different chemical constituents (Skubon, 2005; Yammani, 2007). In such studies, GIS is utilized to locate groundwater quality zones suitable for different usages such as irrigation and domestic (Yammani, 2007). A similar approach was adopted by Rangzan et al. (2008) where GIS was used to prepare layers of maps to locate promising well sites based on water quality and availability. Babiker et al. (2007) proposed a GIS-based groundwater quality index method which synthesizes different available water quality data (for example, TDS, PO4,NO3, DO,) by indexing them numerically relative to the WHO standards.

Water quality assessment involves evaluation of the physical, chemical, and biological nature of water in relation to natural quality, human effects, and intended uses, particularly uses which may affect human health and the health of the aquatic system itself (UNESCO/WHO/UNEP, 1996). In groundwater studies, GIS is commonly used for site suitability analyses, managing site inventory data, estimation of groundwater vulnerability to contamination, groundwater flow modeling, modeling solute transport and leaching, and integrating groundwater quality assessment models with spatial data to create spatial decision support systems (Engel and Navulur, 1999). A GIS-based study was carried out by Barber et al. (1996) to determine the impact of urbanization on groundwater quality in relation to land-use changes. GIS has been useful in establishing the spatial relationship between pollution level and its source in this study. ArcView GIS was used to map, query, and analyze the spatial patterns of groundwater in north-central). Ducci (1999) roduced groundwater contamination risk and quality maps by using GIS in Southern Italy. It was suggested that the use of GIS techniques is vital in testing and improving the groundwater contamination risk assessment methods.

Considering the above aspects of groundwater contamination and use of GIS in groundwater quality mapping, this study was undertaken to map the groundwater quality in Bosso LGA, Niger state, Nigeria. The literature survey indicates that several researchers have made studies on groundwater quality of both bore wells and open wells in the city. Some have studied only physico-chemical parameters, while some have observed the parameters in a combined state. This study aims to visualize the spatial variation of certain physico-chemical parameters through GIS.

The main objective of the research work is to map groundwater quality assessment using GIS, based on the available physico-chemical data from 25 locations in Bosso LGA.

The purposes of this assessment are (1) to provide an overview of present groundwater quality, (2) to determine spatial distribution of groundwater quality parameters such as Hardness, TDS, NO_3^-, and (3) to generate groundwater quality zone map for the Bosso LGA.

MATERIALS AND METHODS

Study area

Bosso Local Government Area lies in the savanna zone of the tropics between latitude (8^0 10^1N and 11^0 30^1N) and longitude (3^0 30^1E and 7^0 30^1E) as shown in (Fig.1) below , it covers an area of about 159km^2. The area is characterized by dry and rainy seasons. The rainy season commences in April and ends late October. The average rainfall is about 1209.75mm, and mean annual evapotranspiration of about 1200mm (Ogunbajo, 1978), and mean minimum and maximum temperatures of 15.2 ^oC and 39.7 ^oC (Adamawa State Diary, 2000). The major occupation of the people is agriculture and the area is characterized by rural setting. Sources of water supply are from hand-dug wells, shallow boreholes and streams. These sources of water supply are unreliable as the quality of the water is poor coupled with poor sanitary conditions. The type of waste disposal practice in the area is the open dump waste disposal system for household solid waste, and most residents use pit latrines. The main objectives of the present study involve assessment of potable groundwater samples for physico-chemical parameters and development of Water Quality Index, and mapping of their spatial distribution using GIS technology.

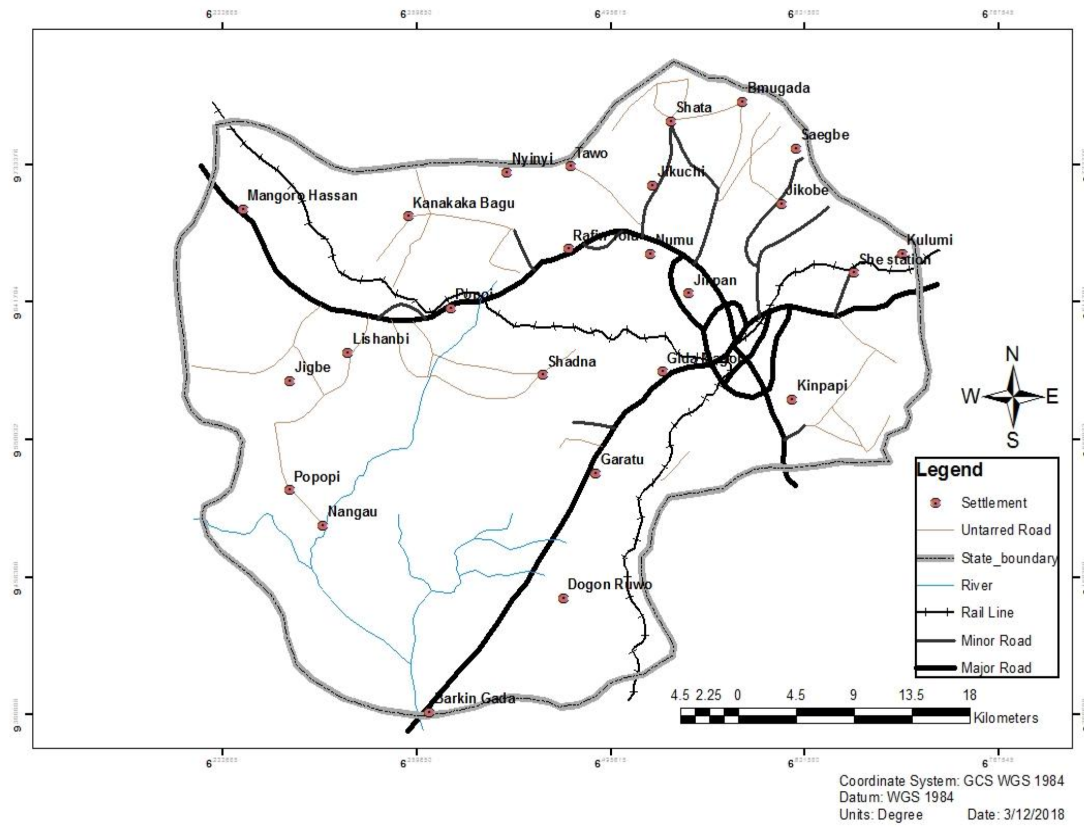

Fig 1 Study area Location Map

Groundwater sample collection and analysis

As part of the study, groundwater samples are collected from 25 shallow wells. The samples were taken during September, 2017 and were analyzed for various physico-chemical parameters. Bottles used for water sample collection are first thoroughly washed with the water being sampled and then were filled. After collection of the samples, the samples are preserved and shifted to the laboratory for analysis. Physico-chemical analysis was carried out to determine TDS, TH, SO4, and $NO3^-$, and compared with standard values recommended by World Health Organization (WHO, 1993) and Indian Standards Institution (ISI, 1991) (Table 1).

As groundwater in Bosso LGA is extensively used for drinking purpose and the water quality testing in this study is restricted to measurement of Nitrate, Total Dissolved Solids, and Phosphate (TDS, NO3,SO4) and determination of potential contamination. The major indicators of contamination, $SO4^-$, TDS and $NO3^-$ are considered for the analysis. One of the sources of nitrate is on-site disposal systems such as septic tanks. The disturbance of soil during house building can also lead to an amount of nitrate leaching similar to the one observed when grassland is ploughed for agricultural purposes (Wakida and Lerner, 2006).

Preparation of well location point feature

The groundwater quality classification map from thematic maps based on the WHO (1993) and ISI (1991) standards for drinking water. Hand held GPS instrument GARMIN GPS-62 receiver was used to take the coordinates at samples station. GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS. Based on the location data obtained, samples station point feature showing the position of 25 shallow wells (Figure 1)

The water quality data obtained from the non-spatial database. It is stored in excel format and linked with the spatial data by join option in ArcMap. The spatial and the non-spatial database formed are integrated for the generation of spatial distribution maps of the water quality parameters. For spatial interpolation Inverse Distance Weighted (IDW) approach in GIS has been used in this study to delineate the locational distribution of groundwater pollutants.

Inverse distance weighting (IDW)

In interpolation with IDW method, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point.

Criteria for acceptability and rejection in water quality

In this stage, the criteria for suitability and non-suitability of the water samples were elucidated for analysis. This was performed based on the water quality standards stipulated by the WHO, and ISI. Ranks were assigned for each parameter depending on the effect of contaminants.

Table 2. Criteria for acceptability and rejection in water quality. (Unit is mg/L

S/NO	Parameters	Rank	Criteria	unit	Remarks
1	TDS	1	<500	(mg/l)	Desired
		2	500-1000	(mg/l)	Acceptable
		3	>1000	(mg/l)	Not Acceptable
2	TH	1	<500	(mg/l)	DESIRED
		2	500-1000	(mg/l)	Acceptable
		3	>1000	(mg/l)	Not Acceptable
3	NO3	1	<45	(mg/l)	Desired
		2	45-1000	(mg/l)	Acceptable
		3	>1000	(mg/l)	Not Acceptabl

Groundwater quality mapping

Various physico-chemical parameters like nitrate, Sulphate, Phosphate, TDS, and hardness were analyzed in the groundwater samples used for drinking purposes and their levels in different locations of the study area are shown in Table 3. The main sources of nitrate and other pollutants are on-site disposal systems such as septic tanks which is a common practice in most communities. Nitrate may have a high impact on groundwater quality because of the high concentration of potential sources in a smaller area than agricultural land (Wakida and Lerner, 2005).

Table 1 shows a number of major drinking-water quality parameters and their corresponding permissible limits as recommended by WHO (1993) and ISI (1991). Some groundwater samples were found to have Hardness, Nitrate, Sulphate, Phosphate and Total dissolved solids (TDS) values within the range desirable limits. Having plotted the values for various sample locations and interpolated surfaces. Data were generated for water quality thematic maps for NO3, SO4, TDS, and SO4 within the study area showing locations that fell within the potable, potable in the absence of better alternate source and non-potable zones.

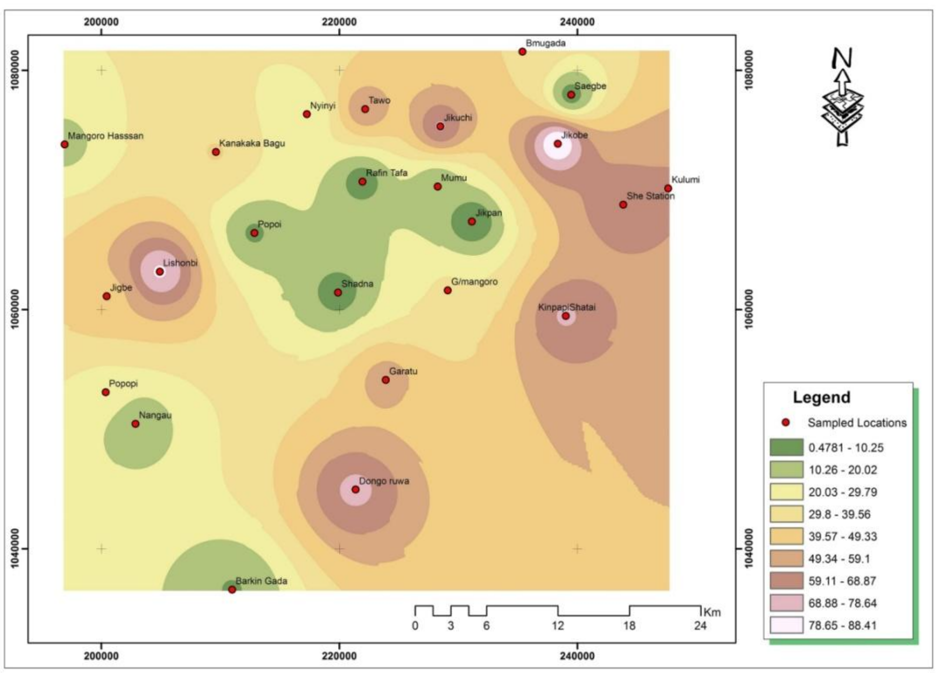

Figure 2: Map of NO3 Distribution for Dry Season

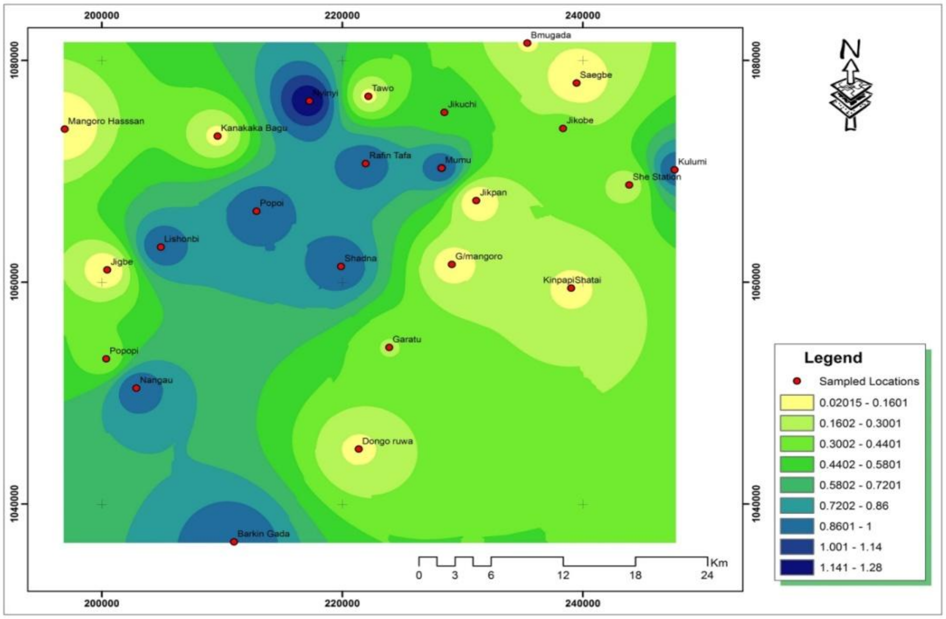

Figure 3: Map of PO4 Distribution for Dry Season

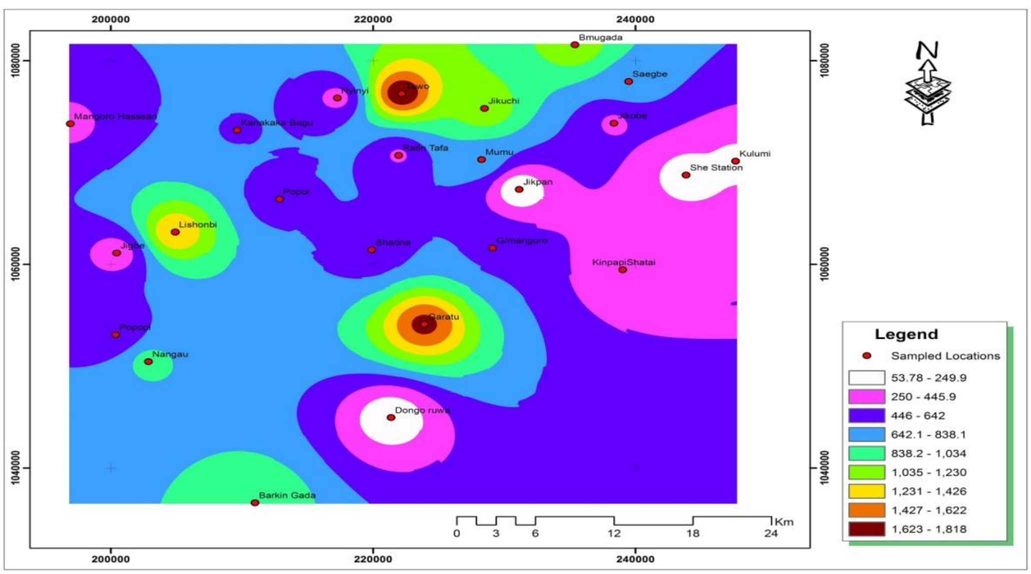

Figure 4: Map of TDS Distribution for Dry Season

Drinking- groundwater quality map

Figure 2, 3, and 4 show the three thematic grid maps for TDS, SO4 and NO_3^- The spatial integration for groundwater quality mapping was carried out using ArcGIS Spatial Analyst extension.

Conclusion

After the overlay of critical parameters for potable and non-potable zones in Bosso LGA, the final Ground-water Quality Map derived shows spatial distribution of the groundwater in the area. The results obtained gave the necessity of making the public, local administrator and the government to be aware on the application of GIS to assess the portability of groundwater quality. The government needs to make a scientific and feasible planning for identifying an effective groundwater quality management system and for its implementation. Since, in future the groundwater will have the major share of water supply schemes, plans for the protection of groundwater quality is needed. Present status of groundwater necessitates for the continuous monitoring and necessary groundwater quality improvement methodologies implementation.

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EVALUATION OF HYDRO WEED CONTROL METHOD ON SAWAH ECO-TECHNOLOGY RICE FARM AT LANDMARK UNIVERSITY, OMU-ARAN, KWARA STATE

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Abstract:

Green revolution has yet occurred in West Africa and Sub-Sahara Africa. West Africa is a core region of SSA as far as rice production and importation and in addition to rice consumption. In Nigeria, rice is the most important food crop, and accounts for 29% of the total calorie intake of her populations. Rice is largely grown on small family farms, which are usually less than 4 hectares, and throughout these smallholder systems, weeds are the most widely reported biological constraint to yields.2 by 3 factorial complete randomized research design was used to evaluate the hydro-weed control method. The results obtained shows that weed did not grow on either of the sawah rice farm basins till the fourth weeks from the date of transplanting. However, the percentage of weed density ranges from 0 to 2% and 2 to 85% for hydro-controlled and not hydro-controlled basins, respectively. Likewise, the mean percentage of weed density ranges from 0 to 0.67% and 0.67 to 76.67% for hydro-controlled and not hydro-controlled basins, respectively. Generally, the results showed that the percentages of weed density increase as the week increases both for the hydro-controlled and non-hydro-controlled basins. Characterization of the little weeds that survives at different water levels in a sawah developed rice farm amongst others were recommended.

Key words: Sawah Technology, Rice Farming, Hydro Weed Control.

1.0 Introduction

Green revolution has yet occurred in West Africa and Sub-Sahara Africa (Wakatsuki, 2011). In spite of the fact that food crops are extremely diverse, the total production per capital of some major crops has been stagnating between140-170kg in Sub-Sahara Africa (SSA) but in tropical Asia, in light of the green revolution, the figures expanded from 205kg in 1961-1965 (Wakatsuki, 2011). This is the establishment of high discrepancy of economic growth between SSA and Asia at present. Presently Asia is a global center of economic growth on account of the green revolution that started in 1970s.

West Africa is a core region of SSA as far as rice production and importation and in addition to rice consumption. Although upland was the major rice ecology 15 years prior, however, it is no more the biggest rice production ecology in West Africa now. If this pattern proceeds, upland rice production ecology will be little in SSA particularly in West Africa sooner rather than later (FAO-STAT, 2006). This is anyway extremely encouraging change to understand the green revolution at long last in West Africa and SSA. In the vicinity of 1984 and 2003, yearly paddy production increased drastically from 3.4 to 7.7 million tons in West Africa. Real increments were from the rain-fed lowland rice production, for the most part inland valleys, which extended from 0.53 to 1.8 million ha and yield expanded from 1.4 to 2.0 t/ha (Wakatsuki, 2011). This process of lowland rice production is otherwise known as sawah eco-technology for rice farming.

The concept and the term "sawah" refers to man-made improved lowland infrastructural development that is characterized with system design, ploughing, bunding, puddling, good agronomic practices and water management for rice farming. Irrigation and drainage canal are provided for effective water management.

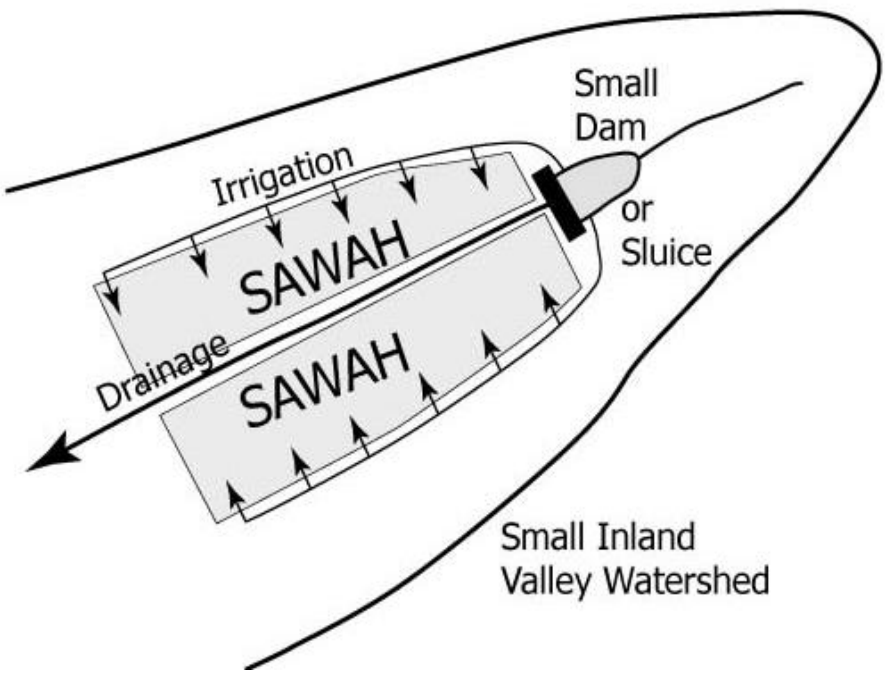

Figure 1: Sawah rice farm showing good water management

If the degree of water control improves, sustainable rice yields will increase (Hiose and Wakatsuki, 2002). In order to control water, sawah system has to be developed, improved and managed as shown in Figure 1. The four basic skills of sawah eco-technology for rice farming include, site selection and system design; skill and Technology for bush clearing and de-stumping; land preparation for bunding, ploughing, puddling, leveling and smoothening; socio-Economic Skills for Rice farmers empowerment; sawah based rice farming management of water intake, storage, distribution and drainage systems.

The number four skill of sawah eco-technology for rice farming is the only one that covers the scope of this study as this study tends to shed more light on the hydro weed control efficiency on sawah rice farm.

In Nigeria, rice is the most important food crop, and accounts for 29% of the total calorie intake of her populations. Rice is largely grown on small family farms, which are usually less than 4 ha, and throughout these smallholder systems, weeds are the most widely reported biological constraint to yields. Upland rice, in particular, competes poorly with weeds and uncontrolled weed growth often results in negligible or zero yield. In West Africa, yields of rice with farmers' weed control, were 44% lower than on researcher weeded plots (David, 2010). Losses due to uncontrolled weed growth in rice farm in India were up to 90%, and in both lowland and upland systems in Africa losses were within the range 28-100% (David, 2010). In Belize, Central America, two years after clearing a fallow, yields of upland rice with no weed control were less than 20% of those when the crop was hand weeded twice after sowing. Losses can be particularly severe in direct seeded lowland rice, as the rice and weed seedlings are at similar growth stages. But, in transplanted rice, the young rice plants have an advantage over germinating weeds.

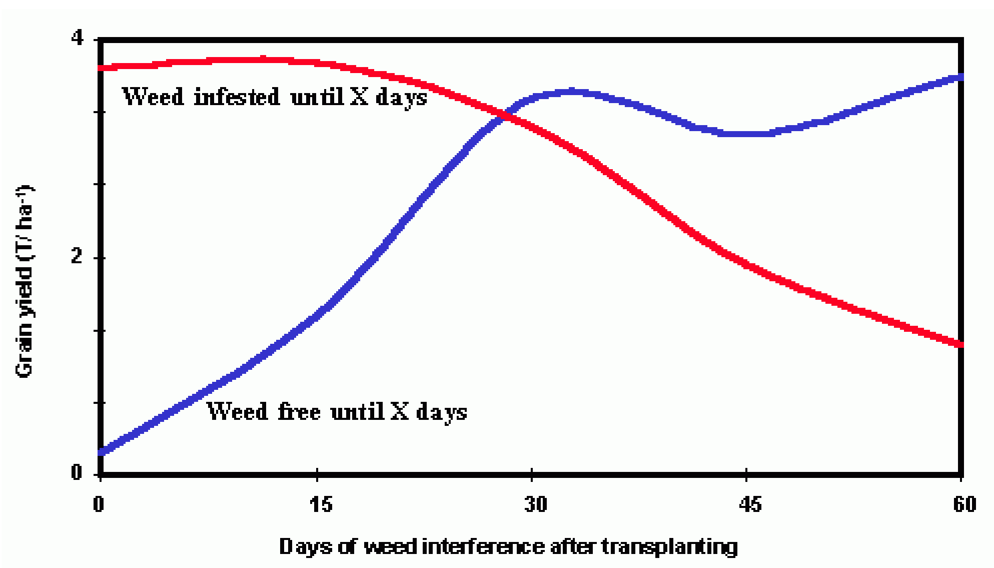

Figure 2: Effect of weed interference on lowland rice yield

2.0 Aim and Specific Objectives

The aim of this study is to evaluate hydro-weed control method on a sawah developed rice farm in Landmark University, Omu-Aran, Kwara State, Nigeria.

The specific objectives were to:

- Prepare the sawah rice farm using G100 Boxer Kubota power tiller
- Prepare each sawahbasins for system design, bunding, ploughing, leveling and smoothening
- Create proper irrigation and drainage canal water management
- Using 2 by 3 factorial complete randomized research designto evaluate the hydro-weed control method.

The power tiller is the only power-driven tool that is effectively being used for "Sawah" activities currently in Nigeria. It is less sophisticated and not too expensive. The power tiller comes in various types and power ratings such as G100 Boxer Kubota or shanty power tillers etc. The unit has two hand steering clutches, for ease of turning and uses two B-section v-belts. The engine block is anchored unto a flattened c-shaped support member, by means of three positioning belts. The block can slide freely by loosening bolts such that the Centre distance between the transmission pulley and engine pulley can be varied if necessary. Principally, power tillers are designed primarily for paddy areas. The best use of power tiller during farming operation is when it is operating at high tractive efficiency. Tractive efficiency is affected by the interaction between ground drive system and ground support at the track-soil contact area. Hence, low tractive efficiency of the power tiller is due to a high percentage of wheel slip. The versatility of the power tiller can be seen in its operation of ploughing, puddling, leveling and harvesting.

3.0 Material and Methods

3.1 Study Area

The study area is Landmark University agricultural research farm which has a coordinate of latitude 8.1239^{o}N and longitude 5.0834^{o}. Landmark University is located at about 95km to Ilorin, the capital of Kwara State. Landmark University a leading agrarian revolutionary university with aim of improving the agricultural sector of the Nigeria and Africa at large.

3.2 Research Methodology

Sawah being a multifunctional lowland infrastructural development requires good sites for sustainable rice production in a revolutionary measure. Sawah rice farming systems was the technology adoptable in this study. The sawah eco-technology for rice farming practices carried out were site selection, system designs, Land preparation (bunding, ploughing, puddling leveling) and water management.

3.2.1 Site selection

The criteria for site selection cannot be overemphasis. The study area was selected based on the fact that it is lowland of a good number of hectares considered enough for the study with the presence of perennial water flow. However it's an area of no strong flood attack. This information was gotten from the Landmark University staff in-charge of the university farm.Care was taken in the design of the drainage canal to ensure that if there is flood at all, the flood depth should be less than 50cm and must not continue for more than 2 days. Another factors considered for the site selection are the topography of the land which is nearly flatwith good access road for plant and machinery mobilization.

3.2.2 System design

Complete Sawah system design is multifaceted as the lowland was designed based on the decent gradient of the land topography. This operation was followed after successful site selection exercise. Various skills such as site survey and mapping through which upland and lowland border were drawn, irrigation and drainage canal line are identified and constructed. Sawah delineation was based on control line between 20-30cm height differences. This reduced the quantity of soil movement for leveling and the target height difference of 10cm or less was expected after leveling in standard quality of Sawah farm. The delineations were started from the lowest valley bottom of the farmland and was straight and large as possible for efficient use of power tiller.

3.2.3 Rice seed selection

The need to select good seed was to produce strong, healthy seedlings that will give maximum yield possible under prevailing sawah conditions. Steps taken in obtaining good seed and raising healthy seedlings were to select a good variety and clean healthy seeds, test the percentage of germination and so raised them in nurseries for possible transplanting. Although, variations ingottengood seedlings could also arise due to grain size, tillering ability, percentage of germination, expected losses caused by birds and diseased.

3.2.4 Land preparation

Land preparation are usually defined as the mechanical manipulation of the soil aimed at improving soil conditions affecting crop production. The land preparation started with the complete removal of all vegetation, which were buried completely to avoid re-growth through the pulverization of the soil to destroy lumps for proper land leveling. The order of the activities involved in land preparation were:

Ploughing

This is a process of overturning the top soil to bury the previous vegetation, loosen and aerate the soil, and bring leached nutrients back to the surface. Ploughing was done from one week before seedlings transplanting so as to give time for overturned vegetation to rot/decompose. Land preparation was frequently mechanized by using power tiller machine and its associated plough implement. The ploughing depth of cut was between 10and15cm. The ploughing was done with a power tiller implement called mould board plough.

Bunding

This simply means making soil mounds round the perimeter of the Sawah basin. Powertiller was also used to do approximately 70%of the bunding while the remaining 30% was complemented using human effort. The size of the basinin terms of the height, width with compaction and surface sealing to control leakage was determined by the slope of the land.

Flooding

flooding the ploughed sawahbasins was carried out to soften the overturned top soil and thereby preventing the log of soil from gotten dried up. Also, the ploughed basins were flooded to provide better working environment for the next operation and to ensure easy movement of power tiller within the basins. The bunds of each basins were kept closed In order to hold the flood water inside the basins.

Puddling

Puddling was carried out to soften the soil and turn it into slurry form. This is for reducing percolation and help with in leveling. Puddled basins was not allowed to stay long as it was done a day before transplanting in the case of this study. The puddling was done with a power tiller implement called puddler.

Leveling

The aim of leveling in land preparation was to produce a flat field where water management and nutrient distribution can be made easier. This stage involves the movement of soil from higher spots to lower spots; ending up with a smooth, level area before transplanting. The leveling was done with a power tiller implement called leveler.

3.2.5 Water management

The water management is the practice that has to do with when and how to irrigate(flooded) or drained sawah basins. The main objective of water management was to avail enough amount of water required to improve the soil moisture conditions for the cultivation of rice. The basins were filled with water at depth considered suitable for the sawah rice cultivation. The irrigation and drainage canals were controlled in a way to ensure almost constant water levels inside the basins. The bunds were constantly maintained throughout the period of this study to ensured blockages free, no leakages, cleaning for over-grown weeds along the canals and bunds if the cave in were immediately reshaped and corrected.

Water management being the major sawah component for the hydro weed control was treated at different levels such as.

Water Management before Planting (Land Preparation)

Water management in rice cultivation under the "sawah" system started during puddling and leveling. Large volume of water, about 5 cm depth and above of water was required at this stage. Puddling was down to turn the soil into a fine medium (mud). Through this process the soil structure is practically destroyed or disorganized. It was necessary to build bunds where they are not available and to repair any broken ones. This improves the impounding of water. Leveling is the process of moving soil from one point (higher level) to another (lower level) in order to create an even and level surface for uniform water retention and distribution. These were the stages of land preparation that needs a very good water management for easy soil movement and equipment operations.

Water Management during Planting (Seeding and Transplanting)

The rice nursery was established and wetted until it was fully grown up to 25 cm and above for a period of three to four weeks. The nursery was kept moist till it was transferred into the prepared basins. A seedling of about two to three stands were transplanted into the basins that have been prepared, however, a minimum water level of about 5 cm and above was maintained to prevent the basins drying up. The water level was increased as the rice seedlings grow. The water level inside the basins were kept at a constant with the help of an irrigation and drainage canal control weir.The rice seedlings were transplanted at a spacing of 20 x 20 cm intervals. The water level was increased as the rice was growing. Figures 4 to 9 shows different operations carried out on the study area.

Figure 8: Two weeks after seedlings transplanting showing formation of agae

Figure 9: Sawah rice farm showing full weed control

3.3 Research design

A 2 by 3 complete randomize experimental design (CRD) was employed in this study. The transplanted basins were divided into 2 treatment and 6 experimental blocks. The complete randomized experimental design was considered in this study to ensure that the same conditions were allocated to every experimental units in a completely random manner. Also, to avoid bias in experiment resulting from the influence of some extraneous unknown factor that may affect the experiment. Water level of about 10 cm and above was introduced and maintained in three of the experimental conditions, whereas the other three basins (control) hadno water level above the ground level but there was continually maintained wet using a method called alternate wetting and drying. The size of the basins were5 x5 m. Figures 3 shows the field experimental design showing the treatment combination.

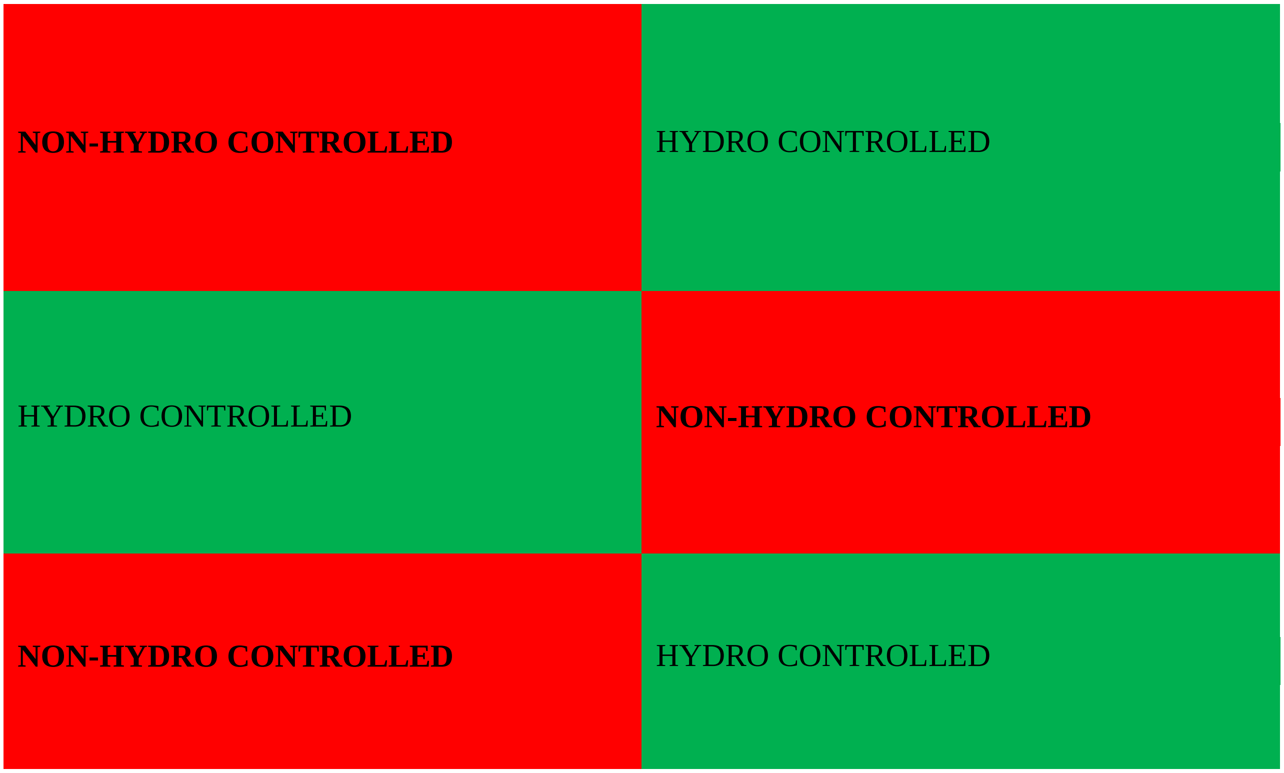

Figure 3: Experimental design showing the treatment combination

4.0 Results and Discussions

4.1 Results

To evaluate the weed density of every basin, a 50 x 50 cm square box made from hard wood was constructed. The square bar accommodated 9 points stands of rice seedlings. The samples were taken randomly in every basin. For every basin, the weed densities were recorded with respect to the rice seedlings. Three samples were taken from each basin and average of the weed density was taken as the true value of the weed density for that basin as at that period. The effect of the hydro-weed control was studied in every two weeks interval for the period of three months given a total observation date of 6. The statistical summary of the results gathered in two weeks intervals are given in table 1 to 3.

Table 1: Percentage of weed density for various treatment conditions for the 1st month

Plot No.	Weed density (%)			
	2nd Week		4th Week	
	Hydro-controlled	Non-Hydro-controlled	Hydro-controlled	Non-Hydro-controlled
1	0	0	0	0

2	0	0	0	0
3	0	0	0	2
Max	**0**	**0**	**0**	**2**
Min	**0**	**0**	**0**	**0**
Mean	**0.00**	**0.00**	**0.00**	**0.67**

Table 2: Percentage of weed density for various treatment conditions for the 2nd month

Plot No.	Weed density (%)			
	2nd Week		4th Week	
	Hydro-controlled	Non-Hydro-controlled	Hydro-controlled	Non-Hydro-controlled
1	0	0	3	20
2	0	0	10	18
3	0	0	15	25
Max	**0**	**0**	**15**	**25**
Min	**0**	**0**	**3**	**18**
Mean	**0.00**	**0.00**	**9.33**	**21.00**

Table 3: Percentage of weed density for various treatment conditions for the 3rd month

Plot No.	Weed density (%)			
	2nd Week		4th Week	
	Hydro-controlled	Non-Hydro-controlled	Hydro-controlled	Non-Hydro-controlled
1	0	0	30	70
2	0	0	40	75
3	0	2	60	85
Max	**0**	**2**	**60**	**85**
Min	**0**	**0**	**30**	**70**
Mean	**0.00**	**0.67**	**43.33**	**76.67**

4.2 Discussions

The results of the study from Table 1 shows that weed did not grow on either of the sawah rice farm basins till the fourth weeks from the date of transplanting. This indicated possible good land preparation such as ploughing and puddling. Weeds of 2% value was observed from the fourth weeks from the date of transplanting in the not hydro-controlled basins.

Tables 1, 2 and 3 also revealed that the percentage of weed density ranges from 0 to 2% and 2 to 85% for hydro-controlled and non-hydro-controlled basins, respectively. However, the mean percentage weed density ranges from 0 to 0.67% and 0.67 to 76.67% for hydro-controlled and not hydro-controlled basins, respectively.

Generally, the results showed that the percentages of weed density increase as the week increases both for the hydro-controlled and not hydro-controlled basins. The results however, shows that hydro weed controlled method has proved its potential in controlling weeds in a sawah developed rice farm.

Further observations from the study reveal that after three weeks of ponding water into the sawah basins, algae was observed to have formed at the surface of the water with some maggots identified. The algae formation from literature helps in fixing nitrogen to the soil. Hence, the interaction or relationship between the algae, maggots and water helps to set the sawah rice farm in favorable ecological condition, thereby improving the soil nutrient which infers farmers will save more money from improving the soil nutrient for better yield.

5.0 Conclusions

Sawah eco-technology for rice farm adopted in this study is a man-made lowland development which is characterized with land site selection, clearing, system design, ploughing, puddling, leveling, smoothening, good agronomic practices and water management. The becomes important as a result of the high drudgery and high cost of weeding in a rice farm, as well as environmental consequences of using chemical weed control methods. The main aim of this study was to evaluate the hydro weed control methods in a sawah developed rice farm at Landmark University Umu-Ara, Kwara state, Nigeria. The result of the study has shown that sawah developed rice farm is capable of holding water at about 10 cm depth and above with great potential of controlling weeds. The water retentionon a sawah field has so much positive effect on the rice growth, enhancement of soil fertility and increasing of rice yields. The challenges of sustaining hydro weed control are drastically increasing as fresh water for agriculture is sought of by other sectors.

Characterization of the little weeds that survives at different water levels in a sawah developed rice farm amongst others were recommended.

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SOLAR DESALINATION: A REMEDY TO HIGH COST OF SALT PRODUCTION IN UBURU COMMUNITY

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ABSTRACT

The major occupation of the women in Uburu community of Ebonyi state, Nigeria is salt production, since they are mainly surrounded by salt lake. Open fire heating method, which encourages deforestation, environmental pollution and degradation is prevailing there. A computer optimized solar desalination system is developed to augment salt production process to drastically reduce the unbearable high cost of salt production in Uburu community of Ebonyi state, Nigeria. The quantitative evaluation of NaCl salt in the saltwater is simulated. The simulated expected yield of NaCl salt from the Uburu salt lake sample based on the laboratory analyses is 34.80g/l. Thermal efficiency of the solar desalination system is up to 43.2% on a very sunny day in November. The qualitative results of the major trace elements in the salt were recommendable, with the absence of common poisonous substance such as lead.

Keywords: Solar energy, Saltwater, Desalination, Uburu Community

1. INTRODUCTION

Various desalination methods and technologies have been reported (Bruggen, 2003; Kalogirou, 2005; Sharma et al., 2016). Reports have shown that most works on desalination have not really been channeled towards salt production, but instead geared towards provision of portable water. They were mainly used in places where there were brackish or contaminated water. Sometimes, the process produces table salt as a by- product, depending on the level of total dissolved solid, TDS available in the saline water. As the TDS in a given saltwater increases, desalination in favour of salt production also increases. Salt, which is however, a by-product of desalination, is physiologically necessary for human life, but in the past, the known mineral sources were limited, so much, that it was a critical demographic power factor for most communities, until industrial means of extraction from brines were devised (Bloch, 1996). However, according to Yates et al. (1998), "desalination first started in Zutshwa in Botswana, with five precast concrete stills. The water available at Zutshwa contained 230g of dissolved salts per litre (seawater contains 35g), made up of almost sodium chloride – common salt. So the operator of these stills was able to make small income by selling the salt from the stills." The economic benefit potential of using solar still for extraction of salt from saltwater of high level TDS triggered the idea of looking for ways of modifying and improving upon the already existing single basin double slope solar still. This study is aimed at adopting an environmental friendly and more economical way of producing salt, to enhancing profit maximization as well as the standard of living of the people concerned with the business of salt production in Uburu community. In this work, an optimized solar desalination system (modified single basin, double-slope solar still) is developed for the purpose of salt production. One of the main objectives of this work is to simulate the quantities of the Sodium Chloride salt expected from various quantities of salt lake water samples, since salt or sea waters are composed of almost Sodium Chloride. More so, qualitative evaluation of the concentrations of some major trace elements in the salt produced from the system, are carried out, and compared with standard regulations. The National Food and Drug Agency Commission (NAFDAC) Regulations for table salt is shown in Table 1.

Table 1: The NAFDAC Regulation for Table or Cooking Salt

Parameters	NAFDAC Regulations
Na	No limit
K	-
Fe	Not more than 10mg/kg
Pb	Not more than 2mg/kg
SO_4	Not more than 5000mg/kg
Cl	No limit

Source: NAFDAC (1996)

1.1 Common Methods and Practices of Salt Production

1.1.1 Traditional Heating (Boiling) Method

A lot of developing countries of the world still uses this method. A typical community that uses this method is Uburu in Ebonyi State, Nigeria. The usual practice over the years has been, sand-filtering of the salt water with salty mud collected from the salt lake area, which incidentally produces more salt than the unfiltered (Ogwo, 2005). Here, a randomly perforated clay pot filled to about one quarter with salty mud is used in the filtration process. At the completion of drains, the filtrate is poured into a heating pot and heated with firewood until all the water evaporates into the atmosphere leaving the crystallized salt in the pot.

One major limitation of this method is that a lot of money is normally spent in purchasing firewood for the process, which drastically reduces the profit gotten from the enterprise. REEEP

(2006) had reported that, "extra cost of about 85% is invariably introduced in purchasing firewood only since 28,000 tons of firewood costing about 200 million naira is spent annually for salt production in Uburu, Ebonyi State Nigeria".

1.1.2 Solar Pan Evaporation Method

Mannar and Dunn (1995) and Bloch (1996) had revealed this method as being used in the maritime countries, where evaporation exceeds rainfall amount by at least 30 inches (75cm), for salt production from seawater. Large shares of the world's consumption of salt is still made by the ancient method of trapping seawater or salt spring brines; evaporate the brine and concentrate the salt, either artificially, or under the sun's heat.

The process is by usually accomplished by allowing the seawater to flow through a series of gates constructed of wood or a combination of wood and concrete into a series of shallow ponds separated by dikes. The solution is then concentrated to a specific gravity of about 1.22 (Bloch, 1996), leading to the removal of suspended impurities such as sand, clay, and less soluble salts such as calcium carbonate, or chalk and calcium sulphate. To hasten the process, dye is added to the water to allow absorption of more sunlight as the layers of brine gets thinner. The brine running through the crystallizing pans, evaporates which raises its concentration as the constituent salts crystallize in set order. Here Sodium chloride fraction separates first at specific gravity of 1.23 which remains partly contaminated with chlorides and sulphates of magnesium, calcium, and potassium. Salt 'harvested' is transferred through a series of conveyors for washing, storage and draining.

In developing countries, after washing, the row-raked salt is allowed to drain for several days, before it is heaped again, drained, and lifted from the pans for final drying. In industrial countries, the salt is mechanically harvesting, washed with saturated brine, de-watered, washed again with fresh water, and stored for further processing or direct sale. The problem of this method is that it demands so much labour and also exposes the salt to contamination with impurities, since the process takes place in an open field.

1.1.3 Solar Still Method

Solar stills had been mainly used more than 2000 years ago for producing salt instead of drinking water with thermal efficiency of about 30% (ITDG, 2005). This came about when primitive man was allowing pools of salt water to evaporate in order to produce salt essential to the human diet (Yellott, 1974). Solar stills are simple to operate and maintain, relatively inexpensive, and can provide small quantities of clear-good tasting water, as well as provide salt for cooking, preserving meat, and curing game skins (Grajdieru, 2005). Salts from the stills were normally removed through the hatches as wet crystals, washed in salt water before being loaded on trays and dried under the Sun (Fig.1). After drying, it is weighed into bags and stored for direct use or for other purposes. The major problem of the earlier designs as can be observed in Fig. 2, is no easy access to 'harvesting' of the salt from the basin, since the systems were completely sealed. This would resort to constantly unsealing and replacing the glass covers before salt harvesting could be made. As a result, incurring of constant extra cost arising from frequent supplies of sealants or even from the frequent replacement of cracked or broken glass covers which would have emanated from the process is evident here.

Fig. 1: Washing Process of Salt Collected from the Stills at Zutshwa Source: Yates et al. (1998)

Fig 2: Picture of earlier designed solar still. Source: (Ogwo 2005)

2. MATERIALS AND METHODS

2.1 Instruments and Measures Used in Collecting Data

HI 8757 K-thermocouple thermometer and mercury- in-tube thermometer: The HI 8757 K-thermocouple thermometer was used in measuring the temperature of the glass and temperature of the water vapour, while the mercury-in-tube thermometer was used in measuring the temperature of the water in the basin. The mercury in-tube thermometer was kept permanently in the desalination basin on each phase of the experiment.

A very sensitive battery powered weighing metre: It was used in determining the weight of the salt crystallized out of the saltwater in grams.

Data logger: This is a computerized gadget used for recording the daily solar radiation in Watt per square metre. The daily solar radiations recorded for the period of the experiment were down loaded and the values for every two hour intervals were taken.

Storage cans: These are three air-tight containers used in storing the three different volumes of the saltwater samples which were kept in a cool place.

2.2 Design Calculations

Output from a solar desalination system at a given period depends on factors such as ambient, design and operating conditions (Muftah et al., 2014). Consider an optimized surface area of the glass cover gotten from simulation as 1m^2 with its most effective dimensions as 1.25m x 0.8m. Total area of glass cover in (m^2) is given as;

$$TA_g = TL_g \times TW_g \tag{1}$$

Where, $TL_g = total\ length\ of\ glass\ (m) = 1.25m$

TW_g = *total width of glass (m) = 0.8m*

Then, total insolation falling on each half of this dimensions which are inclined at optimized (after simulation) angle of 22° from horizontal facing each other is deduced with the formulae;

$$I_1 = \frac{I_n cos\theta \times A_g}{2} \tag{2}$$ and,

$$I_2 = \frac{I_n \sin 112 \times A_g}{sin46 \times 2} \tag{3}$$

Where,

$I_1 and I_2$ are the respective insolation falling on glass one and glass two,

I_n = average all year round insolation for Nsukka, 650W/m^2 Okonkwo and Anyanwu (2004),

θ = Computer-optimized angle of inclination of the glass cover from horizontal (22°).

Therefore, the total insolation (W/m^2) reaching the two inclined glass planes is;

$$I = I_1 + I_2 \tag{4}$$

Then the slanted portion of the glass covers from horizontal, Z, coinciding vertically with an assumed arbitrary thickness of the concrete chamber, T_{CC} (0.05m) shown in is calculated as,

$$Z = T_{CC} / \cos 22° \tag{5}$$

Therefore, effective width of glass covers in m is given by;

$$EW_g = TW_g - 2Z \tag{6}$$

Also, effective length of glass covers in m;

$$EL_g = TL_g - 2T_{cc} \tag{7}$$

Then, effective area of glass covers in m^2;

$$EA_g = EL_g \times EW_g \qquad (8)$$

It follows that the effective insolation $in\ W/m^2$, falling on the glass covers is;

$$EI = EA_g \times I \qquad (9)$$

The effective area of the glass covers corresponds with the area of the inner walls of the solar concrete collection chamber that houses the desalination basin. The basin is of almost the same area with the inner area of the collection chamber. Therefore, the area of the desalination basin is deduced as follows:

Recall that angle of inclination of the glass covers from horizontal is 22°. So, half of the total width of concrete chamber will be;

$$\tfrac{1}{2}TW_{CC} = \left(\tfrac{1}{2}T_{WG} \times cos22°\right) \qquad (10)$$

then, total width of concrete collection chamber in (m) is given as

$$TW_{CC} = (T_{WG} \times 2cos22°) \qquad (11)$$

Implying that the effective width of the concrete chamber in (m) is given as

$$EW_{CC} = (TW_{CC} - 2T_{CC}) \qquad (12)$$

But, total length of concrete chamber,

$$TL_{CC} = TL_G \qquad (13)$$

Therefore, effective length of concrete chamber is given as

$$EL_{CC} = TL_{CC} - 2T_{CC} \qquad (14)$$

Also, the length of the front curb of the desalination basin constructed as a rectangular dovetail-like shape protruding outwards with angles of 60° on all four sides and meeting with the thickness of the concrete chamber is given as;

$$LFC_{WB} = TL_{CC} \qquad (15)$$

Subtracting arbitrary small spaces of 0.02m from the EL_{CC}, we have;

$$TL_{WB} = (EL_{CC} - 0.02) \qquad (16)$$

Also, subtracting an arbitrary small space of 0.01m as allowance and T_{CC}(0.05m) from the TW_{CC}, then total length of desalination basin is gotten as;

$$TW_{WB} = (EW_{CC} - 0.01 - T_{CC}) \qquad (17)$$

Therefore, the effective area of water basin in (m^2) is;

$$EA_{WB} = (TL_{WB} \times TW_{WB}) \qquad (18)$$

Since the sample water in the basin needs to be shallow for easy heat-up, an arbitrary depth of water basin, D_{WB}, say 0.15m is assumed. So the effective volume of the water basin is given as;

$$EV_{WB} = (EA_{WB} \times D_{WB})\ m^3 \qquad (19)$$

Then, from the top of front curb of the water basin, the height x, adjacent to the projected angle of 60° is calculated as;

$$x = 0.05 \div \tan 60° \tag{20}$$

then, height of front curb of water basin, is given as;

$$HFC_{WB} = [D_{WB} + (2x)]m \tag{21}$$

Then, depth of concrete chamber is deduced as

$$D_{CC} = (D_{WB} + 2x + T_{CC}) \tag{22}$$

Expected daily distillate output which is the amount of the energy utilized in vapourizing water in the still over the latent heat of vapourization of saltwater (ITDG, 2005) is given as;

$$Q_e = M_w \times L \tag{23}$$

But,

$$M_w = \{\varepsilon_g \sigma E_{Ag}(T_g^4 - T_{sky}^4) + h_c' E_{Ag}(T_g - T_a) - \varepsilon_{wc}\sigma A_b(T_w^4 - T_g^4) - h_c A_b(T_w - T_g)\}/L \tag{24}$$

And, volume of the fresh water expected to be produced daily is given as;

$$V_w = M_w / D_{SW} \tag{25}$$

Efficiency of solar still is the heat of evaporation of the water produced divided by the total solar energy incident on the cover (Ogwo, 2005) which is given as;

$$\eta_T \quad (Q_e / I) * 100\% \tag{26}$$

where,

$M_w = daily\ distilled\ water\ output\ (\frac{kg}{m^2})$

$Q_e = amount\ of\ energy\ utilized\ in\ vaporizing\ water\ (\frac{J}{m^2}\ day)$

ηT $= Total\ efficiency$ (%)

$I = insolation\ in\ (KJ/m^2)$

$\varepsilon_{wc} = 0.9$ *is for operative condition inside the solar desalination system*

σ = *the Stefen-Boltzmann's constant* = 5.6×10^{-8} *W/m²K⁴*

A_b = *area of basin (m^2)*

T_w = *temperature of water and basin (K)*

T_g = *temperature of glass (K)*

$T_{sky} = 0.0552 T_a^{1.5}$ = *temperature of the sky (K)*, T_a = *ambient temperature (K)*

$\varepsilon_g = emissivity\ of\ glass = 0.92$

D_{SW} = *density of saltwater (kg/m^3)*

$L = 2520 - (2.5 \times T_w)$ =*latent heat of vapourization of saltwater (J/kg).*

$h_c = 8.84 \times 10^{-4} \left\{\frac{(T_w - T_g)}{1} + \left(\frac{P_w - P_{wg}}{2.65(P_T - P_w)}\right) T_w\right\}^{1/3} = convective\ heat\ transfer\ coefficient$

$\boldsymbol{h_c' = 0.884 \left\{\frac{[(T_w - T_g) + (P_w - P_{wg})}{268900 - P_w} \frac{T_w]}{1}\right\}^{1/3} = the}$ *modified convective heat transfer coefficient*

q_e = *heat transferred from the saltwater surface to the glass cover which results in evaporation and condensation of vapour underneath the glass cover.*

2.3 Experimental Procedures

2.3.1 Laboratory Experimental Procedures

The experiment was exclusively done in the laboratory by collecting samples of the saltwater and the salt which were analyzed accordingly. Here a given sample of the salt water was sprayed into a JENWAY PST 7 Flame Photometer. The flame was allowed to stabilize for 4 seconds and Sodium, Potassium, Lead, Iron, Magnesium were analyzed at different wavelengths, band-passes and lamp current intensities. With titrimetric method, Calcium (Ca) and Chloride (Cl^-) were determined. Then, Sulphate (SO_4^{2-}) was determined through gravimetric method.

2.3.2 Field Experimental Procedure

The field work took place in December period (harmattan season with prevailing cool dry wind). Total volume of saltwater sample used in the experiment was 12litres. This was divided into 3 different volumes – 2 litres, 4 litres and 6 litres.

The field experiment started by weighing the empty desalination basin, then the 2 litre-sample was measured out with a 500ml-measuring cylinder and poured into the basin. The basin was placed back into the system and made to lap properly on the concrete chamber. On each day, temperature readings were taken until the salt water in the basin had completely desalinated. The basin was then pulled out and weighed before the salt was scrapped off completely. The process was repeated for the other two samples, 4-litre and 6-litre respectively. The picture of the newly developed solar desalination system is shown in Fig. 3 below.

Fig. 3: The Newly Developed Solar Desalination System.

3. RESULTS AND DISCUSSIONS

3.1 Presentation of Results

3.1.1 Expected Yield of Salt

Table 2 shows the major radicals in the feed sample of saltwater after the laboratory analyses.

Table 2: Concentrations of Elements in mg/l Saltwater Sample

Para-meters	Na	K	Ca	Mg	Fe	Pb	Cl	SO_4	HCO_3	pH
Conc.	33500.00 (mg/l)	3,740.00 (mg/l)	604.70 (mg/l)	21.96 (mg/l)	0.11 (mg/l)	Nd	1279.13 (mg/l)	748.18 (mg/l)	146.40 (mg/l)	9.2

Nd = Not detected

A simple equation representing a simulated chemical formulation of Sodium Chloride salt expected per litre of the sample assuming all the Sodium radicals reacted with all the Chloride radicals is given as:

Na^{+} (aq) + Cl^{-} (aq) → NaCl (aq)

33500.00 mg 1279.13 mg 34,779.13 mg (34.80g)

Based on the output of the above chemical formulation, the simulated expected yields of NaCl salt in 2-litre, 4-litre and 6-litre samples of the same saltwater are presented in Table 3 below.

Table 3: Expected Yields of NaCl Salt from Different Volumes of the Same Feed Sample

Volume of Saltwater (litres)	Expected Yield of NaCl Salt (g)
2.00	69.56
4.00	139.12
6.00	208.67

Actual Yield of Salt

Based on the field experiment, the actual yields of salt, desalinated from the 2-litre, 4-litre and 6-litre of the same sample are presented in Table 4. Table 5 presents the concentrations of the trace elements in the crystallized salt. Some quantities of the salt produced from the system are shown in Fig. 4 below.

Table 4: Actual Yields of Salt

Volume of Saltwater (litres)	Actual Yield of Salt (g)
2.00	66.00
4.00	135.00
6.00	205.00

Table 5: Concentrations of Trace Elements in mg/kg of Salt Produced

Trace Elements	Na	K	Ca	Mg	Fe	Pd	SO_4	Cl
Conc.(mg/kg)	33494.00	*3,714.00*	-	-	Nd	Nd	Nd	1274.50

Nd = Not detected

Fig. 4: Picture of the Salt Produced from the System

3.2 Discussions

Considering the limitation of this study, the expected amount of NaCl salt per litre of the saltwater sample is simulated from the quantity of Sodium and Chloride radicals in the sample.

From the Table 2 above, it is assumed based on the simulation that 33,500.00mg/l of Sodium reacted with about 1,279.13mg/l of Chloride to give about 34,779.13mg/l (approximately 35g/l) of Sodium Chloride salt. This value agrees with the minimum amount of salt (35g) normally found in sea or salt lake waters, which are majorly composed of Sodium Chloride (common salt) as reported by Yates et al. (1998).

It can also be noticed in Table 3 that the results of the simulated expected yields of NaCl in the different volumes of saltwater, decreases almost proportionally if compared with the actual yields of salt, produced from related volumes as seen in Table 4. That is a reduction of approximately 4.00g on each volume of sample. These reductions in the actual amount of salts produced may have occurred as a result of some fractions of the salts being evaporated with the distillate, thereby leaving lesser amounts of the crystallized salt than expected, in the desalination basin. If the values in Table 4 are plotted on a graph, an approximate actual amount of salt the system will be able to produce from a given volume of the sample can be extrapolated from the curve. So based on the graph, someone can estimate the quantity of salt, expected to be desalinated from a given quantity of Uburu salt lake using the desalination system.

At an average insolation of 665.7 W/m^2 and distillate output of 280ml, thermal efficiency of the system was found to improve up to 43.2%, while thermal efficiency reported by ITDG (2005) was about 30%.

Both concentrations of Sodium (33,494.00mg/kg) and that of Chloride (1274.50mg/kg) are acceptable for common salt. According to NAFDAC Regulations in Table 1, there are no limits for the concentrations of these two trace elements in common salt. Also, Potassium with concentration of 3,714.00mg/kg as seen in Table 5 has no recommended regulation limit by NAFDAC (Table 1). Iron and Sulphate are very useful in table salt for human body development with acceptable limits of 10mg/kg and 5000mg/kg respectively by NAFDAC (Table 1), but their concentrations were not detected at all (Table 5). Lead which is a poisonous substance was not also detected in the salt (Table 5).

4. CONCLUSIONS

The concentration of trace elements in the salt produced, compared to the NAFDAC has shown that there are no trace of Pb (poisonous substance), but those missing trace elements like Fe and SO_4 could be augmented up to NAFDAC acceptance limit. However it is recommended that other poisonous substances such as Copper, Mercury, Cadmium and Arsenic should be investigated as well to be fully sure that the salt is completely safe and not causing other harms to the human body. It is recommended that further work should be done with open fire heating to compare the quantity of the salt produced, with the one gotten from the desalination system. This solar desalination system is recommended to be used in augmenting the salt production during the dry season, that is period of high sunlight, so as to provide encouraging outputs.

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SPATIAL INTERPOLATION OF REFERENCE EVAPOTRANSPIRATION DATA USING ARCGIS IN SOUTH-EAST NIGERIA: A COMPARATIVE STUDY

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Abstract
For the purpose of effective water management in irrigation water supply, the quantification of crop water needs depends on evapotranspiration. This study used historic data to estimate reference evapotranspiration in the south-east geopolitical zone of Nigeria with FAO Penman Monteith model. The inverse distance weighting and kriging interpolation methods in Arcgis 10.2.2 package were used to map reference evapotranspiration across the study area. The spatial maps of monthly, annual and seasonal reference evapotranspiration were produced for the study area and performances of the interpolation methods were compared. The results showed that reference evapotranspiration gradually increased southwards of the study area. The rate of reference evapotranspiration was higher during the dry season when compared to rainy season. Estimates by both interpolation methods have positive correlations with the observed data, correlation coefficients were R = 0.83 and R = 0.50 for inverse distance weighting and kriging, respectively. The study through data spatialization has provided reference evapotranspiration information for places that have no weather stations. It has also provided useful background information for irrigation management, water resources management and climate change studies.
Keywords: Reference evapotranspiration, ArcGIS, Spatial Interpolation, inverse distance weighting and Kriging,

1.0 Introduction

Evapotranspiration is the integrated process of evaporation and transpiration. Reference is a climatic parameter expressing the evaporative power of the atmosphere. Reference evapotranspiration (ET_o) is the water evaporated from a reference surface, and was presented to quantify evaporative demand of the atmosphere, independent of the crop growth parameters and management practices. The concept of the reference evapotranspiration was to study the evaporative demand of different crops and develop good management practices. It also expected to manage large, well watered fields that achieve full production under the given climatic conditions.

ET_o varies in time and space controlling varieties of issues in water management, hydrology, agriculture, irrigation scheduling, and proper planning of available fresh water resources. Among the different components of the hydrological cycle, a precise approximation of evapotranspiration is perhaps most difficult due to its complex interactions with the soil-plant-atmosphere system (Pandey *et al.*, 2016).

Efficient water use in agriculture requires the accurate determination of crop evapotranspiration and irrigation water requirements of crops, applying water only when necessary at the right quantity (Sharma and Irmak, 2012). Irrigation water requirements of crops are primarily affected by evapotranspiration (ET), other factors include crop factors, soil factors and agronomic management. Meteorological data (temperature, solar radiation, relative humidity and windspeed) can be used to estimate ET in the field. Direct measurement of ET is by lysimetric study which is time-consuming and expensive (Okechukwu and Mbajiorgu 2012).

In Nigeria and south-eastern region, limited number of weather stations and paucity of data has made studies difficult for researchers, though, it is difficult to provide weather station at every space and time. Lysimetric studies on a spatio-temporal basis are practically impossible but, spatial interpolation methods can be used with a GIS, to estimate spatial and temporal data from any geographic point. This is done by using known data to estimate the unknown or unmeasured data. There are no best methods of interpolation (Rana and Katerji, 2000). A GIS stores, manipulates, analyzes, retrieves, and displays data referenced in space and time.

Spatial interpolation techniques have wide applications, including ground water pollution and contamination (Arslan and Turan, 2015, Gong *et al.*, 2014), groundwater level (Xiao *et al.*, 2016), weather variables (Di Piazza *et al*., 2015, Lanciani and Salvati, 2008, Goodale *et al*., 1998) and agro-climatic parameters (Dalezios *et al*., 2002). It has also been applied in irrigation and determination of crop water requirements of crops. Fortes *et al*. (2005) developed GISAREG, a GIS based irrigation scheduling simulation model, to support improved water use. It is an improvement of ISAREG, an irrigation scheduling simulation model that performs the soil water balance at the field scale. Rao *et al.* (2004) developed a GIS-based decision support system for real time water demand estimation in canal irrigation systems. Dhakal (2010) developed a Web GIS to support irrigation management using Geo-statistical interpolation techniques to generate evapotranspiration maps, published as web maps. Mardikis *et al* 2005 introduced elevation and compared four interpolation methods for predicting reference evapotranspiration in Greece; their results revealed that the incorporation of elevation significantly improved the performance of interpolation methods. Liang *et al*. (2010) considered the effects of elevation, slope and aspect on spatial distribution of ET in Taoer river basin, China. Their results showed that IDW performed best for interpolating windspeed while Tri-variate secondary trend surface method of interpolation was suitable for mean air temperature and relative humidity. Their result also showed a strong seasonal variation in respect to elevation of the area. Sharma and Irmak (2012) applied interpolation techniques to generate maps for precipitation, ETo, Actual Crop Evapotranspiration and Net Irrigation Requirements in Nebraska. Their results suggest that such maps are important background information for climate change studies and for effective and efficient water management. Accurate estimates of ET require meteorological stations to form a dense network to achieve a fine resolution. In Nigeria and most developing countries, observation stations are poorly and sparsely distributed and are prone to frequent breakdowns. Nigeria has some weather stations managed by NIMET (Nigerian Meteorological Agency) but, these stations do not measure ET directly (Ogolo, 2006). The objectives of this study are to use historic weather data to estimate ET_o in Southeast Nigeria, to analyze spatial and temporal trends of ET_o in the study area, to generate background ETo data information for irrigation and water resources management in various locations of no weather stations in the study area.

2 Materials and Methods

2.1 The Study Area

The study area comprises the five states of the Southeast geopolitical zone of Nigeria. It is located between latitudes 04.5° N and 07.5° N and longitudes 06.75° E and 08.75° E and is bounded by Kogi State in the Northwest, Benue State in the northeast, Cross River and Akwa Ibom States in the Southeast, Rivers and Bayelsa States in the South and Delta State in the West (Figure 1). Southeast Nigeria has early occasional rainfall usually in January/February with full commencement of rainy season in March/ April ending about November each year. The dry season lasts between four to five months (November to March).

The highest rainfall is recorded from July to October with a break for about a week in August. The average annual rainfall is about 2000 mm (Okonkwo and Mbajiorgu, 2010). The average daily and annual temperatures are about 28^{o}C and 27^{o}C respectively (Igbokwe *et al*., 2008).

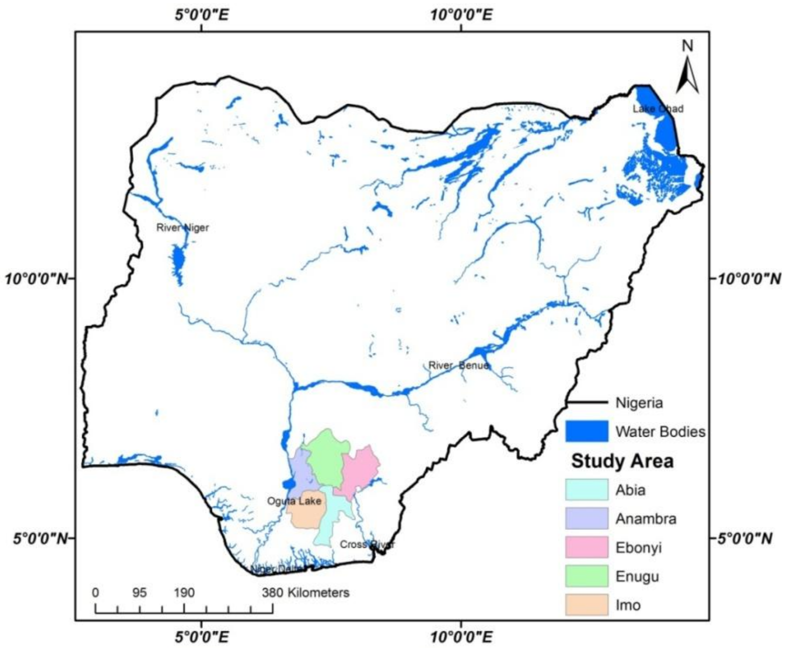

Figure 1: Nigeria showing the study area comprising the 5 geopolitical States of Southeastern Nigeria.

2.2 Data Requirement, Acquisition and Preparation

Long term historical climatic data were obtained from Nigerian Meteorological Agency (NIMET) at Lagos and the Center for Basic Space Science (CBSS) Nsukka, for 17 weather stations in and around the study area (Figure 2). These include minimum and maximum temperature (^{o}C), wind speed (m/s), relative humidity (%) and solar radiation (MJm^{-2}d^{-1}) for a 21-year period (1993 to 2013). Reference evapotranspiration (ET$_o$) was determined by the FAO Penman- Monteith model and the data were processed into monthly and annual values. (Allen *et al.*, 1998). The daily data were processed using Microsoft Excel Spreadsheet into monthly, annual and seasonal averages. ArcGis 10.2.2 software package was used for spatial interpolation mappings of ET$_o$

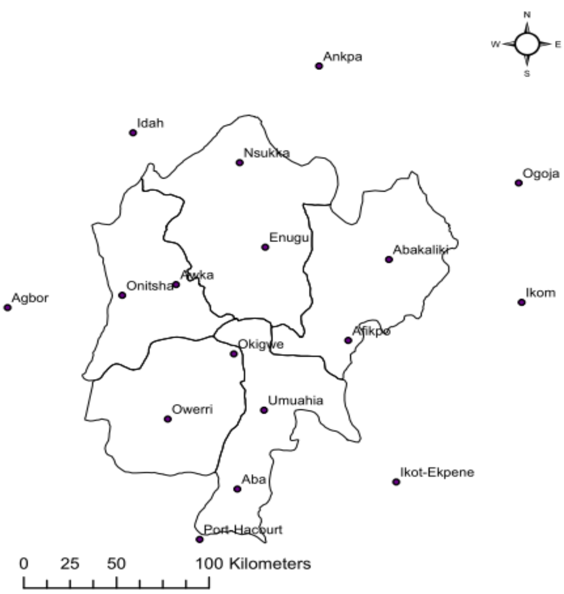

Figure 2: The study area showing locations of the weather stations in and around the study area.

2.3 Reference Evapotranspiration Determination

ET_o was calculated on a daily time step using the FAO-Penman-Monteith (FAO-PM) method (equation 1). The equation uses standard data of solar radiation, temperature, humidity and wind speed. The computations were at a 2 m reference height of green grass, shading the ground and not short of water (Allen *et al.*, 1998).

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_{2(e_s - e_a)}}{\Delta + \gamma(1 + 0.34_{u_2})} \quad (1)$$

where, ET_o = Alfalfa reference evapotranspiration (mm day^{-1})
R_n = net radiation at the crop surface (MJ m^{-2} day^{-1})
G = soil heat flux density (MJ $m^{-2}day^{-1}$)
T =mean daily air temperature at 2m height (^{0}C)
u_2 = mean daily wind speed at 2m height (m s^{-1})
e_s = saturation vapour pressure (kPa)
e_a = actual vapour pressure (kPa)
e_s - e_a = saturation vapour pressure deficit (kPa)
Δ = slope of the saturation vapour pressure curve (kPa $^0C^{-1}$)
γ = psychrometric constant (kPa $^0C^{-1}$)

2.4 Shapefile and Attribute Table

Before creating a map using ArcGis, the South-eastern geopolitical map of Nigeria was chosen as the basemap of study area, which was drawn with great cartography and scales to fit perfectly to its location in the global map and was imported into the ArcGis environment The map layers added in this case were the five States that made up the South-eastern geopolitical zone of Nigeria which include Abia, Anambra, Ebonyi, Enugu and Imo. The locations (longitude and latitude) of the weather stations were also added to the map. The styles of the layers were changed with various colours for distinctions. The map was saved as a shapefile. A shapefile is a vector data storage format for storing the location, shape, and attribute table of geographic features. It is stored as a set of related files and contains feature class.

2.5 Spatial Interpolation Methods

There are many interpolation methods available for use but, IDW and kriging were chosen because they are widely used for spatially explicit hydrologic/watershed models that require continuous data surfaces like temperature and evapotranspiration. Another reason was that one deterministic (IDW) interpolation method and one geostatistical interpolation method (kriging) was chosen so that different interpolation methods could be used. The IDW is a simple and intuitive deterministic interpolation method based on the principle that sample values closer to the prediction location have more influence on prediction value than sample values farther apart and its “bull's eye” effect (higher values near observed location) and edgy surface are advantages. The kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. The basic tool of geostatistics and kriging is the semivariogram. It captures the spatial dependence between samples by plotting the semivariance against separation distance. In kriging, the weights are based not only on the distance between the measured points and the prediction location, but also on the overall spatial arrangement of the measured points.

3.0 Results and Discussions

3.1 Air Temperature

Air temperature is an important driver of climate variability. Average monthly air temperatures varied between 30.6 ^{o}C (March) and 24.7 ^{o}C (August). The long term average air temperatures across the states were; 28.2^{0}C (Ebonyi), 26.2^{0}C (Anambra), 27.7^{0}C (Imo), 27.6^{0}C (Enugu) and 27.4^{0}C (Abia). The average annual air temperature in the study area was 28^{0}C. The average annual air temperatures for the states in the study area were; 28.1^{0}C, 27.5^{0}C, 27.6^{0}C, 27.7^{0}C and 27.4^{0}C for Ebonyi, Anambra, Enugu, Imo and Abia States, respectively. Nwaiwu *et al*., (2014) reported a temperature range of between 25.95^{0}C and 27.65^{0}C for the same study area, based on data from 1971 to 2011.

3.2 Wind speed

The average annual wind speed for the study area was 1.7 m/s, which can be said to be moderate speed (Allen *et al*., 1998). The average state-wide wind speed for the study area were 1.9 m/s, 1.8 m/s, 1.3m/s, 2.4 m/s and 1.1m/s for Ebonyi, Anambra, Imo, Enugu and Abia states, respectively. The study area recorded the highest value of 2.2 m/s in the dry season (March/April) and lowest value of 1.4 m/s during the rainy season (September/October). Oyedepo *et al*., (2012) reported average monthly values of 5.42 m/s, 3.36 m/s and 3.59 m/s for Enugu, Owerri and Onitsha, respectively, based on measurements at 10 m height instead of 2 m height used for this study because it is believed that higher altitudes tend to give higher wind speed values.

3.3 Solar Radiation

The average monthly solar radiation values decreased between the month of March (21 MJ/m^2/day) and April (20 MJ/m^2/day) to July/August (15 MJ/m^2/day) before increasing in November to 20 MJ/m^2/day (dry season). Ebonyi State received the highest average monthly radiation of 19.16 MJ/m^2/day**,** followed by Enugu State (19.0 MJ/m^2/day), Anambra (18.36 MJ/m^2/day), Abia (18.31 MJ/m^2/day) and Imo (18.27 MJ/m^2/day). The average annual solar radiation across the study area was 18.64 MJ/m^2/day.

3.4 Relative Humidity in the Study Area

The average monthly relative humidity (RH) for the states showed high percentages in July, August and September (rainy season) averaging 89%, 89% and 90% respectively. The lowest percentages were in January (dry season), averaging 54.32%. The trend of variation across the year showed that relative humidity increases southwards. It was noted that while temperature and solar radiation decreased at the onset of the rainy season, relative humidity increased in the study area. All the States had values of between 80% and 90% RH at the full commencement of the rainy season between May and September.

3.5 Reference Evapotranspiration Maps

The spatial distribution of average monthly ET_o for the study area are presented in Figures 3 (a – f). The average monthly ET_o ranged from 93 mm (August) to 158 mm (January), with an annual average of 1547 mm across the study area. The average seasonal ET_o showed very close values of 765 mm and 782 mm for dry and rainy seasons respectively. The higher rate of ET_o in dry season was balanced by the 7-months duration of rainy season, as against the dry season duration of 5 months.

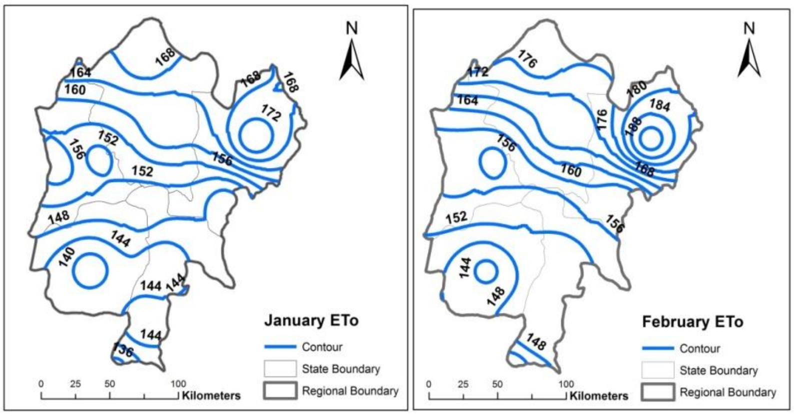

Figure 3(a)

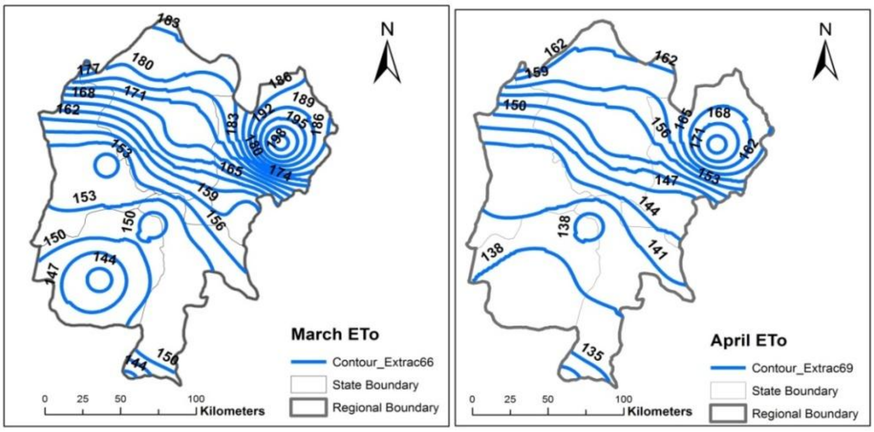

Figure 3(b)

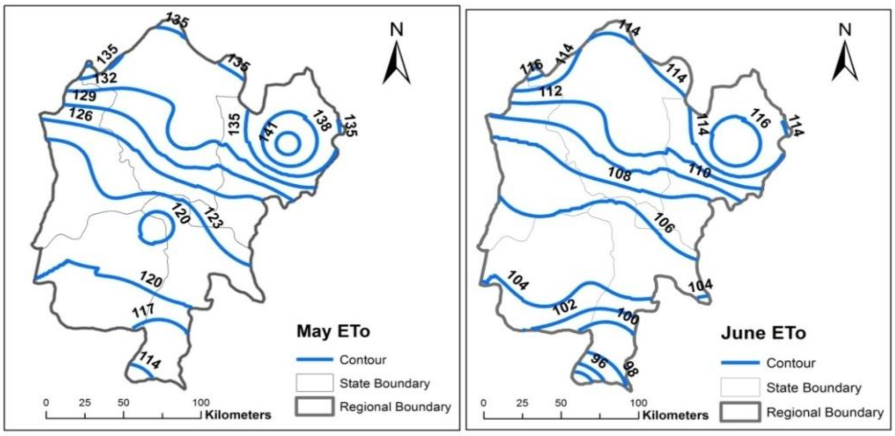

Figure 3(c)

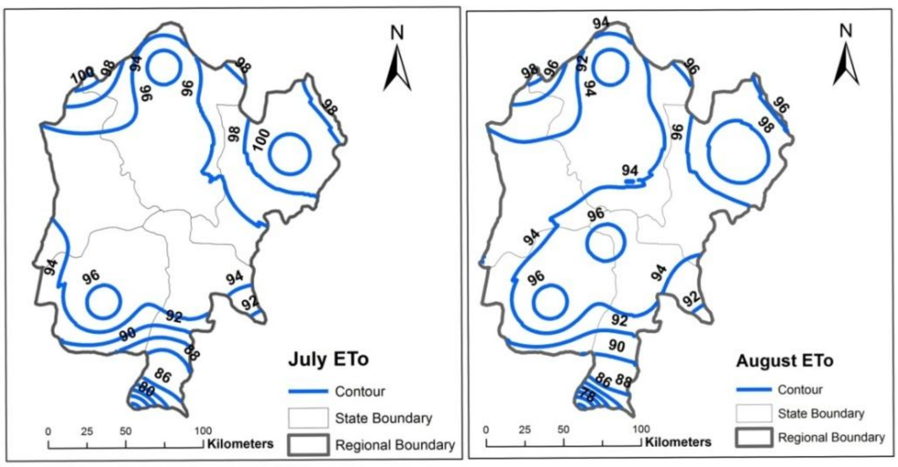

Figure 3(d)

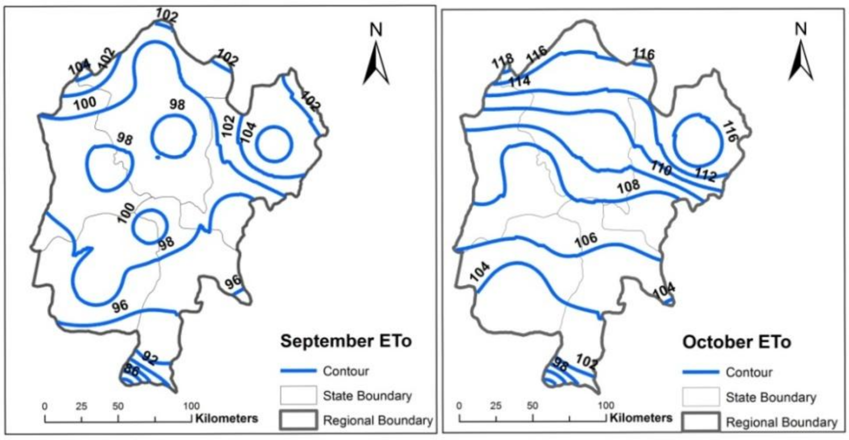

Figure 3(e)

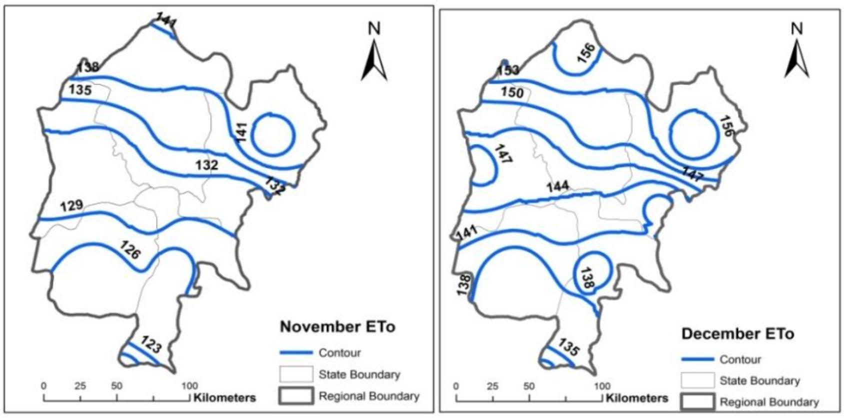

Figure 3(f)

Figures 3(a-f): Spatial distribution of average monthly reference evapotranspiration (mm) in South-eastern Nigeria

3.6 Statistical Analysis

The descriptive statistics for mean monthly, annual and seasonal ET_o are presented in Table 1, while the of state-wide seasonal ET_o are presented in Table 2. The dry season has a lower range of SD (17.5 to 8.2) than the rainy season (24 to 14.8) across the States of the study area. In dry season, States in the north of the study area had higher SD values than those in the south. The CV increased proportionally with the SD as Ebonyi had the highest variation of 11% among the States. Others are Enugu (9.8%), Anambra (7.2%), Abia (7.5%) and Imo (5.9%). In the rainy season, the SD and CV exhibited similar patterns. The dry and rainy seasons ET_o have SDs of 73.2 and 67.2, respectively, while their CVs are 9.6% and 8.6%, respectively. This indicates there was not much spatial variability of ET_o in both seasons. Sharma and Irmak (2012) reported ET_o to be twice as much during late summer compared to winter, in a temperate climate.

Table 1: Descriptive statistics of mean monthly, annual and seasonal reference evapotranspiration in South-eastern Nigeria

	Mean	Max	Min	SD	CV (%)
Jan	156	178	135	14.5	9.3
Feb	163	190	141	18.1	11.1
Mar	166	205	143	22.2	13.4
Apr	150	185	130	17.2	11.5
May	127	152	112	11.7	9.2

Jun	109	124	92	9.5	8.7
Jul	95	110	77	8.4	8.8
Aug	93	107	77	7.8	8.3
Sep	99	114	85	7.4	7.5
Oct	110	130	95	8.8	8.0
Nov	133	153	118	9.2	6.9
Dec	147	164	131	10.3	7.0
Annual	1547	1820	1336	137.1	8.9
Dry Season	765	892	668	73.2	9.6
Rainy Season	782	928	668	67.2	8.6

Table 2: Descriptive statistics of state-wide mean seasonal reference evapotranspiration in the study area

Dry season	**Mean**	**Max**	**Min**	**SD**	**CV (%)**
Abia	142	152	126	10.6	7.5
Ebonyi	159	179	136	17.5	11.0
Anambra	148	156	139	10.7	7.2
Enugu	162	177	138	15.9	9.8
Imo	141	147	127	8.2	5.9
Rainy Season	**Mean**	**Max**	**Min**	**SD**	**CV (%)**
Abia	106	137	93	16.5	15.6
Ebonyi	116	158	97	22.3	19.2
Anambra	109	142	93	17.4	15.9
Enugu	114	158	92	24.0	21.0
Imo	109	137	96	14.8	13.6

3.7 Comparative Maps of Spatially Distributed Average Annual and Seasonal Reference Evapotranspiration by Interpolation Method

The IDW and kriging interpolation methods were also used to map annual and seasonal ET_o across the study area. The maps developed by each method are shown in Figures 4, 5 and 6. The annual average ET_o ranges were 1319 mm – 1685 mm and 1326 mm – 1700 mm for IDW and kriging methods respectively. The rainy season values were 670 mm – 856 mm and 674 mm – 866 mm, and the dry season values were 669 mm – 865 mm and 672 mm – 865 mm, for the IDW and kriging methods, respectively.

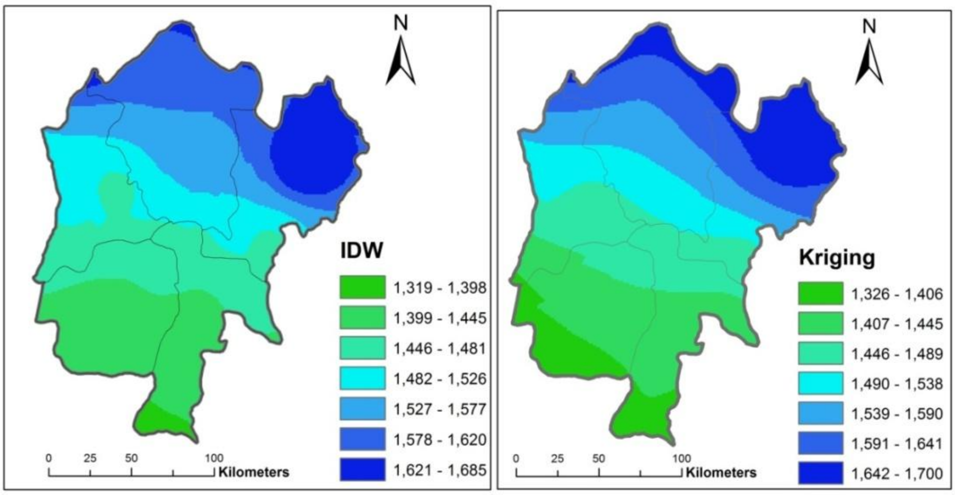

Figure 4: Spatially distributed average annual ET_o (mm) in South-eastern Nigeria as developed by the two interpolation methods

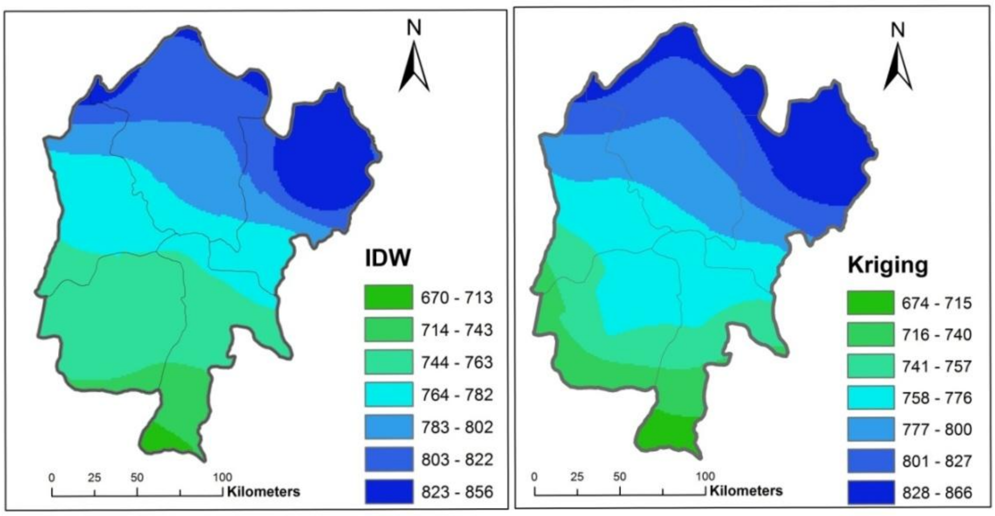

Figure 5: Spatially distributed average rainy season ET_o (mm) in South-eastern Nigeria as developed by the two interpolation methods

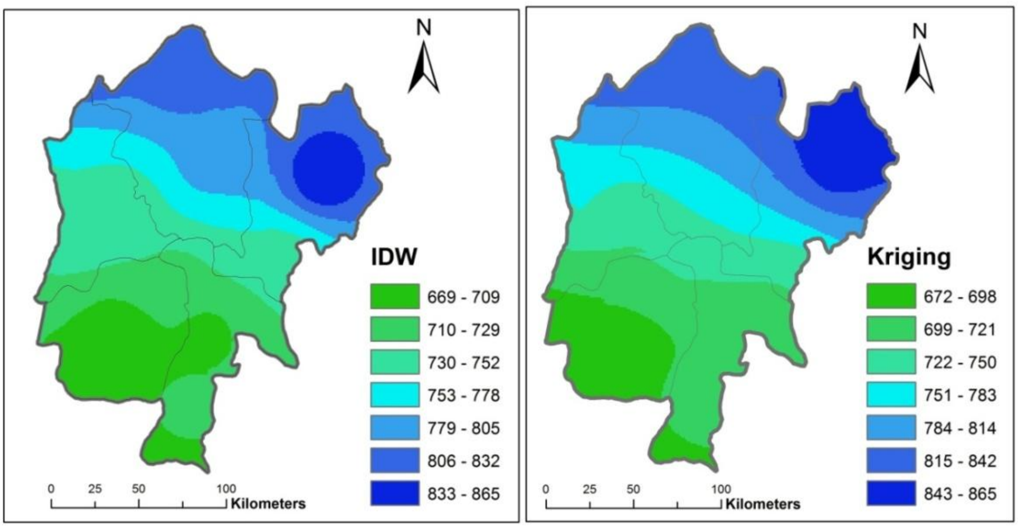

Figure 6: Spatially distributed average dry season ET_o (mm) in South-eastern Nigeria as developed by the two interpolation methods

An analysis of reference evapotranspiration was performed as presented in Figures 7(a) and (b). Estimates by both methods have positive correlations with the observed data, with correlation coefficients R = 0.83 and R = 0.50 for IDW and kriging methods respectively. Regression coefficients of determination, were $R^2 = 0.69$ and $R^2 = 0.25$ for IDW and kriging methods, respectively.

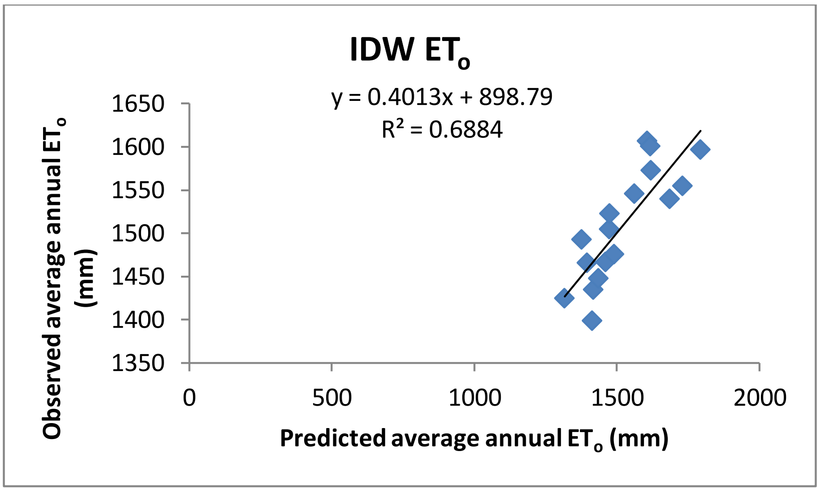

Figure 7(a)

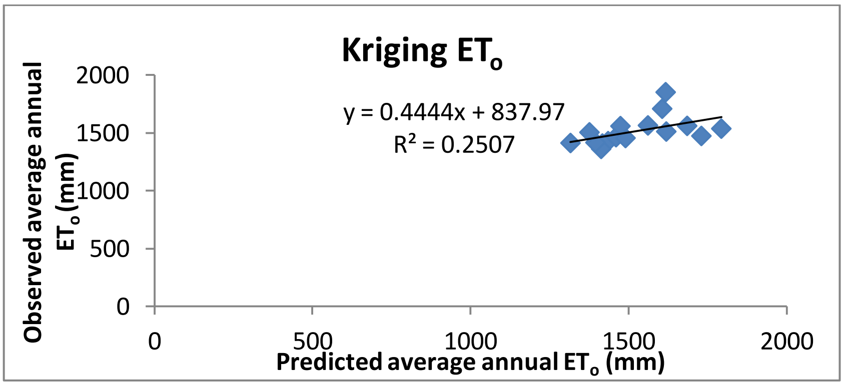

Figure 7(b)

Figure 7: (a and b): Regression of ET_o as estimated by IDW and kriging interpolation methods on observed ET_o

Conclusions

The average temperature, wind speed and solar radiation were increasing northwards while relative humidity was increasing in opposite direction. There was high spatial variation in seasonal reference evapotranspiration in the study area. The inverse distance weighting interpolation method performed better than kriging interpolation method.

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BIOCHAR AND ITS APPLICATION IN SOIL TREATMENT AND AMENDMENT: A REVIEW

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Abstract:

Biochar employed to improve land scope and impound carbon is attracting a great deal of attention. Ensuring food security/ safety through increased income and productivity, adapting to climate change and contributing to climate change mitigation are some intertwined challenges agriculture has to address.The concept to use biochar as a soil amendment may seem recent but really comes from the study of very ancient soils in the Basin of Amazon. Biochar a fine-grained charcoal high in organic carbon is largely resistant to decomposition. The presence of biochar in the soil can improve soil chemical and physical properties. The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soil with very little biological decay.

Keywords: Biochar, Biomass, Production conditions, Characteristics, Soil Amendment.

1. INTRODUCTION

A vigorous and sustainable food system is dependent on the health of the soil. Low nutrient content and accelerated mineralization of soil organic matter (SOM) are the two major constraints currently encountered in sustainable agriculture (Renner, 2007). Plants obtain their nutrient from organic matter and minerals found in soils. As the land is farmed, the agricultural process disturbs the natural soil systems such as nutrient cycling and the release and uptake of nutrients (Bot, A and Benites, J., 2005). Modern agriculture is apt to mine the soil for nutrients and to reduce soil organic matter levels through repetitive harvesting of crops. This decline of the soil continues until management practices are improved, additional nutrients are applied, rotation with nitrogen-fixing crops is practiced, or until a fallow period occurs allowing a gradual recovery of the soil through natural ecological development. As the natural stores of the most important nutrients for plant growth decline in the soil, growth rates of crops are inhibited. The most widespread solution to this depletion is the application of soil amendments in the form of fertilizers containing the three major nutrients: nitrogen, phosphorus, and potassium. Among these nutrients, nitrogen is considered the most limiting for plant growth. Nitrogen builds protein structures, develops hormones, chlorophyll, vitamins, and enzymes, and promotes stem and leaf growth. Inorganic or commercial fertilizers have been the primary soil amendment since the dawn a of the industrial age. Nitrogen fertilizers are often made using the Haber -Bosch process utilizing natural gas (CH_4) for the hydrogen and nitrogen gas (N_2) from the air to form ammonia (NH_3) as the end product. This ammonia is used as a feedstock for nitrogen fertilizers, such as anhydrous ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) (Erisman et al., 2008). However, the use of fossil fuel based fertilizers contributes to greenhouse gas emissions while similarly encouraging the depletion of the natural nutrient and minerals in healthy soils. As a soil amendment, biochar can greatly influence various soil properties and processes (Lehmann and Joseph, 2009) which is a carbon-rich product obtained by heating biomass in a closed system under limited or low supply of oxygen.

Biochar, a fine-grained charcoal high in organic carbon is largely resistant to decomposition. The presence of biochar in the soil can improve soil chemical (e.g. pH, CEC) (Liang et al., 2006), and physical properties (e.g. soil water retention, hydraulic conductivity) (Major et al., 2010). Biochar is commonly defined as charred organic matter, produced with the intent to deliberately apply to soils to sequester carbon and improve soil properties (Lehmann and Joseph, 2009). It is produced from pyrolysis of plant and waste feedstocks. Presently, there are several thermochemical technologies such as pyrolysis, gasification, and hydrothermal conversion to produce biochar. Pyrolysis involves the heating of biomass or organic materials at high temperature (≈400 – 800^{o}C) in a limited oxygen environment to yield a series of bio-products: biochar, bio-oil, and syngas. Pyrolysis is a simple and inexpensive process which has been used to produce charcoal for thousands of years. The pyrolysis of biomass results in biochar as well as gas and liquid products in varying proportions depending on the type of organic material and heating temperature (Verheijen et al., 2010). The only difference between biochar and charcoal is in its utilitarian intention; charcoal is produced for other reasons (e.g. heating, barbeque, etc.) than biochar. However, traditional earthen and brick kilns used to produce charcoal usually vent a large amount of volatiles to the atmosphere, which causes air pollution. Modern pyrolyzers are designed to capture the volatiles for the production of bio-oil and syngas. Gasification is a thermochemical process where biomass is heated with a small amount of air to produce a main product—syngas and a by-product—biochar. Hydrothermal conversion primarily focuses on using wet biomass to generate bio-oil. Biochar is a by-product of that process as well.

The “Terra Preta de Indio” or “black soil of the Indian” the Amazon basin was formed from the practices of Indigenous people’s centuries ago when the amassed charcoal and different wastes, nutrient trash like animal bones and fish bones (Taylor, 2010; Bates, 2010; Bruges, 2010) and has been found to be highly fertile and richer in carbon compared to neighbouring soils. This sustained fertility and carbon content has been attributed to the accumulation of charcoal in the soil over time (Solomon et al., 2007). Charcoal is present in many soils around the world as a result of both anthropogenic and natural causes. For instance the fertile dark Chernozemic soils, present across Western Canada, have been reported to contain between 25-65% carbon derived from charcoal (Ponomarenko and Anderson, 2001). Radiocarbon dating has shown that forest soils in east-central British Columbia contain carbon derived from charcoal ranging from 182 to 9558 years old (Sanborn et al., 2006). Researchers has seen that the biochars in these soils, is the one that keeps them so fertile over such extensive stages in an environment that rapidly filters nutrients out of soil and where organic materials decomposes so quickly (Bates, 2010; Bruges, 2010).

2. BIOCHAR PRODUCTION CONDITION

The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soil with very little biological decay (Lehmann and Rondon, 2006). As raw organic materials supply nutrients to plants and soil microorganisms, biochar serves as a catalyst that enhances plant uptake of nutrients and water. The artificial production of biochar generally applies two methods, pyrolysis and hydrothermal carbonization. In both charring processes, organic biomass substrates (feedstock, manure, straw, etc.) are converted to carbon rich products, due to thermochemical processes under limited or no available oxygen supply (Lehmann and Joseph, 2009). Different biomass contains different fractions of fixed carbon and different amounts of lignin, cellulose and other organic compounds that will degrade at different rates and respond differently to temperatures. For the pyrolysis process, there are different operating modes, including fast, intermediate and slow pyrolysis and gasification. The starting material for all modes of pyrolysis has to be dried (less than 10% moisture content) before entering the pyrolyser, and during pyrolysis three products are always produced, namely gas, liquids and char.

Generally, the slow pyrolysis with low process temperatures (~400°C) and long vapor residence times (hours-days) are resulting in high yields of charcoal (approximately 35%). The intermediate and fast pyrolysis with moderate temperatures (~500-700°C) and short vapor residence time (1 to 30 sec.) favors the production of liquids (50-75%). Biochar yields and volatile contents will decrease with increasing treatment temperatures. Therefore, high temperatures (~750-900°C) and longer residence time favor biomass conversion to gas (85%) (Bridgwater, 2012). Several studies have shown that higher treatment temperatures lead to higher surface areas, until temperatures are reached where deformation occurs (Lehmann and Joseph, 2009).The hydrothermal carbonization treatment takes place in a wet environment, where the biomass is placed in an autoclave under pressure and temperatures ranging from 200-250°C for 2- 4 hours. For both the pyrolysis and the hydrothermal carbonization, studies have shown that the original porous structure of the organic biomass broadly will be maintained (Cutter et al., 1980).

Organic materials used as feedstock and process temperature are the primary factors in the determination of the quality of biochar (Gaskin et al., 2008). Different elements such as lignin, hemicelluloses and cellulose are degraded at different production temperatures. Since organic material differs in the composition of these elements the decomposition rate between plant species will vary. Further, time for harvest, climate and nutrient status of the soil affects the composition. All organic materials start to undergo thermal decomposition at temperatures above 120˚C. The ash content is important for the physical properties of biochar and varies between organic materials. High ash content may cause deterioration of structure, hence resulting in less stable biochar (Lehmann & Joseph, 2009).

The active surface area is enhanced by high temperature conditions, while cation exchange capacity (CEC) is decreased as a result of loss of functional groups (Gou and Rockstraw, 2007). Further, studies have indicated that high temperatures might result in nutrient loss via volatilization (Jensen et al., 2000; Olsson et al., 1997). When the temperature exceeds 500˚C as much as 50 % of N may be lost (Gaskin et al., 2008). In addition, P concentration decreases at higher temperatures. Other factors affecting the properties of biochar are heating rate, heat transfer inside the vessel and pressure during production (Lehmann and Joseph, 2009).

3. BIOCHAR CHARACTERISTICS AND PROPERTIES

Biochar is a light weight, highly porous material with high carbon content, a portion of which has a stable chemical structure resistant to decay, also a firm substance achieved with organized carbonization. Biochar is typically low in available nutrients, though contains some ash content, which adds some nutrients, and typically has an alkaline pH (Downie et al., 2009). Depending on the starting material and process parameters (temperature, residence time, etc.), the biochar will obtain different physical and chemical structures that can modify the physical and chemical characteristics of the soil. The biochar product is believed to be resistant to microbial decomposition (Lim et al., 2016). Biochar additions may positively affect the soil carbon (C) sequestration and, thus, act as a sink and long-term storage of carbon due to its long residence time in the soil ranging from 100 to 1000 years (Verheijen et al., 2010). There is a high variability among the characteristics of different biochars, but in case of pH, biochars are usually alkaline (pH>7) (Lehmann and Joseph, 2009). For instance a wood derived biochar will contain a higher proportion of carbon than a manure biochar due to starting differences in carbon content. In turn a manure biochar will contain more ash than wood biochar due to higher nutrient content in manure (Novak et al., 2009; B. Singh et al., 2010). A review of the literature found that biochar can be made out of a wide diversity of feedstocks including various types of wood, straw and stalks, grasses, nut shells, algae, manure, paper mill waste, and sewer sludge. To be sustainable, biochar should be produced from a waste biomass stream and not from the primary production of biomass. The pyrolysis heating temperature and duration can vary and has an important impact on a biochar's final properties. As production temperature increases, the amount of biochar produced decreases (liquid and gases increase), pH increases, porosity and surface area increase up to a certain temperature, carbon content becomes concentrated, proportion of labile carbon content decreases, and proportion of recalcitrant carbon content increases (Gundale and De Luca, 2006; Keiluweit et al., 2010; Novak, et al., 2009; Peng et al., 2011). Labile carbon refers to forms of carbon that are more readily broken down in the soil and recalcitrant refers to forms of carbon resistant to decay. As a result of feedstock and pyrolysis variability, there is a wide variation in the properties of biochars, which in turn contributes to the variability of its impact when used as an agricultural soil amendment. For this reason there has been significant research to characterize the chemical and physical properties of biochars produced from different feedstocks under different pyrolysis conditions, including a local project based out of Langara College Vancouver (Břendová et al., 2012; Novak et al., 2009).

3.1 Physical properties

The physical characteristics of biochar depends on the biomass used, the pre- and post handling and the type of treatment. It is expected that the maximum treatment

temperature is the most important factor for physical changes of the biochar product, followed by the heating rate and pressures (Lehmann and Joseph, 2009). The biochar structure is amorphous, containing local crystalline structures of joint aromatic compounds (Graber et al., 2011). The carbon skeleton formed during pyrolysis of organic matter results in a high porosity of biochar, due to its sponge-like structure (Kumari, 2015). The voids are formed as pores present as macro- (>50µm), meso- (2-50µm) and micropores (<2µm). The large proportions of micropores (<2 x 10-3µm in diameter) is responsible for the increasing surface area, that can reduce the mobility of soil water (Lehmann and Joseph, 2009). The high porosity results in a low bulk density, which when incorporated to the soil in sufficient concentrations can reduce the total bulk density of the soil (Laird et al., 2010). Most biochar exhibits a large surface area, depending on the base material and treatment. For biochar obtained from pyrolysis, surface areas range from 20 m^2g^{-1} (Chen et al., 2008) up to 3000 m^2g^{-1} (Guo et al., 2002). The large surface area of biochar will increase the ion exchange capacity and the sorption of nutrients (Lehmann and Joseph, 2009). The amount of adsorbed water is directly dependent on the surface area, therefore biochars are able to adsorb large amounts of water. The process of water adsorption on the surface area of biochar is governed by the functionalgroups (Antal and Grønli, 2003).

When added to the soil, biochar will increase the total soil surface area, which is one characteristic, that is believed to be responsible to overcome the problem of too much water held in clay soils, due to increased soil aeration, and increase the water content/water holding capacity in sandy soils (Lehmann and Joseph, 2009). The particle size distribution of biochar is highly dependent on the feedstock used. In general, wood-based biochars are coarser and of xylem structure, while biochars obtained from crop residues are finer and of recalcitrant structure (Verheijen et al., 2010).

3.2 Chemical properties

The chemistry of biochar is highly dependent on the biomass used, temperature during pyrolysis and residence time. However, all biochars are composed of condensed aromatic ring structures that become larger and even more condensed with increasing pyrolysis temperature. Hamer et al. (2004) found that biochars obtained by maize, mineralized more rapidly than wood biochar and concluded this to be due to wood biochar having greater aromatic carbon content. Studies on the effect of pyrolysis temperature on biochar chemistry found that faster mineralization occurred in biochars produced at 400°C than in biochars produced at 550°C (Singh et al., 2012). It is known that a range of functional groups exist on the surface of biochar, such as Hetero-atoms (hydrogen, oxygen, nitrate, phosphorus and sulfur), acidic carboxyl groups and other basic functional groups (chromenes and pyrenes) (Lehmann and Joseph, 2009).

However, the presence of functional groups on the surface of biochar depends on the type of feedstock. Moreover, the overall assumption is that temperatures above 600°C will decompose the functional groups through heat degradation (Jindo et al., 2014). Most biochars have a strong surface area charge and thereby a high cation exchange

capacity (CEC) having both cation and anion exchange capacity (Gai et al., 2014). Mukherjee et al. (2011) stated that the surface properties of biochar lead to its potentially useful properties, such as contaminant control and the release and retention of nutrients. There is small variability for the pH between biochars, with typical values above seven (Verheijen et al., 2010). The pH and electrical conductivity (EC) for biochars has been found to be higher with higher temperatures. Gundale and DeLuca (2006) concluded that the higher pH with higher pyrolysis temperatures might occur due to the accumulation of oxides of alkaline metals. The high pH of biochar will have a liming capacity, when incorporated into the soil (Chintala et al., 2014).

4.0 BIOCHAR AS AN AMENDANT

Biochar can be used directly as a replacement for pulverized coal as a fuel. But one of the major distinctions between biochar and charcoal (or char) is that the former is produced with the intent to be added to a soil as a means of sequestering carbon and enhancing soil quality. When used as a soil amendment, biochar has been reported to boost soil fertility and improve soil quality by raising soil pH, increasing water holding capacity (Karhu et al., 2011), attracting more beneficial fungi and microbes, improving cation exchange capacity (CEC), and retaining nutrients in soil (Lehmann et al., 2006; Lehmann, 2007). Another major benefit associated with the use of biochar as a soil amendment is its ability to sequester carbon from the atmosphere-biosphere pool and transfer it to soil (Winsley, 2007; Guant and Lehmann, 2008; Laird, 2008). Biochar may persist in soil for millennia because it is very resistant to microbial decomposition and mineralization. This particular characteristic of biochar depends strongly on its properties, which is affected in turn by the pyrolysis conditions and the type of feedstock used in its production. Previous studies indicate that a bioenergy strategy that includes the use of biochar in soil not only leads to a net sequestration of CO_2 (Woolf et al., 2010), but also may decrease emissions of other more potent greenhouse gases such as N_2O and CH_4 (Spokas et al., 2009). Biochar can be considered as part of a larger picture which includes the generation of renewable energy from biomass and the redirection of organic waste streams.

Similar to activated carbon, biochar can serve as a sorbent in some respects. Biochar usually has greater sorption ability than natural soil organic matter due to its greater surface area, negative surface charge, and charge density (Liang et al., 2006). Biochar can not only efficiently remove many cationic chemicals including a variety of metal ions, but also sorb-anionic nutrients such as phosphate ions, though the removal mechanism for this process is not fully understood (Lehmann, 2007). Thus, the addition of biochar to soil offers a potential environmental benefit by preventing the loss of nutrients and thereby protecting water resources. Furthermore, soils containing biochar have a strong affinity for organic contaminants (Yang and Sheng, 2003a; 2003b; Yu et al., 2009). For example, one study revealed that unmodified biochar pyrolyzed from waste biomass could effectively sorb two triazine pesticides, effectively retarding their transport through the soil (Zheng et al., 2010). Additionally, some modified biochars (i.e., biochar modified by some

specific physical and chemical activation treatments) have demonstrated the potential to effectively remove a variety of organic contaminants from water as a sorbent (Chen et al., 2008; Cao et al., 2009).
As a soil amendment, biochar creates a recalcitrant soil carbon pool that is carbon-negative, serving as a net withdrawal of atmospheric carbon dioxide stored in highly recalcitrant soil carbon stocks. The enhanced nutrient retention capacity of biochar-amends soil not only reduces the total fertilizer requirement, but also the climate and environmental impact of croplands.

CONCLUSIONS

Biochar have a potential to sequester carbon and improve soil microbial activities. It can be seen that biochar can help in improving the environmental condition by mitigating green house effects and improve soil chemical and physical properties. There, it is necessary to inform farmers of the importance of biochar to improve soil and increase productivity by improving water and nutrient retention.

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MAPPING THE SOIL FERTILITY OFTEACHING AND RESEARCH FARM OF FEDERAL UNIVERSITY OF TECHNOLOGY MINNA USING GIS

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Abstract

The study was conducted at FUT Minna researchfarm with a view to coming up with the fertility status of the farm and prepare GISbased property map. The soil samples were collected at 10 m^2 spacing using GPS.The 100 grids in the farm covering an area of one hectare from which soil samples were collected and analyzed using standard procedure for assessing chemical properties and available N, P and K nutrient status. The available Nitrogen, Phosphorus and Potassium ranged from high to low, but sample from the depth of 0-15cm have higher N, P and K concentrations. The soilfertility map indicates clustering of the nutrients at the lower elevation of the farm while the upper elevation has lower sparse concentration. The maps indicated the fertility status of farm based on which recommendation forapplication of manure to the depth of 15 to 45 cm of the soil could bemade for the soil to support shallow rooted crops.

Keywords: GIS Technique, GPS, Nutrients, Soil fertility map

1. Introduction

Soil is life supporting system and one of the most vital and precious natural resource of any country and socio-economic development ofpeople (Kanwar, 2004). Soils considered as the integral part of landscape and their characteristics are largely governed by landforms in which they are developed. The information on their characteristic, classification, location and distribution, is required for any developmental planning in particular area. As a vital natural resource, soil should be used judiciously according to its potential to meet the increasing demands of ever growing population. To ensure optimum agricultural production, it is imperative to know best fact about our soils and their management to achieve sustainable production. The quality of soil needs to be looked into because presently the natural resources are being over exploited. Intensively cultivated soils are being depleted with available nutrients especially micronutrients (Challa *et al.*, 1995). Therefore, assessment of nutrient constraints of soils that are being intensively cultivated with high yielding crops needs to be carried out. Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are not useful for site specific recommendations and subsequent monitoring. Soil available nutrients constraints of an area using Global Positioning System (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. Geographic information system (GIS) is a powerful tool which helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, etc. to derive useful information (Adornado and Yoshida 2008). It has been documented very well that dryland soils are not only thirsty but hungry too meaning that besides soil and water conservation, if nutrient management issues are addressed, the productivity of a watershed is further enhanced.

Soil fertility mapping using GIS is therefore useful to fully have an idea of nutrient distribution in form of graphic with a view to ascertaining what type of nutrient enrichment a particular soil need and at what rate per hectare. This research is therefore conducted to assess the soil macro and micronutrients status of selected portion of the farm, to employ the concept of geographical information system (GIS) to map the soil macronutrients (Nitrogen, Phosphorus and Potassium) distribution and to study the variation of macronutrients with respect to depth in the study area.

Materials and methods

The study area (figure 1) lieson longitude of 6^0 28' E and latitude of 09^0 35' N. The site is bounded at Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga. The entire site is drained by rivers Gwakodna, Weminate, Grambuku, Legbedna, Tofa and their tributaries. They are all seasonal rivers and the most prominent among them is the river Dagga.

Climate, Rainfall, Temperature and Soil of the study area

Minna generally is known to experience rainfall from the month of May to the month of October and on rear occasions, to November. It is known to reach its peak between the months of July and August. Towards the end of the rainy season, around October, it is known to be accompanied by great thunder storms. The maximum temperature period in this area is usually between the months of February, March and April which gives an average minimum temperature record of 33^0C and maximum temperature of 35^0C (Minna Airport Metrological Centre, 2000).

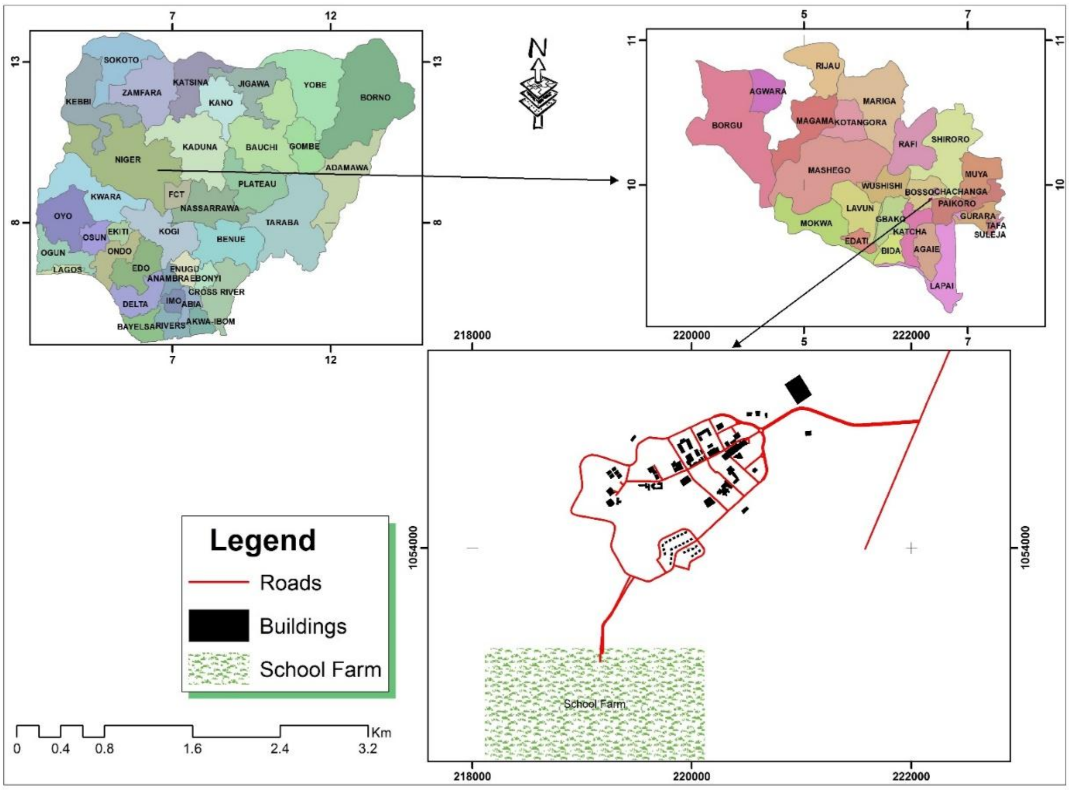


Figure 1: Map of the study area

During the rainy season, the temperature within the area drops to about 29^0C. The major soil found in this area is the sandy loam type with a sparse distinction of the sandy – clay soil and sandy soils. This has so far encouraged the residents of Minna metropolis and neighboring villagers to use the land for agricultural activities such as farming and grazing by the nomadic cattle herders.

Sample Collection

A total of 300 soil samples were collected with auger and packed into well labeled bags from selected 1ha of land in the study area. The samples were collected at interval of 10m and three soil samples were collected at each sample point at varying depths of 0 - 15cm, 15 - 30cm and 30 - 45cm respectively. The exact sample locations were recorded using GPS instrument. The soil samples were analyzed for Nitrogen, Phosphorus and Potassiumusing digestion method after which Atomic Absorption spectrophotometer (Model: Perkin Elmer AAS 200).was used for chemical analysis. Textural classification was also done using sieve analysis.

Preparation of soil characteristics maps with GIS software

Base map of the Federal University of Technology Minna Teaching and Research farm was digitized and geo-referenced. The study portion of the Farm was extracted using a polygon layer on the geo-referenced map. The GPS coordinates in latitude and longitude were used to plot the observed sample positions and linked with the attribute table for the analysis in ArcGIS 10.1 software to generate the soil fertility map for Nitrogen, Phosphorus and Potassium content.

Results and Discussion

Figures 1 to 3 shows the distribution of nitrate, phosphate and potassium at various depths of the soil.

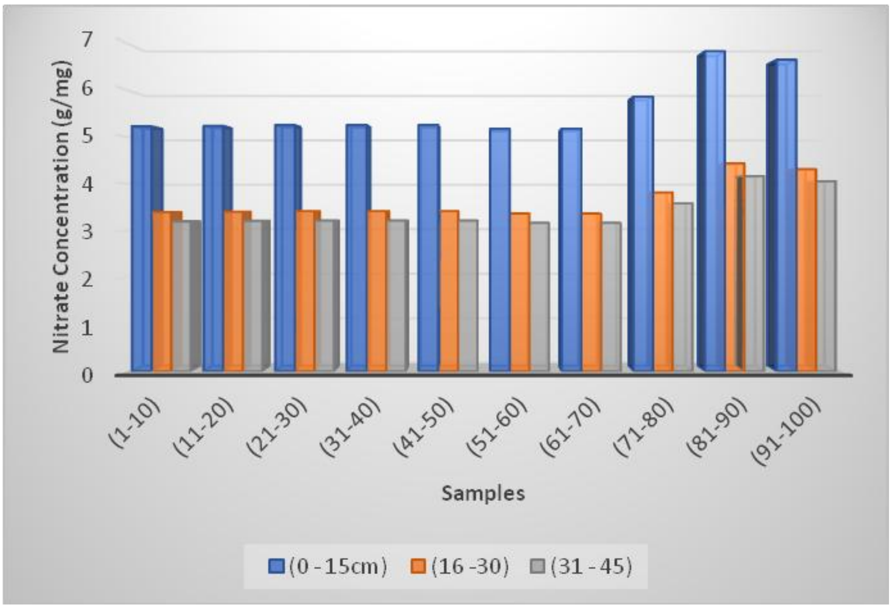


Figure 2: Nitrate Concentration at different Depths of the Experimental Plot

From the figure the nutrient level decreases with depth with a difference between 15 cm depth and 30cm depth. However, statistical analysis carried out using Duncan multiple range tests showed that there is no significant difference between depth 30 cm and depth 45 cm. This might have clearly responsible for why the soil is only performing well when shallow rooted crops are cultivated on it but yield very little with deep rooted crops. Binita*et al,* (2009) recorded scenario similar to this after analyzing soil of Karnataka, India research farm. It was suggested in their research that a soil that is deficient in macronutrients after 20cm depth will not be good for many arable crops. Remedial measures such as incorporation of farmyard manure which will be worked into required depth and cultivation of leguminous crops like soybean could help improve the nutrient level at sub soil depth.

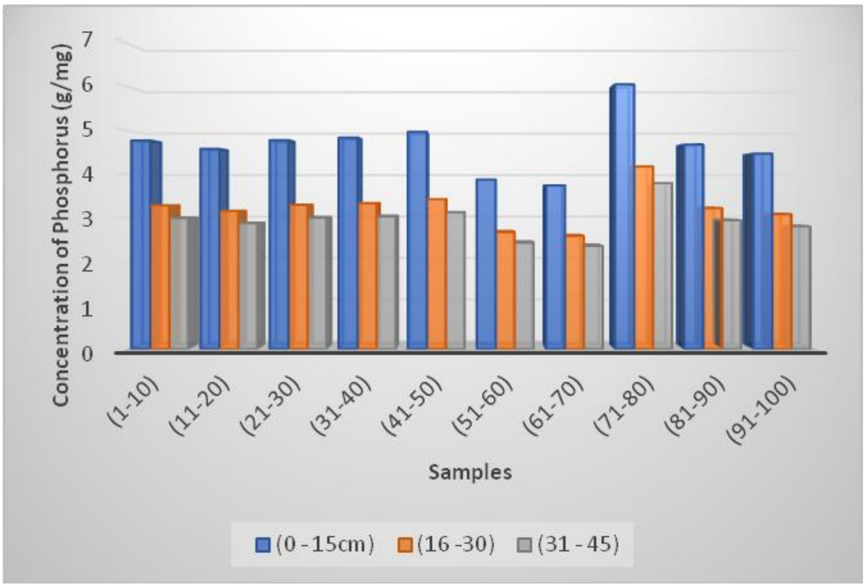


Fig. 3: Phosphate Concentration at different Depths of the Experimental Plot

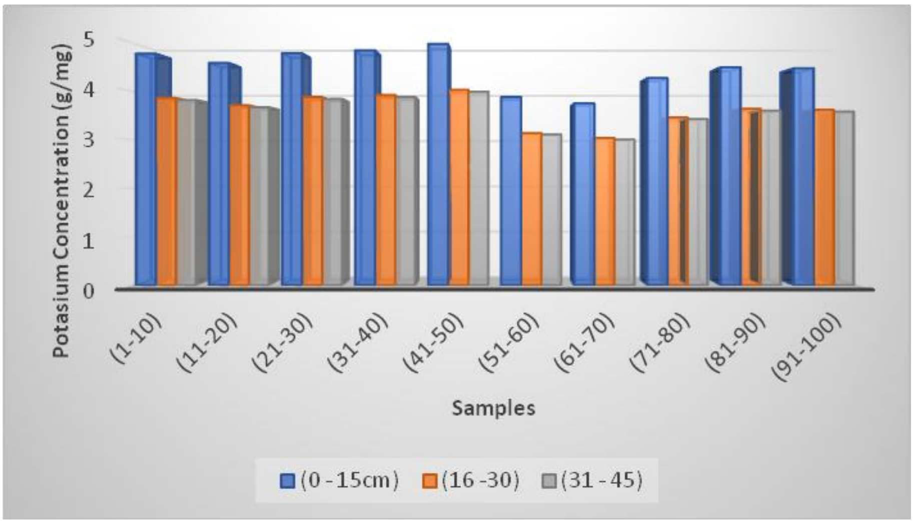
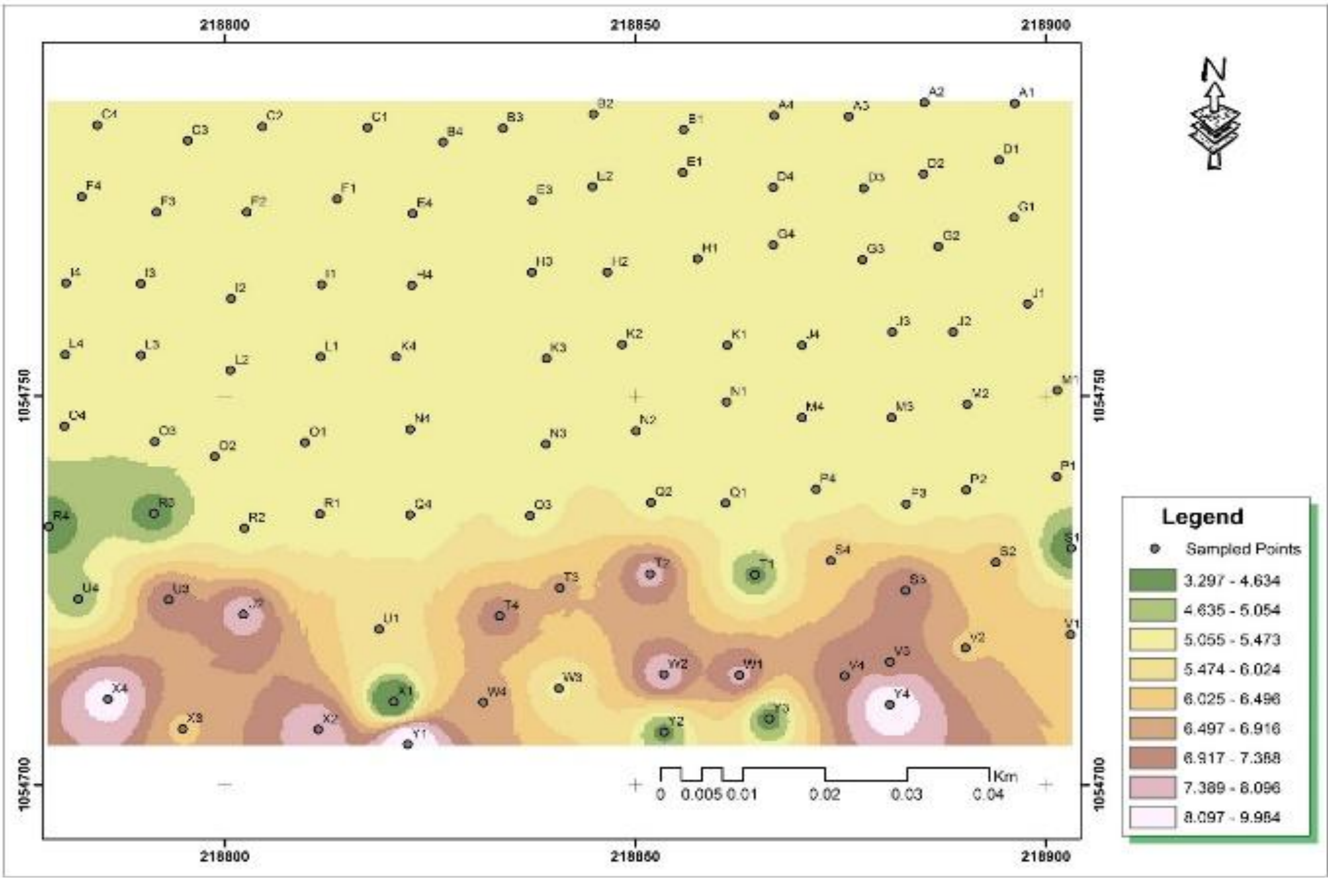


Fig. 4: Phosphate Concentration at different Depths of the Experimental Plot

GIS Mapping

The graphic output of GIS mapping for Nitrate, phosphate and potassium at the three depths are as presented in Figures 5 to 7. The available nitrogen in soil ranged from 5.2 to 3.4mg/g with a mean value of 4.6mg/g. This low to high status of available N in soils of studied area might be due to alkaline soil reaction and high content of $CaCO_3$in the soil. The range is quite not significant especially between depths of 30 cm and 45 cm which might be due to slight variation in soil organic matter content, various management and Agronomic practices. The similar trends of available nitrogen were also reported in soils of Nandurbar Agriculture college farm, India (Shinde *et al.*, 2016). The available Phosphorus in soil was ranged from 10.9 to 5.9mg/g. Almost all the samples were categorized very high (38.27%) followed by moderately high (18.51%) in terms of phosphorus content.

The slight variation in phosphorus content in the tested soil might be because of decomposition rate of substrate andprevious application of phosphate fertilizer as a result continuous cultivation of soil in the study area.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3.297 - 4.634
4.635 - 5.054
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5.474 - 6.024
6.025 - 6.496
6.497 - 6.916
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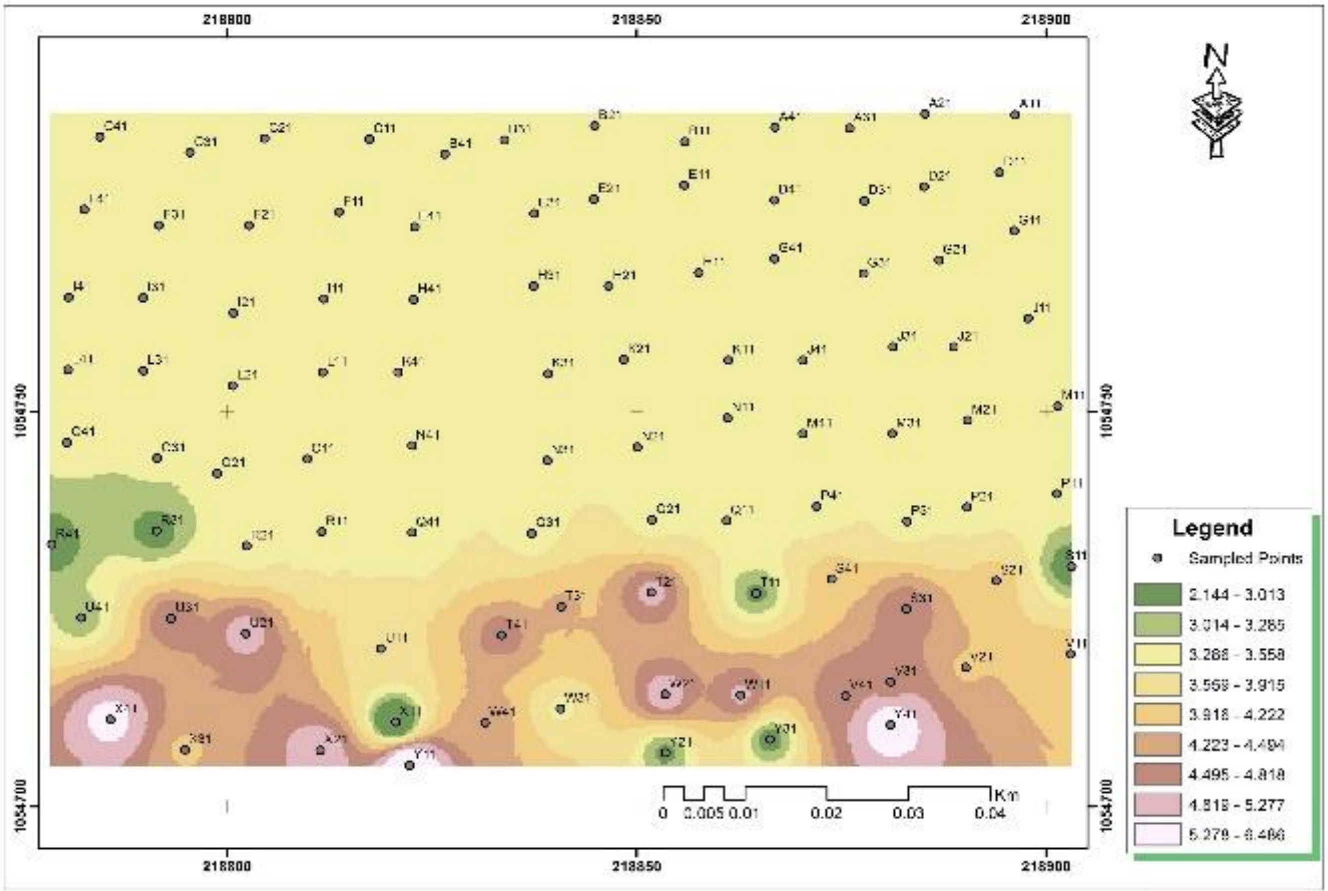
0 0.005 0.01 0.02 0.03 0.04 Km

(a)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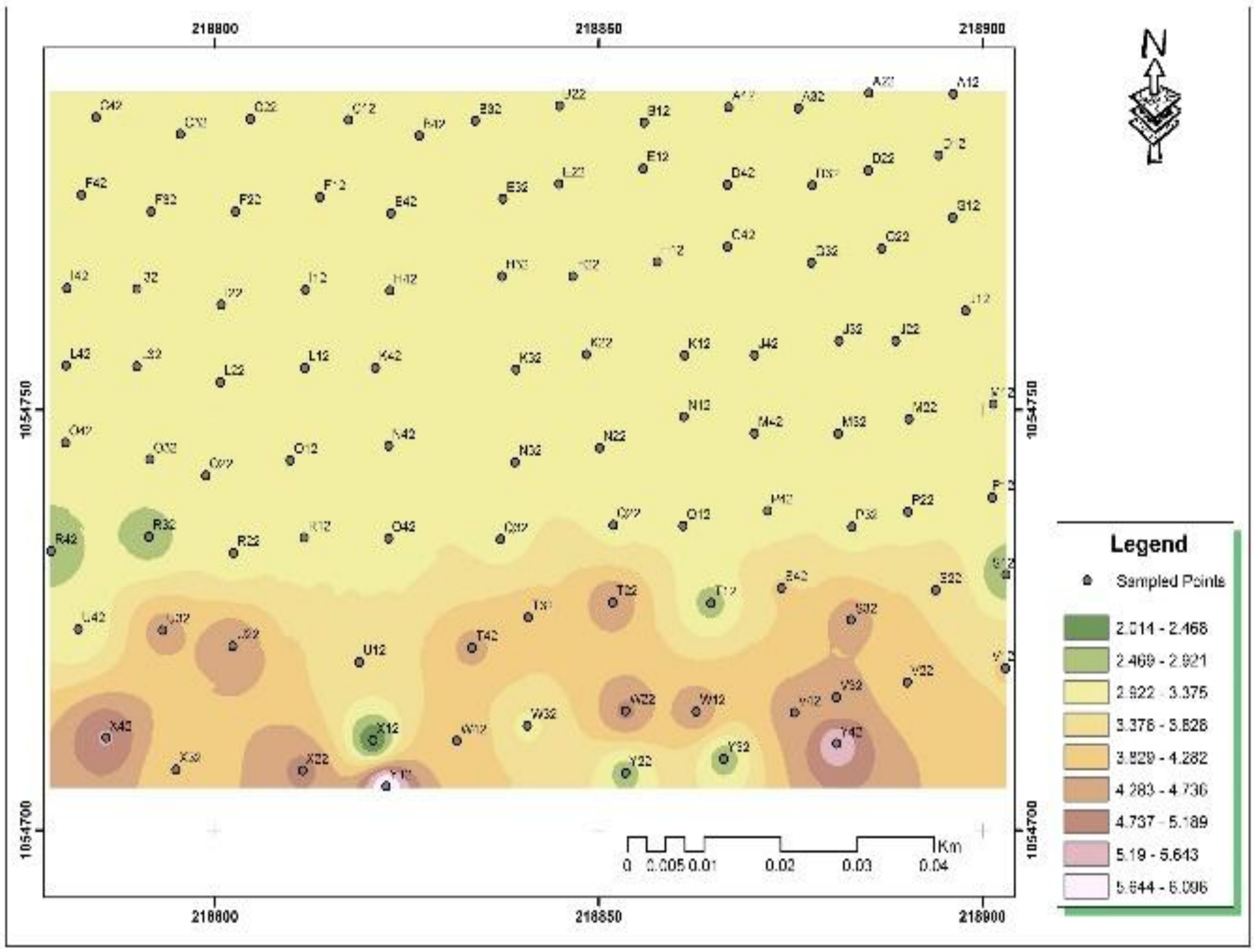
3.014 - 3.285
3.286 - 3.558
3.559 - 3.915
3.916 - 4.222
4.223 - 4.494
4.495 - 4.818
4.819 - 5.277
5.278 - 6.486
0 0.005 0.01 0.02 0.03 0.04 Km

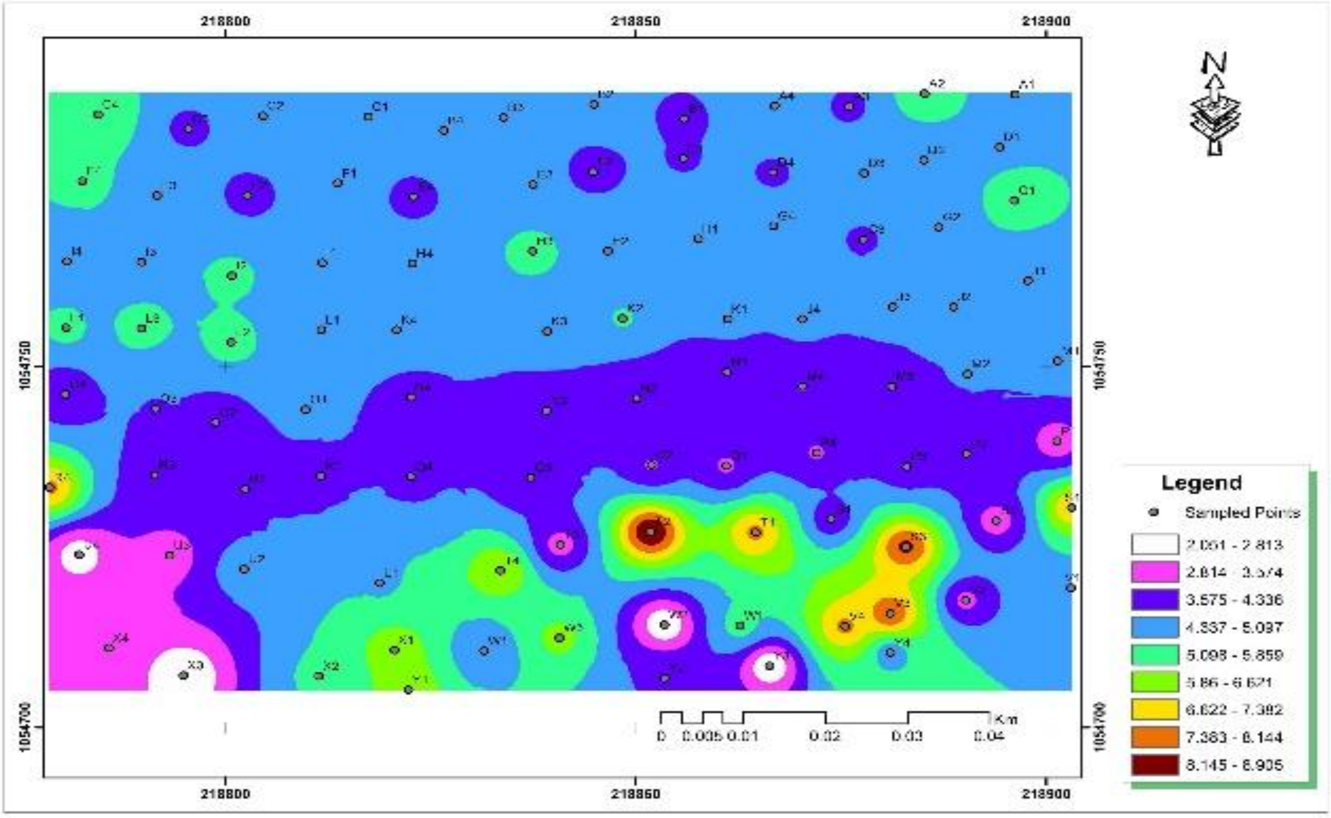
(b)



(c)

Figure 5: Nitrate Distribution at (a) 0 - 15cm depth (b) 15 - 30cm depth (c) 30 - 45 cm depth

As shown in Figure 5lower part of the study area was high in available nitrogen status upper part was low in available nitrogen status. Nitrogen is the most limiting nutrient in black soils, which is subjected to losses mainly through volatilization. The total nitrogen content in the soils is dependent on temperature, rainfall and altitude. The nitrogen status of the soils studied might be due to liberal crop residue addition to the soil, which is generated in large quantities (10-15 tones/ha/year) in the study area(Shinde *et al.*, 2016).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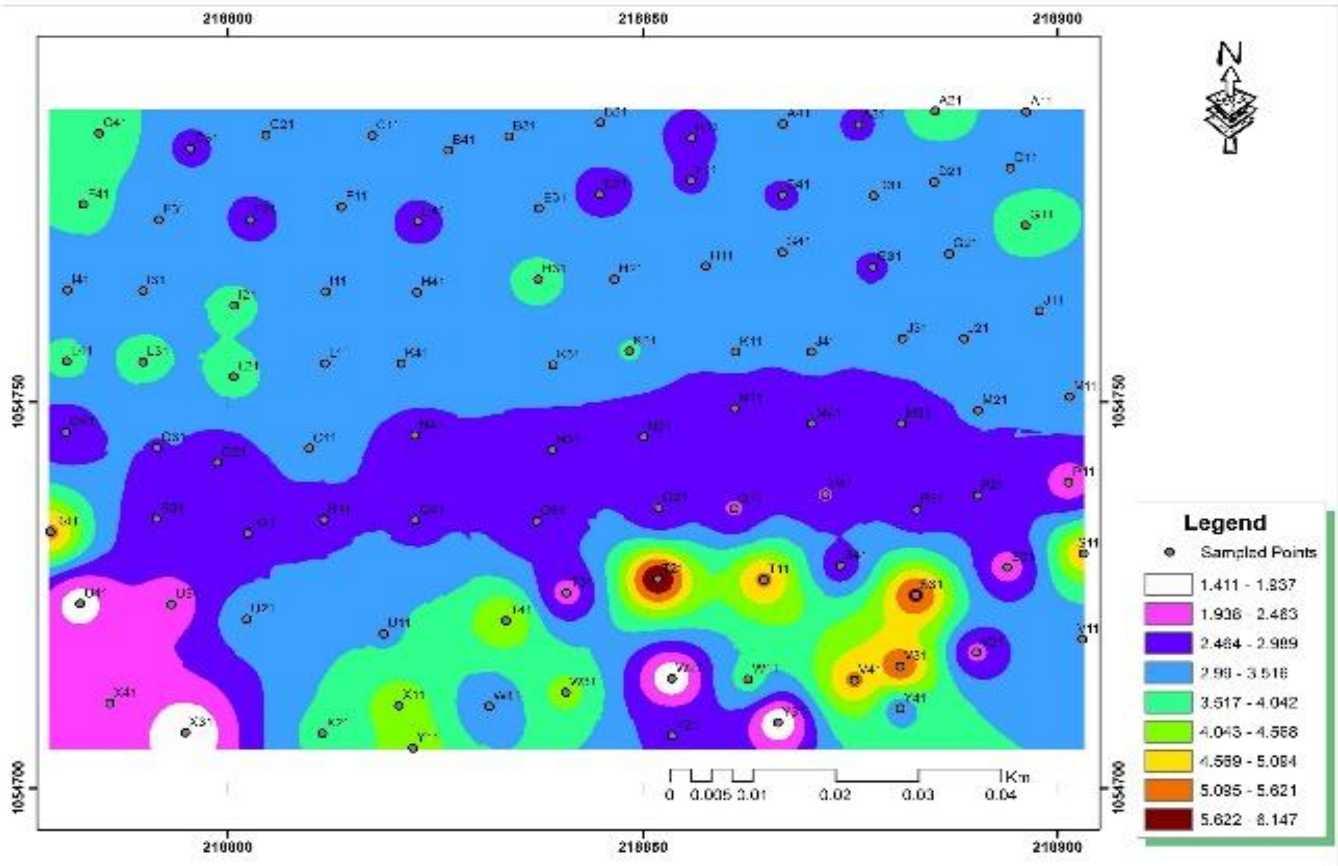
3.575 - 4.336
4.337 - 5.097
5.098 - 5.859
5.86 - 6.621
6.622 - 7.382
7.383 - 8.144
8.145 - 8.905

(a)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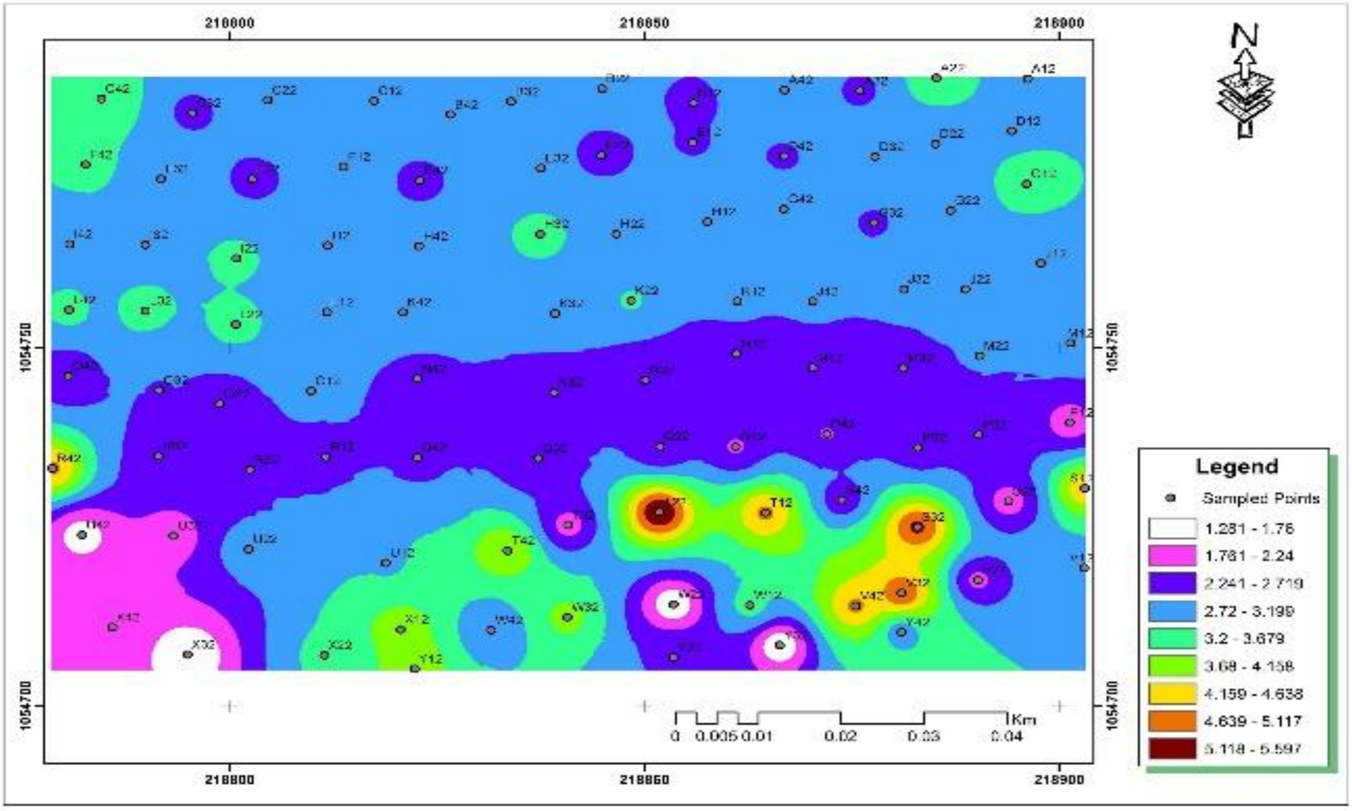
Sampled Points
1.411 - 1.937
1.938 - 2.463
2.464 - 2.989
2.99 - 3.516
3.517 - 4.042
4.043 - 4.568
4.569 - 5.094
5.095 - 5.621
5.622 - 6.147

(b)

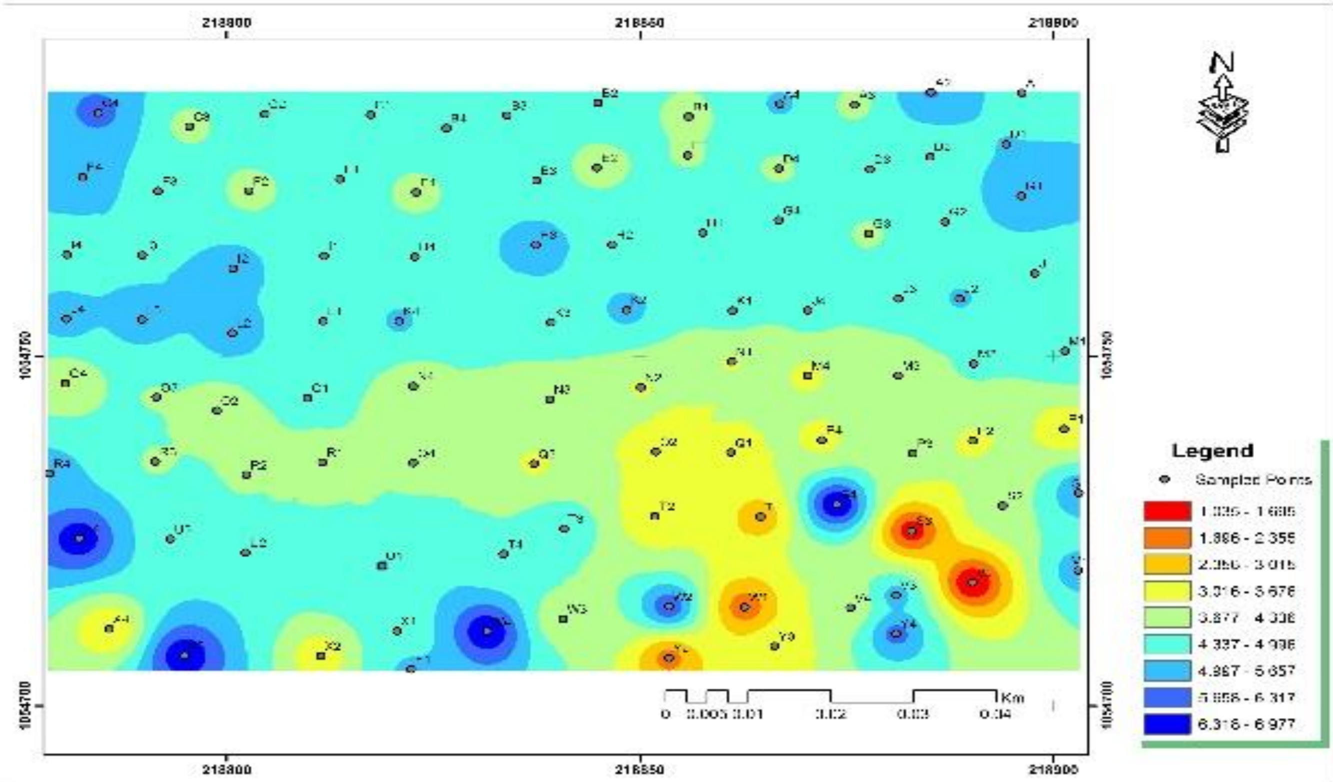


(c)

Figure 6: Phosphorus Distribution at (a) 0-15cm depth (b) 15-30cm depth (c) 30 - 45 cm depth

Figure 6 showed that the soil in the study area was medium in available phosphorus and the spatial distribution behaves in similar pattern to that of nitrogen. Though P is the second limiting element in vertisoil and phosphorous content of the study area could be increase by applying phosphorous fertilizer to the soil, but the phosphorous content at the top soil is satisfactory while amendment needs to be done at the subsurface level.

The soils of the study area were foundto be high in available potassium status Figure 7 around 88 per cent of the study area recorded high K values, while only 12 per cent of the area had medium available potassium content. It is observed that many vertisols are able to maintain a sufficient or even high level of exchangeable K and can provide a good supply of K to plants for many years in the study area. However, good nutrient management practices need to be imbibed to maintain the status over a long period.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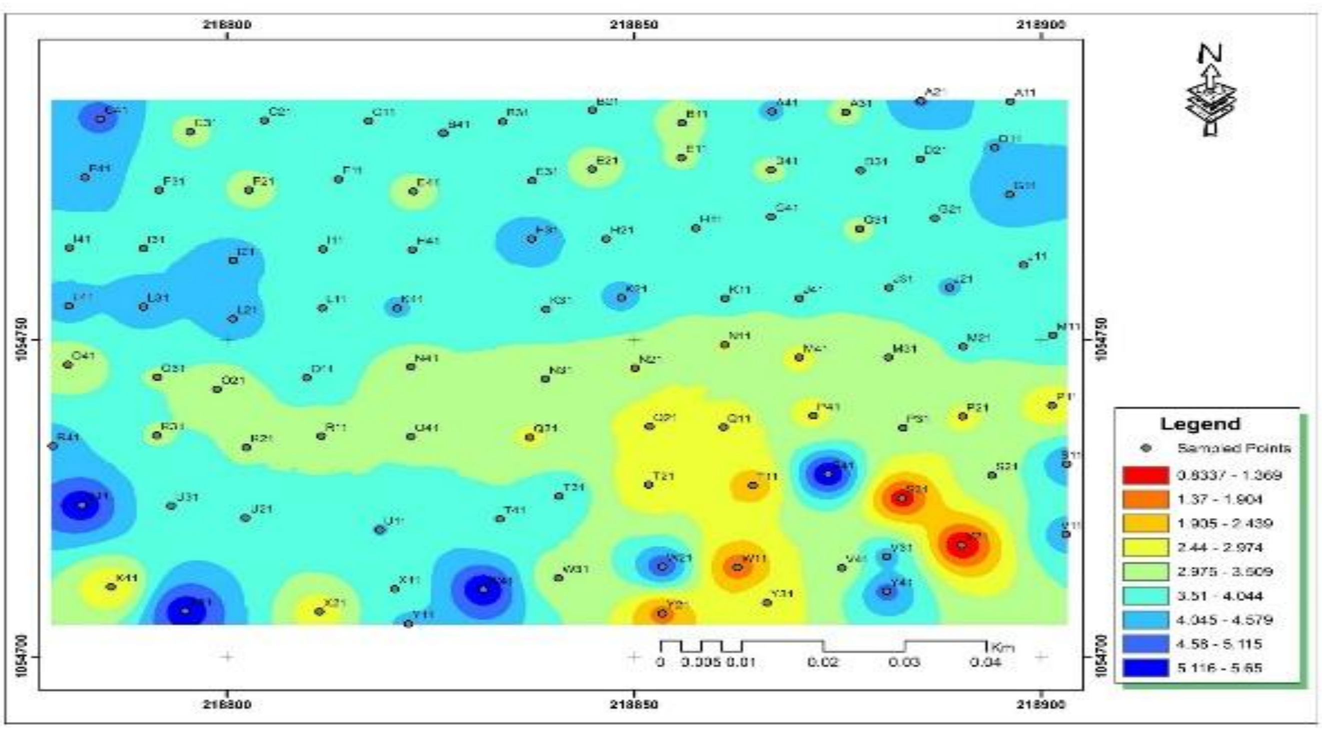
4.337 - 4.996
6.316 - 6.977

(a)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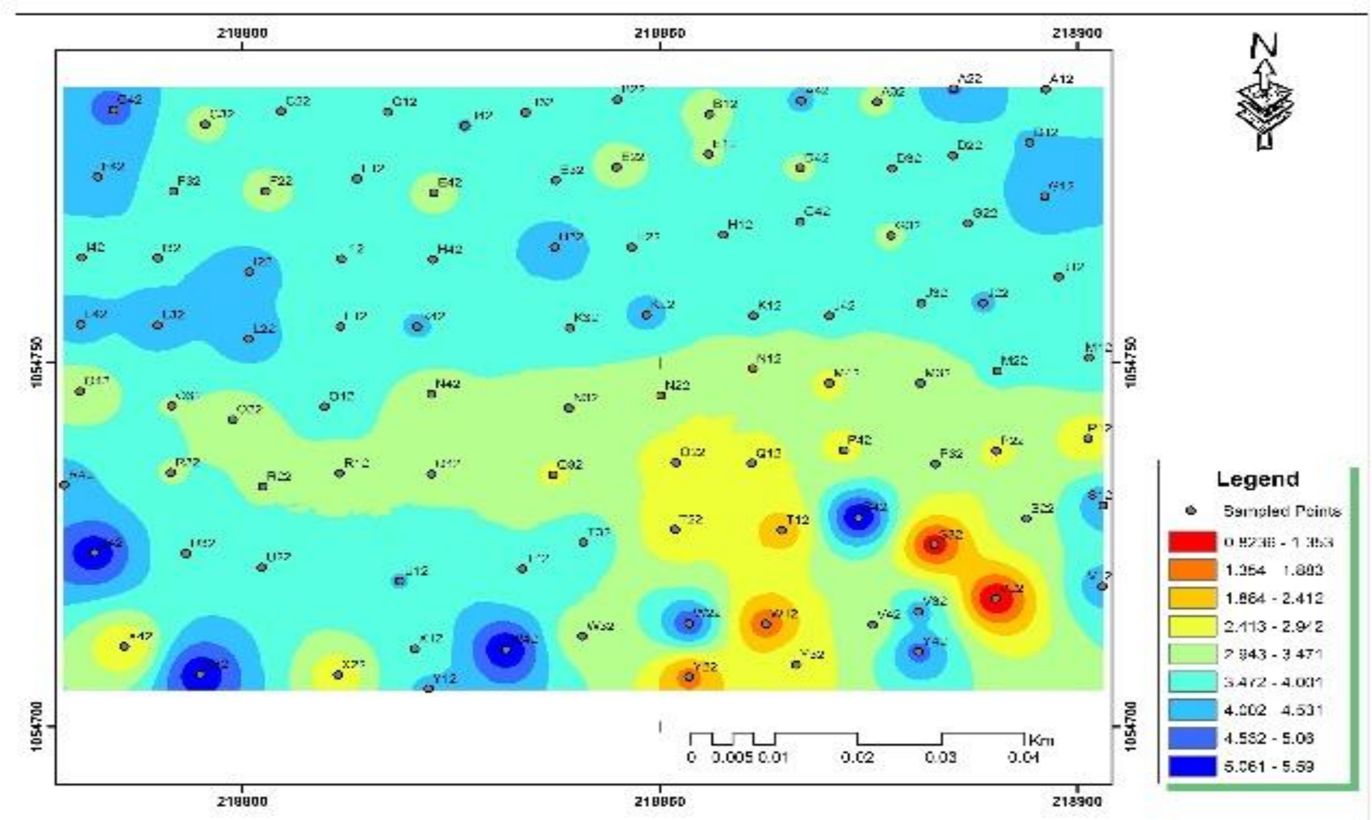
0.03
0.04
Km
Legend
Sampled Points
0.8337 - 1.369
1.37 - 1.904
1.905 - 2.439
2.44 - 2.974
2.975 - 3.509
3.51 - 4.044
4.045 - 4.579
4.58 - 5.115
5.116 - 5.65

(b)



(c)

Figure 7: Potassium Distribution at (a) 0 - 15cm depth (b) 15 – 30cm depth (c) 30 - 45 cm depth

Conclusion

The soils collected from FUT Minna teaching and research farm were high in macronutrients at depths of 0 – 15 cm while below this depth, the macronutrient level of the soil is generally low. The very less variation in soil macronutrients may be due to inherent heterogeneity of soil. The result indicates that all the soils are normal in nature and for healthy plant growth due to the soils are free from salinity. Holistic survey and precise use of analytical techniques in this investigation gave rise to production of soil fertility maps of selected portion of FUT Minna farm. The use of GIS technique for soil sampling is new landmark, which will enable the further researcher and officials to monitors the changes in the soil fertility status for years to come. Moreover, the timely monitoring of soil health deterioration can also be maintained by appropriate soil reclamation techniques.

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MULTIVARIATE ANALYSIS OF WATER QUALITY OF AMANSEA RIVER

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ABSTRACT

Variations in water quality of Amansea River were evaluated using multivariate statistical techniques (Principal Component Analysis (PCA) and Cluster Analysis (CA)) to analyze the similarities or dissimilarities among the sampling points so as to identify spatial and temporal variations in water quality and sources of contamination over time. Water quality data were obtained from five (5) sampling points for a period of three months. The samples were analyzed for physico-chemical parameters and heavy metals such as temperature, pH, total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), and heavy metals (Cd, Cu, Fe, Mn). PCA assisted to extract and recognize the factors responsible for water quality variation for the period studied. Dissolved oxygen, hardness, cadmium, phosphate, sulphate were the significant parameters contributing to water quality variation for the period studied Cluster analysis was used to classify the five (5) stations based on water quality characteristics. The result obtained from this study will help relevant authorities in identifying priorities to improve water quality that has deteriorated due to pollution from various anthropogenic activities

Keywords: Heavy metals; surface water; water quality; multivariate statistical techniques

INTRODUCTION

Water has become one of the major ecological concerns and is affected by anthropogenic influences. Surface water is exposed to contamination as a consequence of urban, industrial and horticultural activities. Lately more consideration has been paid to surface water quality as a result of its solid linkage with human beings. Polluted surface waters critically alter the balanced ecosystem which is essential for the beneficial interactions of the living things and the environment (Iscen et al, 2008). Water pollution is harmful not only to aquatic organisms but also to human beings. Anyata and Nwaiwu (2000) defined water pollution as the biofouling of aquatic environment in such a way that it interferes with the intended use of water. The source of pollution could be concentrated at a point or randomly deposited in the water body. Of all the pollutants, heavy metals can endanger human health by being incorporated into food chain (Adebola et al, 2013). Heavy metals are not biodegradable and tend to accumulate in water ways in association with organic and inorganic matter (Huong et al., 2008). In addition to assessment of quality of aquatic systems, identification of the factors controlling their behavioral properties is increasingly becoming inherent part of the water quality management programmes. However, due to spatial and temporal variations in hydro chemical and biological properties, continuous and regular monitoring programmes are required to have reliable information about the water quality (Singh et al, 2005). The level of water quality is dictated by the substance of physical, concoction and natural parameters accessible in it. Due to the spatial and temporal variation in water quality conditions, a monitoring program which provides a representative and reliable estimation of the quality of surface water is necessary (Dixon and Chiswell, 1996).

Multivariate statistical techniques are powerful tools for analyzing large numbers of samples collected in surveys, classifying assemblages and assessing human impacts on water quality and ecosystem conditions. According to Varol et al, (2013) the application of different multivariate statistical techniques such as principal component analysis , factor analysis and cluster analysis assists in the interpretation of complex data matrixes for a better understanding of water quality. These techniques provide the identification of possible factors /sources that affect water environmental systems and offer a valuable tool for a reliable management of water resources as well as rapid solution for pollution issues (Palma et al, 2010; Morales et al, 1999). Multivariate statistical techniques have been widely adopted to analyze and evaluate surface water quality, and also used to analyze temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality (Wunderlin et al, 2001; Simenova et al, 2003). Human need for water is a function of both its quantity and quality (Kowalkowskiet al, 2007). The aim of this study is to determine the physico-chemical water quality (parameters and concentration of heavy- metals) of Amansea River.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted on Amansea River (Fig. 1) in Awka North Local Government Area of Anambra State, Nigeria. Towns that make up Awka North Local Government are Awbaofemili, Ugbene, Ebenebe, Achalla, Urum, Amansea, Amanuke, Isu-Aniocha, Mgbakwu and Ugbenu. The human population in Anambra state is 112608 as at 2006 census. Amansea River is a tributary of River Niger and derives its source from Agbuogugu community in Enugu state and flows through Oji to Amansea. This river serves as a boundary between Enugu State and Anambra state. It is also major source of water to the people of Amansea and neighboring villages.

Sample Collection

Water samples were collected from five (5) sampling points once in a month for a period of three months (June-August). Grab samples were collected by dipping already cleaned sample containers gently into the river bed at different points. At each sampling points, five samples were collected and mixed together to form a composite. The collected samples were stored in a cooler containing ice and transported to the laboratory for analysis (Adebola et al, 2013).

Analytical Method

Temperature and pH were measured with mercury thermometer (range 0^0 to 100^0C) and Laboratory pH Meter Hanna model H1991300 (APHA; 1998), respectively. Total dissolved solids (TDS) was determined using APHA 2510 A TDS 139 tester (APHA; 1998), total hardness (TH) using titration method, dissolved oxygen (DO) was measured using Winkler's method, chemical oxygen demand (COD) (open reflux), phosphate was measured using Standard Method 4500-P B.5 and 4500-PE (APHA; 1998), sulphate was analyzed according to (APHA, 1998), nitrate was determined using PD303 UV spectrophotometer (APHA, 1998). Heavy metal

analysis was conducted using Varian AA240 Atomic Absorption Spectrophometer according to the method of APHA 1995 (American Public Health Association).

Fig.1: Map of the Study Area

Cluster Analysis (CA)

Cluster analysis is one of a large family of statistical techniques used to categorize entities (e.g. sampling site) into distinct groups or clusters according to some criteria. According to Martınez-

Martınez et al. (2008), cluster analysis is a multivariate technique used to find homogeneous groups with respect to certain properties. Hierarchical agglomerative clustering is the most common approach which provides intuitive similarity relationships between any one sample and entire data set (McKenna, 2003). The Euclidean distance is a commonly used distance coefficient, which usually gives the similarity between two samples and a "distance" that can be represented by the "difference" between analytical values from both the samples (Otto, 1998). The result of hierarchical clustering is typically illustrated by a dendrogram (a tree-like Plot) which provides a visual summary of the agglomeration processes depicting a picture of the clusters, their similarity, with a dramatic reduction in dimensionality of the original data set (Shrestha and Kazama., 2007).

Principal Component Analysis (PCA)

Principal component analysis provides information on the most meaningful parameters which describe the whole dataset interpretation, data reduction and summarize the statistical correlation among constituents in the water with minimal loss of original information (Helena et al, 2000; Wunderlin et al, 2001). PCA is designed to transform the original component analysis into new uncorrelated variables called principal components, which are linear combinations of the original variables. PCA provides the objective way of finding indices of this type so that the variation in the data can be accounted for as concisely as possible (Brumelis et al., 2000). PCA provides information on the most meaningful parameters that describe the majority of the data set, affording data reduction with minimum loss of original information (Helena et al., 2000)

RESULTS AND DISCUSSIONS

Current Water Quality

The results of the physico-chemical parameters and heavy metals of the samples collected at different points from the month of (June-August) are presented in Tables 1, 2 and 3.

Table 1: Physico-chemical parameters and heavy metals of samples collected at different points for month of June

PARAMETER	Sampling Points				
	A	**B**	**C**	**D**	**E**
pH	5.31	5.33	5.40	5.52	5.41
Hardness (mg/l)	190.00	116.00	152.00	100.00	162.00
Temperature (^oC)	28.00	30.00	28.00	28.00	30.00
Nitrate (mg/l)	0.82	0.97	0.84	0.79	0.78
Phosphate (mg/l)	0.27	0.35	0.35	0.31	0.36

Total suspended solid (mg/l)	1.46	1.38	1.22	1.26	1.16
Total dissolved solid (mg/l)	0.68	0.74	0.56	1.50	1.48
COD	420.00	675.00	680.00	350.00	725.00
Dissolved Oxygen	4.60	2.70	3.70	0.39	3.90
Manganese (ppm)	0.56	0.23	0.35	0.19	0.21
Copper (ppm)	0.06	0.04	0.05	0.05	0.10
Iron (ppm)	13.69	9.24	13.22	9.26	6.72
Cadmium (ppm)	0.02	0.09	0.04	0.02	0.00
Sulphate (mg/l)	113.99	144.85	156.370	255.95	58.02
Lead (ppm)	0.63	0.88	0.53	1.25	1.52

Table 2: Physico-chemical parameters and heavy metals of samples collected at different points for month of July

PARAMETER	**Sampling Points**				
	A	**B**	**C**	**D**	**E**
pH	6.86	6.41	5.80	6.36	6.98
Hardness (mg/l)	26.00	16.00	14.00	10.00	36.00
Temperature (^oC)	28.00	29.00	28.00	29.00	27.00
Nitrate (mg/l)	6.47	4.79	6.34	5.25	5.93
Phosphate (mg/l)	1.23	1.39	1.41	1.46	1.29
Total suspended solid (mg/l)	0.12	0.10	1.50	0.40	0.08
Total dissolved solid (mg/l)	0.12	0.38	0.08	0.46	0.04
Dissolved Oxygen	4.54	3.52	3.02	4.06	4.42
COD	139.00	205.00	269.00	306.00	231.00
Manganese (ppm)	0.00	0.00	0.04	0.00	0.04
Copper (ppm)	0.06	0.039	0.05	0.05	0.10
Iron (ppm)	0.48	0.64	0.77	0.41	0.51

Cadmium (ppm)	0.00	0.01	0.00	0.00	0.01
Sulphate (mg/l)	403.68	527.95	557.17	419.73	387.22
Lead (ppm)	0.63	0.88	0.53	1.25	1.52

Table 3: Physico-chemical parameters and heavy metals of samples collected at different points for month of August

PARAMETER	Sampling Points				
	A	**B**	**C**	**D**	**E**
pH	6.09	5.87	5.60	5.94	6.20
Hardness (mg/l)	108.00	66.00	83.00	55.00	98.00
Temperature (^oC)	28.00	30.00	28.00	29.00	28.00
Nitrate (mg/l)	3.64	2.89	3.59	3.02	3.35
Phosphate (mg/l)	0.75	0.87	0.88	0.89	0.82
Total suspended solid (mg/l)	0.79	0.74	1.36	0.83	0.62
Total dissolved solid (mg/l)	0.40	0.56	0.32	0.98	0.76
Dissolved Oxygen	4.57	3.11	3.36	2.23	4.16
COD	279.50	440.00	474.50	328.00	478.00
Manganese (ppm)	0.10	0.03	0.19	0.00	0.12
Copper (ppm)	0.06	0.04	0.05	0.05	0.10
Iron (ppm)	7.09	4.94	6.98	4.83	3.62
Cadmium (ppm)	0.00	0.05	0.02	0.00	0.00
Sulphate (mg/l)	258.83	336.39	356.77	337.84	223.62
Lead (ppm)	0.63	0.88	0.53	1.25	1.52

Preliminary Analysis

Prior to multivariate analysis, descriptive statistics were used to describe the data for the three months studied as shown in Table 4.

Table 4: Mean concentration and general descriptive statistics of the physico-chemical parameters and heavy metals of Amansea River for the month of June.

PARAMETER	Sampling Points					Descriptive Statistics				
	A	B	C	D	E	Mean	Std deviation	Range	Skewness	Kurtosis
Ph	5.31	5.33	5.40	5.52	5.41	5.39	0.066	5. 31-5.52	-0.28	-1.32
Hardness (mg/l)	190.00	116.00	152.00	100.00	162.00	144.00	36.139	100.00 - 190.00	-0.03	-1.44
Temperature (^oC)	28.00	30.00	28.00	28.00	30.00	28.80	1.095	28.00 - 30.00	0.61	-3.33
Nitrate (mg/l)	0.82	0.97	0.84	0.79	0.78	0.84	0.076	0.78 - 0.97	1.72	3.14
Phosphate (mg/l)	0.27	0.35	0.35	0.31	0.36	0.33	0.038	0.27 - 0.36	-1.14	0.02
Total suspended solid (mg/l)	1.46	1.38	1.22	1.26	1.16	1.30	0.122	1.16 - 1.46	0.46	-1.51
Total dissolved solid (mg/l)	0.68	0.74	0.56	1.50	1.48	0.99	0.459	0.56 - 1.50	0.52	-3.18
Lead (ppm)	0.63	0.88	0.53	1.25	1.52	0.96	0.418	0.53 - 1.52	0.46	-1.81
Manganese (ppm)	0.56	0.23	0.35	0.19	0.21	0.31	0.154	0.19 - 0.56	1.49	1.68
Copper (ppm)	0.06	0.04	0.05	0.05	0.10	0.06	0.023	0.04 - 0.10	1.74	3.32
Iron (ppm)	13.69	9.24	13.22	9.26	6.72	10.43	2.956	6.72 - 13.69	0.04	-2.00
Cadmium (ppm)	0.02	0.09	0.04	0.02	0.00	0.03	0.034	0.00 - 0.09	1.35	2.10
Sulphate (mg/l)	113.99	144.85	156.370	255.95	58.02	145.84	72.393	58.02 - 255.95	0.69	1.45

COD	420.00	675.00	680.00	350.00	725.00	570.00	169.041	350.00 - 725.00	0.49	-3.20
Dissolved Oxygen	4.60	2.70	3.70	0.39	3.90	3.06	1.916	0.39 - 4.60	-0.09	-2.58

The pH values ranged from 5.31 -5.52 with a mean value of 5.39. The temperature ranged from 28^{o}C – 30^{o}C with a mean value of 28.8^{o}C. However, the highest temperature of 30^{o}C was recorded at sample B and sample E. Total hardness concentration obtained for this month ranged from 100-190 mg/L with a mean concentration of 144mg/L. According to USGS water-quality information (2016), Amansea River is characterized as hard water and cannot be used for industrial purposes as hard water forms clogs that can block boilers and pipes, thus necessitating its treatment before use for certain industrial purposes. The range and mean concentration of TSS of River Amansea are 1.16-1.46mg/L and 1.30mg/L respecgively. River Amansea has a low TSS concentration according to WHO standard. TDS ranged from 0.56-1.50mg/L with a mean concentration of 0.99mg/L. TDS comprises of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amount of organic matter that are dissolved in water. TDS in water originate from natural sources, sewage, urban runoff and industrial wastewater.

The range and mean concentration of DO are 0.39-4.60mg/L and 3.06mg/L respectively. The decrease in DO values noticed from one sample point to another could be attributed to the fact that as the river flows along its course, it carries sediments, partially dissolved and undissolved organic and inorganic matters resulting to a decrease in the DO. Low DO values could be as a result of the degradation of cattle waste and hot discharges into the river which are oxygen demanding (Adebola et al., 2013). The range and concentration of chemical oxygen demand are 350-725mg/L and 570mg/L respectively. The presence of high biodegradable and non-biodegradable waste as well as presence of sediment in the river could be responsible for this trend. The concentration of nitrate ranged from 0.78-0.97mg/L with a mean concentration of 0.84mg/L. Nitrates are high oxide form of nitrogenous compounds and are usually present in streams. It is the end product of aerobic decomposition of organic nitrogenous matter present in animal waste. The range of sulphate concentration in the river was 58.02-255.95mg/L and mean concentration of 145.8mg/L. This could be as a result of sulphate occurring naturally in numerous minerals and being used principally in chemical industries. They are discharged into streams as industrial wastewater. Phosphate concentration ranged between 0.27-0.36mg/L with a mean concentration of 0.33mg/L. Nitrate and phosphate are nutrients very essential for plant growth. However, high concentration tends to pose more harm on the water body as they can lead to algae bloom. Concentration of copper ranged from 0.04-0.1ppm with a mean concentration of 0.06ppm. Copper is both an essential nutrient and a drinking water contaminant with many commercial uses. It is used to make pipes. Copper sulphate pentahyrate is sometimes added to surface water for the control of algae growth. Copper concentration in drinking-water varies widely with the primary source most often being the corrosion of interior copper plumbing. The concentration of iron ranged from 6.72-13.69ppm with a mean concentration of 10.43ppm. Corrosive materials and landfill leachate contribute significantly to amount of iron in water. Iron is one of the most abundant metals in the earth crust. It is found in natural fresh waters at levels ranging from 0.5 to 50ppm. The concentration of cadmium ranged from 0.00-0.09ppm with a mean concentration of 0.0ppm. Cadmium is released into the environment through wastewater. The concentration of lead ranged from 0.53-1.52ppm and mean concentration of 0.96ppm. The concentration of manganese ranged from 0.19-0.56ppm with mean concentration of 0.31ppm.

Table 5: Mean concentration and general descriptive statistics of the physico- chemical parameters and heavy metals of Amansea River for the month of July

PARAMETER	**Sampling Points**					**Descriptive Statistics**				
	A	**B**	**C**	**D**	**E**	**Mean**	**Std deviation**	**Range**	**Skewness**	**Kurtosis**
pH	6.86	6.41	5.80	6.36	6.98	6.48	0.47	5.80 - 6.98	-0.58	-0.22
Hardness (mg/l)	26.00	16.00	14.00	10.00	36.00	20.40	10.53	10.00 - 36.00	0.89	-0.47
Temperature (^oC)	28.00	29.00	28.00	29.00	27.00	28.20	0.84	27.00 - 29.00	-0.51	-0.61
Nitrate (mg/l)	6.47	4.79	6.34	5.25	5.93	0.96	0.42	4.79 - 6.47	0.46	-1.81
Phosphate (mg/l)	1.23	1.39	1.41	1.46	1.29	0.09	0.15	1.23 - 1.46	2.14	4.66
Total suspended solid (mg/l)	0.12	0.10	1.50	0.40	0.08	0.56	0.14	0.08 - 1.50	0.75	-0.56

Total dissolved solid (mg/l)	0.12	0.38	0.08	0.46	0.04	0.44	0.01	0.04 - 0.46	0.61	-3.33
Lead (ppm)	0.63	0.88	0.53	1.25	1.52	0.96	77.70	0.53 - 1.52	0.59	-2.74
Manganese (ppm)	0.00	0.00	0.04	0.00	0.04	0.02	0.02	0.00 - 0.04	0.61	-3.33
Copper (ppm)	0.06	0.039	0.05	0.05	0.10	0.06	0.15	0.05 - 0.39	2.13	4.59
Iron (ppm)	0.48	0.64	0.77	0.41	0.51	0.56	0.14	0.41 - 0.77	0.75	-0.56
Cadmium (ppm)	0.00	0.01	0.00	0.00	0.01	0.004	0.01	0.00 - 0.01	0.61	-3.33
Sulphate (mg/l)	403.68	527.95	557.17	419.73	387.22	459.15	77.70	387.22 - 557.17	0.59	-2.74
COD	139.00	205.00	269.00	306.00	231.00	230.00	63.65	139.00 - 306.00	-0.44	-0.03
Dissolved Oxygen	4.54	3.52	3.02	4.06	4.42	3.91	0.64	3.02 - 4.54	-0.63	-1.33

Table 6: Mean concentration and general descriptive statistics of the physico-chemical parameters and heavy metals of Amansea River for the month of August.

Parameter	**Sampling Points**					**Descriptive Statistics**				
	A	**B**	**C**	**D**	**E**	**Mean**	**Std deviation**	**Range**	**Skewness**	**Kurtosis**
pH	6.09	5.87	5.60	5.94	6.20	5.94	0.23	5.60-6.20	-0.65	0.33
Hardness (mg/l)	108.00	66.00	83.00	55.00	98.00	82.00	21.90	55.00-108.00	-0.08	-1.91
Temperature (^{o}C)	28.00	30.00	28.00	29.00	28.00	28.60	0.89	28.00-30.00	1.26	0.31
Nitrate (mg/l)	3.64	2.89	3.59	3.02	3.35	3.30	0.33	2.89-3.64	-0.27	-2.57
Phosphate (mg/l)	0.75	0.87	0.88	0.89	0.82	0.84	0.06	0.75-0.89	-1.28	0.79

Total suspended solid (mg/l)	0.79	0.74	1.36	0.83	0.62	0.87	0.29	0.62-1.36	1.80	3.69
Total dissolved solid (mg/l)	0.40	0.56	0.32	0.98	0.76	0.60	0.27	0.32-0.98	0.54	-1.14
Lead (ppm)	0.63	0.88	0.53	1.25	1.52	0.96	0.42	0.53-1.52	0.46	-1.81
Manganese (ppm)	0.10	0.03	0.19	0.00	0.12	0.09	0.08	0.00-0.19	0.21	-0.98
Copper (ppm)	0.06	0.04	0.05	0.05	0.10	0.06	0.02	0.04-0.10	1.74	3.32
Iron (ppm)	7.09	4.94	6.98	4.83	3.62	5.49	1.50	3.62-7.09	0.04	-2.10
Cadmium (ppm)	0.00	0.05	0.02	0.00	0.00	0.01	0.02	0.00-0.05	1.53	1.75
Sulphate (mg/l)	258.83	336.39	356.77	337.84	223.62	302.69	58.03	223.62-356.77	-0.72	-2.03
Dissolved Oxygen	4.57	3.11	3.36	2.23	4.16	3.49	0.92	2.23-4.57	-0.25	-0.76
COD	279.50	440.00	474.50	328.00	478.00	400.00	90.74	279.50-478.00	-0.65	-2.32

Statistical Analysis

Principal Component Analysis (PCA)

PCA was performed in this study in order to identify important water quality parameters. An eigenvalue gives a measure of the significance of a factor and factors with the highest eigenvalues are the most significant. Eigenvalues of 1.0 or greater are considered significant (Shrestha et al., 2007). Classification of principal components is thus "Strong"," Moderate" and "Weak", corresponding to absolute loading values of > 0.75, 0.75-0.50 and 0.50-0.30, respectively (Liu et al., 2003). Tables 7, 8 and 9 summarizes the PCA including the loadings, eigenvalues of each PCs, total variance explained as well as the cumulative variance and strong loading values highlighted.

Table 7: PCA of water quality parameters of the River in June

Variables	Component			
	1	**2**	**3**	**4**
DO	**.959**	-.271	-.015	.085
Sulphate	**-.944**	-.229	.041	-.236
Hardness	**.887**	-.300	-.311	-.162
pH	**-.788**	.192	**-.561**	.165
Fe	.156	**-.932**	.076	-.318
Pb	-.169	**.893**	-.396	.133
Temperature	.326	**.759**	.393	.404
TDS	-.355	**.752**	**-.556**	-.005
Mn	**.566**	**-.631**	-.034	**-.530**
Nitrate	.008	-.030	**.993**	.117
Cd	-.166	-.121	**.968**	.142
Cu	**.529**	**.508**	-.646	.211
Phosphate	-.033	.291	.160	**.943**
COD	.448	.136	.252	**.847**
TSS	.215	-.228	**.557**	**-.769**
Eigenvalues	4.38	3.886	3.781	2.954
% Variance Explained	29.197	25.905	25.205	19.693
% Cumulative Variance	29.197	55.102	80.307	100

Note: Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; Bold figures indicate absolute values >0.5 of parameters with strong loading value

The PCA of the data obtained in June (Table 7) showed four PCs which explained 100% of the total variance. The first PC explained 29.197% of the total variance and was best represented by DO, Sulphate, Hardness, pH, Manganese, Copper. PC 2 was dominated by iron, lead, temperature, TDS, Manganese, copper, accounted for 25.905% of the total variance. PC 3 explained 25.905% of the total variance and load heavily on pH, TDS, Nitrate, Cadmium and TSS. PC 4 was responsible for 19.693% of the total variance and was best represented by manganese, phosphate, COD, TSS.

Table 8: PCA of water quality parameters of the River in July

Variables	Component 1	2	3	4
Sulphate	**.974**	-.208	.084	.036
Fe	**.973**	.219	-.043	.056
DO	**-.938**	.136	-.320	.012
pH	**-.800**	.216	-.456	.323
TSS	**.719**	.235	.402	**-.516**
Pb	**-.662**	.186	.470	**.553**
Temperature	.181	**-.970**	.158	-.047
TDS	-.122	**-.920**	.336	.157
Mn	.320	**.894**	.306	.070
Cu	**-.522**	**.816**	.020	.249
Hardness	-.433	**.723**	-.431	.322
Nitrate	.008	**.690**	-.299	**-.660**
COD	.116	.057	**.991**	-.041
Phosphate	.368	-.473	**.801**	.021
Cd	-.011	.155	-.123	**.980**
Eigenvalues	5.13	4.748	2.847	2.275
% Variance Explained	34.199	31.654	18.98	15.167
% Cumulative Variance	34.199	65.853	84.833	100

Note: Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; Bold figures indicate absolute values >0.5 of parameters with strong loading value.

In the PCA of data obtained in July (Table 8), four components were extracted which explained 100% of the total variance. PC 1 explained 34.199% of the variance and loaded heavily on sulphate, iron, DO, pH, TSS, Lead, copper. PC 2 was loaded primarily by temperature, TDS, Manganese, Copper, Hardness, and Nitrate. PC 3 was dominated by COD and Phosphate which accounts for 18.98% of the total variance, PC 4 explained 15.167% of the variance was best represented by TSS, Lead, Nitrate and cadmium.

Table 9: PCA of water quality parameters of the River in August

Variables	**Component**			
	1	**2**	**3**	**4**
Pb	**-.995**	-.033	.064	.074
Fe	**.941**	.066	.221	-.249
TDS	**-.879**	-.384	-.006	-.283
TSS	**.745**	-.476	.369	.286
pH	**-.691**	**.652**	.055	-.306
Cu	**-.615**	**.534**	.491	.308
COD	.163	**.949**	.241	.118
Phosphate	-.095	**-.917**	-.194	.336
Hardness	.186	**.881**	.424	.097
Sulphate	.484	**-.830**	-.274	.024
Temperature	-.137	-.377	**-.910**	-.102
Cd	.332	-.174	**-.836**	.401
Nitrate	.498	.468	**.727**	.068
DO	-.108	-.124	-.070	**.984**
Mn	.478	.285	**.575**	**.600**
Eigenvalues	6.277	5.218	2.032	1.473
% Variance Explained	41.846	34.789	13.545	9.819
% Cumulative Variance	41.846	76.636	90.181	100

Note: Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; Bold figures indicate absolute values >0.5 of parameters with strong loading value.

Finally, the PCA of the data obtained in August (table 9) extracted four components which accounted for 100% of the total. PC 1 explained 41.84% of the total variance and loaded heavily on lead, iron, TDS, TSS, pH, and Copper. PC 2 was loaded with pH, Copper, COD, Phosphate, Hardness and sulphate accounted for 34.78% of the variance. PC 3 was responsible for 13.545% of the total variance and was best represented by temperature, cadmium, nitrate and manganese. PC 4 explained 9.819% of the variance and was best represented by DO, manganese. The most significant water quality parameter that contributed to variations in the quality parameter of River Amansea water is represented in table 10. DO, Hardness, Cadmium, Phosphate, COD, Sulphate and pH were the significant parameters contributing to the water quality variations of the river.

Table 10: The most significant parameters

Month	**Parameters with strong positive loading**	**Parameters with strong negative loading**
June	DO, Hardness, Lead, Temperature, TDS, Nitrate, Cadmium, phosphate, COD	Sulphate, pH, iron, TSS
July	Sulphate, iron, manganese, copper, COD, phosphate, cadmium	DO, pH, temperature, TDS
August	Iron, COD, Hardness, DO	Lead, TDS, Phosphate, sulphate, temperature, cadmium

Cluster Analysis (CA)

Different sampling station in a river can be group into cluster of similar water quality feature. It is usually used for a visual summary of the intra-relationship amongst variation parameter and can lead to a better understanding of the governing factors in a studied system. Figures 2, 3 and 4 show the dendrogram output using the ward's linkage method. The clustering procedure generated two group as the point in these group have similar characteristic features. Clusters 1, and 2 correspond to relatively low pollution, moderate pollution of the river. The CA of data obtained in the month of June (figure 4.1) displayed two clusters. Cluster 1 (station points 1, 3, 2) corresponding to low polluted sites located at the downstream, application not completely been engaged at this stations. Hence the impact of human being activities on the reverie environment is relatively low at this cluster. Cluster 2 (station point 4 and 5) located at the upstream corresponds to moderately polluted site, domestic activities attributed to the contamination of the region. The data obtained in July display also two clusters with point (2, 3, and 4) forming cluster one which corresponds to low polluted region. Less human activities such as swimming characterized this region. Point 1 and 5 forming cluster 2 which corresponds to moderately polluted region which was characterized by laundry activities and sand mining. Two clusters were also generated from the data obtained in August, points (2, 4 and 3) formed cluster 1 which corresponds to low polluted region, swimming activities and discharge of wastewater from car wash was noticed at point 4. Cluster 2 which correspond to moderately polluted region, sand mining and discharge of cattle waste was noticed at this region. For the period of three months study it was observed that sampling points/station points with similar features and human activities is low and moderately polluted.

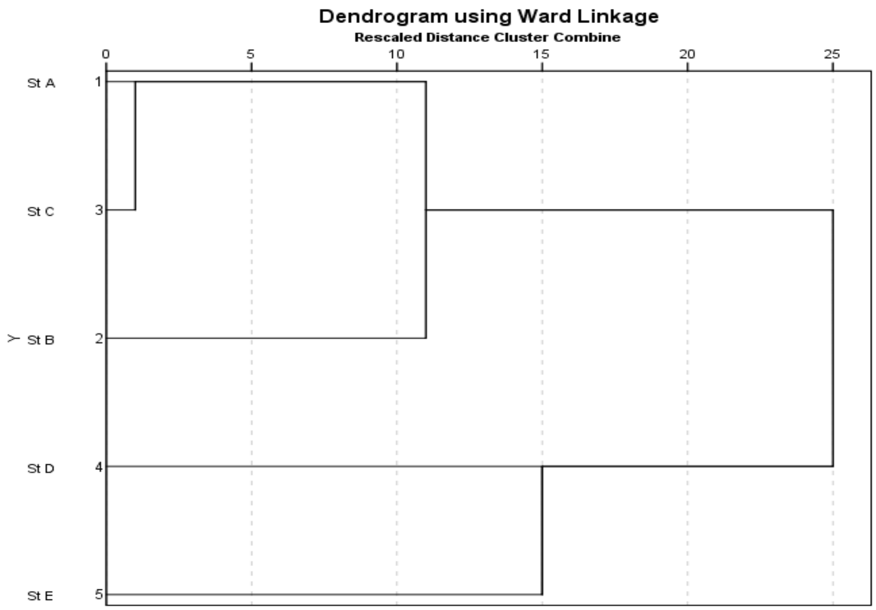

Fig 2: Dendrogram of cluster analysis of water quality parameters of the River for June 2017

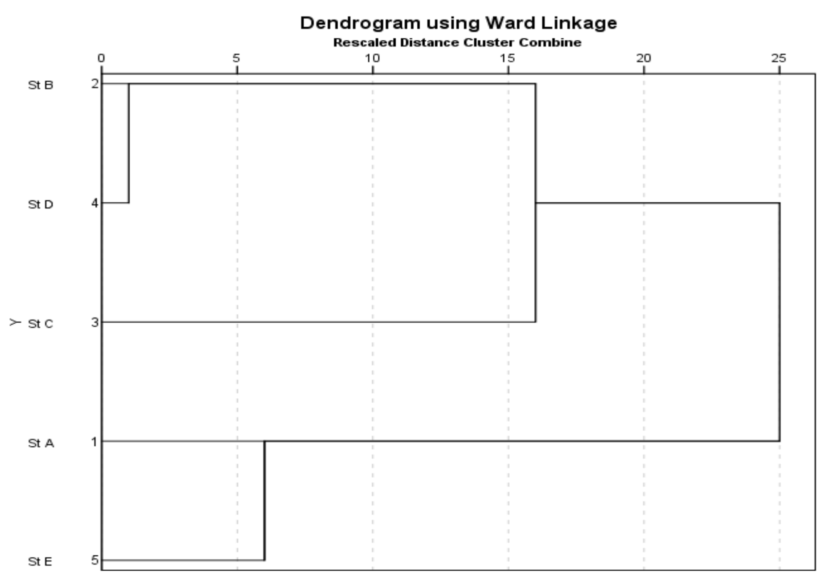

Figure 3: Dendrogram of cluster analysis of water quality parameters of the River July 2017

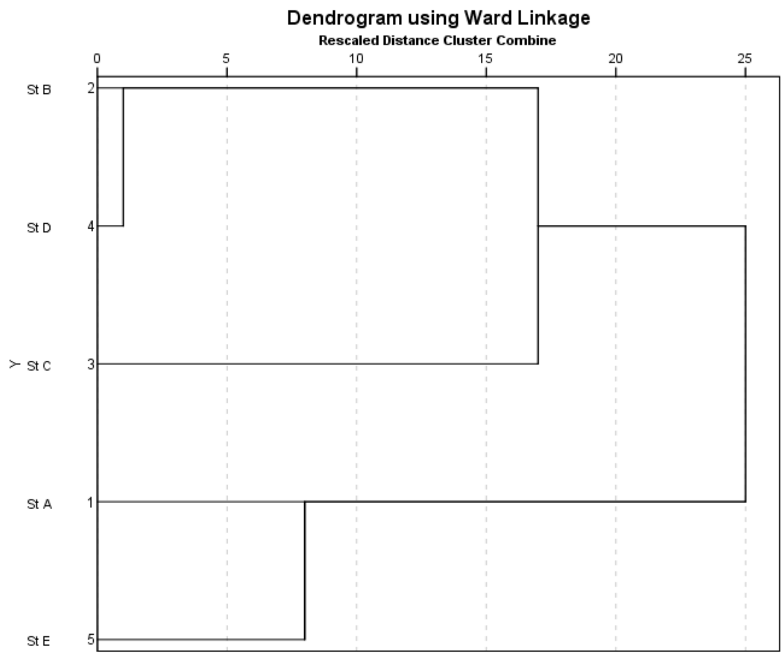

Figure 4: Dendrogram of cluster analysis of water quality parameters of the River for August

Conclusions

In this study multivariate statistical analysis were successfully applied to analyze the variation in the surface water quality of Amansea River. The results obtained from PCA showed the parameters responsible for water quality variation for the period of study. The significant parameters that affected the water quality were identified. CA was used in the spatial classification of water quality variation of the river. Study results can assist relevant authorities in establishing priorities to augment stream water quality that has deteriorated due to pollution from anthropogenic activities.

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