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Production and Characterization of Briquettes from Melon Seed Shell, Corn Stalk and Sawdust

***Dauda S. M., Usman M., Mustapha A., Aliyu M. and Mohammed I. S.**
Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, Niger State, Nigeria.
*smdauda@futminna.edu.ng

Abstract

This study was to assess the proximate and ultimate composition of briquettes produced from the blend of melon seed shell, corn stalk and sawdust using cassava starch as binder. The formulations of corn stalk, sawdust and melon seed shell for production of composite using simple latex mix design were taken in the following ratios; (0:50:50), (41.67:16.67:41.67), (16.67: 41.67:41.67), (50:50:0), (25:50;25), (50:25:25), (50:0;50), (25:25:50), (33.33:33.33:33.33) and (41.67:41.67:16.67) respectively. Each formulation contained 300 g of the composite blend with binder (starch) constituting 15%. The physical properties, proximate and ultimate analysis were carried out. From the proximate analysis results, briquettes with 50% Sawdust and 50% Corn Stalk have the highest calorific value of 32,636.40 Kcal/Kg while briquettes containing 25% Sawdust, 25% Corn Stalk and 50% Melon Seed Shell have the lowest calorific value of 28,652.49 Kcal/Kg. From the ultimate analysis, briquettes with the blend of 16.67% Corn Stalk, 41.67% Sawdust and 41.67% Melon Seed Shell were found to have the highest carbon content of 78.28% while the lowest carbon content was again obtained from the blend of 16.67% Corn Stalk, 41.67% Sawdust and 41.67% Melon Seed Shell with 64.55% carbon content which shows the reason for its lower calorific value. Design validity in the formulation of composite briquette, the plot indicates absence of point of critical error indicating the design levels significantly represent the composite estimate of the biomass. Consequently, the proximate analysis shows that only volatile content significantly varies from the actual response, while ultimate analysis shows significant level of variation from the actual values in carbon and oxygen content of the briquette.

Keywords: Briquettes, corn stalks, melon seed shell, sawdust.

Introduction

Biomasses are secondary resources of plant and animals. The term biomass simply means organic matter generated by plants through photosynthesis which is renewable in nature. After petroleum, gas and coal, biomass is the 4th highest major source of energy in the world; contributing 10.6% of the total global primary energy supply (Demirbaş, 2001). As a very relevant source of energy, it accounts for 33.3% of the total fuel used in India which is predominantly used in rural households for water heating, cooking and also in rural industries (Birwatkar *et al*., 2014). Biomass is considered as an important source of energy that is environmental friendly and sustainable alternative energy for the future, It can easily be transformed into solid, gas, and liquid fuels using thermo-chemical and biological methods like digestion, pyrolysis, and combustion (Bemgba *et al*., 2014; Homdoung *et al*., 2019).

Most of the residues from thermo-chemical and biological means of biomass productions are usually dumped and flared on the farms, where they constitute health risk to both human and ecology. In addition, it is widely accepted that the looming fossil-fuel depletion is one of the crucial issues for many countries. This results in ever increasing price of such fuels in the world markets, which adversely affect economies worldwide. The use of fossil fuels is also partially responsible for global warming due to the greenhouse effect of the emissions, such as carbon dioxide (Sajjakulnukit and Verapong, 2003; Mitchual *et al*., 2014; Prasityousil and Muenjina, 2013). Therefore, there is the need to gradually shift attention from fossil fuels. In this regard, agricultural residues can play a significant role in alternative energy generation (Oladeji and Lucas, 2014)

One of the processes through which these residues could be converted to biomass energy is briquetting (Olorunnisola, 2007). Wilaipon (2008) described briquetting as a process of compacting residues into a product of higher density than the original material, while Kaliyan and Morey (2009) defined briquetting as a densification process. Briquetting process can be grouped under two broad classifications, which are briquettes without binder and briquettes with binding agent.

About 80% of Nigerians live in the rural or semi-urban areas and they depend solely on fuel wood for their energy needs. Fuel wood accounts for about 37% of the total energy demand of the country. Investigations have shown that out of the total wood demand from the forest, 90% goes to fuel wood (Sambo, 2009).

Sawdust, as a type of lignocellulosic biomass, is a by-product from mechanical milling or processing of wood with various useable sizes, which can account for up to 20% of the total input mass (Falcão and Araújo, 2014). Currently, most of this wood waste is burnt directly for energy recovery, while a small proportion is land filled, resulting in air pollution and occupation of useful land. Thus, increasing attention has been paid to the disposal of sawdust. Sawdust is usually used as a powder for mineral-bonded composites, filler of polymers, or chemical intermediates (Hu *et al.*, 2014). Besides, the use of lignocellulosic sawdust for the production of low cost activated carbon materials is another popular approach due to its high carbonaceous content (Huang *et al.*, 2017).

Melon seed shell is a readily available waste material; this also indicates that utilising it for prominent energy content is a means of eradicating or reducing environmental waste from melon seed. (Aibudefe *et al.*, 2014)

Therefore, reducing the fuel consumption together with increasing the use of alternative renewable energy sources seems to be a promising solution to these problems since the renewable energy is generally clean, safe and environmentally friendly. Among renewable energy sources, biomass plays a major role in the foreseeable future, particularly for developing countries whose economies are largely based on agriculture. It has a potential to substantially reduce carbon dioxide (CO_2) emissions since nearly zero net gain of CO_2 can be achieved when sustainable production and utilization are implemented (Sajjakulnukit *et al.*, 2005). This work is aimed at production and characterization of briquettes from blend of melon seed shell, corn stalk and sawdust.

Materials and Methods

Materials and Instrumentation

The materials used for the experiments were Melon seed shell, Corn Stalk Sawdust, Binder (Cassava Starch), Electric Weighing Scale, Mortar and Pestle, Milling Machine, Hydraulic Operated Manual Briquetting Machine, Wooden Stirrer, Crucible, Tong, Vernier calipers, rubber buckets and Gallenhamp Muffle Furnace (Tactical 308).

Methodology

Melon Seed Shells were collected from Gurara, Minna. Niger State, Nigeria. The corn stalks were obtained from Federal University of Technology Minna staff quarters farmland, while the Sawdusts were obtained at Shango market, Minna, Nigeria.

The Melon Seed Shells were sun-dried for seven (7) days to reduce the moisture content to about 12.67 % making it suitable for the briquetting process. They were then reduced in size by mortar and pestle to enhance further grinding with hammer mill and were finally sieved with a 2mm Associated Scientific and Engineering Works (ASEW) 110055 sieve.

Preparation of Corn Stalk

The corn stalks were sun-dried for about 48 hours to standard moisture of 12.67% after which the backs were peeled in order to extract its inner content. They were then further sun-dried for seven (7) days to reduce the moisture level to 8.25% as shown in Figs. 1 and 2. Reduction in size with the aid of mortar and pestle was then done to aid further grinding with the hammer mill. After which it was then sieved using a 2mm ASEW 110055 sieve.

Fig. 1: Drying of Peeled Corn Stalk

Fig. 2: Drying of Corn Stalk

Preparation of Sawdust

The collected sawdust was sun-dried for seven (7) days to reduce the moisture content to 12.67 %. It required no further size reduction and hence was sieved by the 2mm ASEW 110055 sieve directly.

Sample Mixture Preparation

Experimental design was performed using design expert 7.0 to create the simplex lattice run for three parameters (Corn Stalk, Sawdust and Melon Seed Shell).The three biomass were mixed in fourteen (14) proportions as shown in the simplex lattice design in Table 1. Each formulation contains 300 g of biomass.

Table 1: Composition of various Samples of the biomass

Sample	Corn Stalk (%)	Sawdust (%)	Melon Seed Shell (%)
1	0	50	50
2	41.67	16.67	41.67
3	16.67	41.67	41.67
4	50	50	0
5	25	50	25
6	50	25	25
7	0	50	50
8	50	0	50
9	25	25	50
10	25	25	50
11	33.33	33.33	33.33
12	41.67	41.67	16.67
13	50	50	0
14	50	0	50

Production of the Briquettes

The mixtures of the different proportions were fed into the cylindrical moulds of the manually-operated hydraulic jack briquetting machine in different batches as shown in Fig. 5. The lid of the briquetting machine was then firmly tightened to ensure maximum compression and the hydraulic handle was jacked up to compress the samples inside the mould at a pressure of approximately 15 MPa. The lid was then loosened and the briquette was produced and ejected as shown in Fig. 3. The procedure was repeated and for each round, four sets of briquette were produced. The samples of the briquettes produced were taken immediately after ejection from the mould for all the samples.

Fig. 3: Moulding of the Briquettes

The produced briquettes were oven dried at 105°C for 24 hours as indicated in Fig 4. The weight was taken again, sundried and then stored (Orhevba *et al*., 2015).

Fig. 4: Oven drying of the Briquettes

Characterization of the Briquette

Physical Properties of the Briquettes

In determining the physical properties of the briquettes, three briquettes were chosen randomly from each production group for the experiment.

Determination of density of the Briquettes

The density of the briquette was determined by using Equation 1

$$\rho = \frac{m}{v} \qquad (1)$$

Where,

ρ = density of the material (kg/m^3)
m = mass of the material (kg)
v = volume of the material (m^3)

The maximum density of the briquettes was determined by taking the mass immediately after rejecting the briquettes from the mould.

Determination of the mass of the briquette

The mass of the briquette was determined immediately after ejection from the machine and the average weight taken. This was also repeated after oven drying at 105°C for 24 hours

Determination of the volume of the Briquette

This is the amount of space occupied by the briquettes. The volume was determined by taking the dimensions of the cylindrical briquettes (i.e. the radius and the height) by applying the formula given in Equation 2.

$$V = \pi r^2 h \qquad (2)$$

The radius was obtained by measuring the diameter using a digital venier caliper then applying theoretical formula for radius in Equation 3.

$$r = D/2 \qquad (3)$$

Where,

D is the diameter (mm)
r is the radius (mm)
h is the height (mm)

Proximate Analysis of Briquettes

Proximate analysis of the briquette samples was carried out to determine the percentage volatile matter content, percentage ash content, and percentage content of fixed carbon. The procedure of ASTM standard D5373-02 (2003) was adopted.

Moisture content of the briquettes

The moisture content was determined by pulverizing 1g of the dried sample of the briquettes into a crucible and placed inside an electric oven set at 105°C for one (1) hour. It was then removed and placed immediately in the desiccators to cool. The weight was then taken using digital weighing balance OHAUS CORP AR3130 Model (Sanger *et al.*, 2011). The procedure was repeated for all the samples and the moisture content was calculated using Equation 4.

$$MC\ (\%\, wb) = \frac{w2 - w3}{w2 - w1} \times 100 \qquad (4)$$

where,

w1 = weight of crucible, (g)

w2 = weight of crucible with the sample before heating (g)

w3 = weight of crucible with the sample after heating (g)

Volatile matter of the briquettes

The volatile matter of the briquettes was determined as given in Equation 5. This was carried out by pulverizing 1g of dried sample in a crucible, covered and oven-dried until a constant weight was attained. It was then heated in a muffle furnace at 600ºC for six (6) minutes then at 900ºC for another six (6) minutes based on ASTMD-3275 (2018). The difference in the weight as a result of loss of volatile matters was taken as the total volatile matter in the sample on percentage basis (Sanger *et al.*, 2011, Vivek *et al*, 2019).

$$V\,M\,C\,(\%) \;=\frac{A}{B}\times 100 \qquad (5)$$

where,

VMC = Volatile Matter Content (%)
A = W2-W1
B = W3-W2
W1 = weight of the crucible (g)

W2 = weight of oven dried crucible with sample (g)
W3 = weight of crucible with the sample after heating in muffle furnace (g)

Ash content of the briquettes
Ash content was determined using ASTM standard D5373-02 (2003), given by Equation 6.

$$Ash\ content, (\%) \;=\frac{C}{A}\times 100 \qquad (6)$$

where, A=W2-W1

C=W3-W1

W1 = weight of the crucible (g)

W2 = weight of oven dried crucible with sample (g)

W3 = weight of crucible with the sample after heating in muffle furnace (g)

Fixed carbon of the briquettes
The percentage of fixed carbon in a material was determined using the ASTM standard D5373-02 (2003) as given in Equation 7.

$$FC(\%)=100-(\%MC+\%AC+\%VC) \qquad (7)$$

where;

FC =fixed Carbon Content (%)
MC = Moisture Content (%)
AC= Ash Content (%)
VC = Volatile Content (%)

Calorific value of the briquettes
The gross calorific value of the samples of biomass materials was determined with Equation 8 in accordance with Sanger *et al.* (2011) this was determined by taking a known mass of a sample in a dirt-free crucible and done in conformity with ASTMD-3174.

$$CV(\%) =\ 2.326(147.6\,FC + 144\,VM) \ (8)$$

where;

CV = Calorific Value
FC = Percentage fixed carbon (%)
VM = Percentage Volatile matter (%)

Ultimate Analysis of Briquettes
Carbon content of briquettes
The carbon content was determined by using Equation 9 as reported by Sanger et al. (2011).

$$\text{Carbon content } (\%) = [(0.97FC) + 0.7(VM - 0.1) - M\,(0.6 - 0.01)] \qquad (9)$$

where,

FC = percentage fixed carbon content (%)
VM = percentage volatile matter and (%)
M = percentage moisture content (%)

Hydrogen content of briquette
The hydrogen content of the sample was determined by using Equation 10 as reported by Oladeji, (2012) and Vivek, (2019).

$$\text{Hydrogen Content } (\%) = [(0.036\ FC) + 0.086\ (VM - 0.1\ A) - (0.0035\ M2)\ (1 - 0.02\ M)] \qquad (10)$$

where,

FC = percentage fixed carbon content (%)
VM = percentage volatile matter (%)

A = percentage ash content and (%)
M = percentage moisture content (%)

Nitrogen value of briquette

The nitrogen content was determined using Equation 11 as reported by Oladeji, (2012).

$$Nitrogen\ Content\ (\%) = 2.10 - 0.020\ VM \qquad (11)$$

where,

VM = percentage of Volatile Matter (%)

2.9.4 Oxygen content of briquette

The oxygen content was determined using Equation 12 as reported according to ASTM, (2003)

$$Oxygen\ Content\ (\%) = 100 - (C + H + N + A) \qquad (12)$$

where,

C = percentage carbon content (%)
H = percentage hydrogen content (%)
N = percentage Nitrogen content (%) and
A = percentage ash content (%)

Results and Discussion

Results obtained from the physical properties of the briquettes

The result of the physical properties of the briquettes produced according to the number of design formulation are shown in Table 2,

Table 2: Results of Physical Properties of the Briquettes

S/N	Height (cm)	Diameter (cm)	Mass (g)	Volume (cm^3)	Density (kg/m^3) $x10^{-3}$
1	6.521	4.343	48.485	96.599	0.506
2	6.453	4.356	43.961	95.862	0.459
3	6.518	4.357	44.067	94.398	0.467
4	6.857	4.250	47.418	97.189	0.488
5	7.863	4.248	45.012	110.667	0.407
6	5.837	4.286	39.809	83.886	0.474
7	7.562	4.269	47.017	106.906	0.440
8	6.372	4.255	42.686	90.373	0.472
9	7.127	4.1848	50.225	97.719	0.514
10	8.078	4.279	49.638	110.742	0.448
11	7.672	4.237	46.798	105.290	0.444
12	6.956	4.234	49.689	97.671	0.509
13	7.372	4.282	51.846	106.037	0.489
14	7.577	4.367	47.714	109.935	0.434
Mean	6.735	4.223	39.472	86.317	0.467

From the result of the physical properties of the briquette shown in Table 2, the mean values of the height and diameter were 6.735 cm and 4.223cm respectively indicating the briquettes can easily be packaged and transported. This also applies to the mean mass 39.472 g and the density of 0.467 g/cm^3 of the briquettes. The volume with mean value of 86.317 cm^3 implies they will occupy little space which will ease the solid fuel's transportation and storage when compared to fuel-wood as reported by Oladeji (2012).

Results of the Proximate Analysis of the Samples

The results of the moisture content analysis on dry basis as shown in Fig. 5 indicates that sawdust and melon seed shell had the highest moisture content of 7.731% while corn stalk had the lowest moisture content of 1.530% for (50% corn stalk, 50% sawdust and 50% melon seed shell). Consequently, the low moisture content in a briquette enhances faster ignition process of the briquette. This indicates that sample formulation with higher percentage of corn stalk will have faster ignition capability.

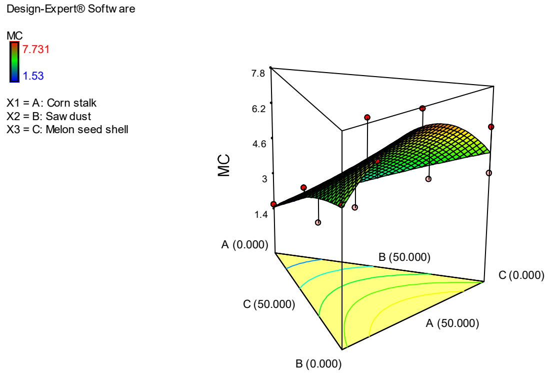


Fig. 5: Moisture Content of the samples

Volatile matter refers to the part of a biomass material that is released as volatile gases when it is heated up to 400˚C - 500˚C. Biomass generally has high volatile matter content of around 70% and 86% and low char content. The high volatile matter content of a biomass material indicates that during combustion, most of it will volatize and burn as gas in the cook stove (Akowuah *et al*., 2012). The volatile matter of the samples obtained were 30.921% melon seed shell, 30.93% sawdust to 72.826% corn stalk as shown in Fig. 6. This will result in low volatile content of the composite, which does not conform to 70% - 80% volatile matter of biomass as reported by Akowuah *et al.* (2012). However, materials with high volatile matter tends to release more smoke (Thabuot *et al*., 2015), Therefore, the relatively low volatile compositions of melon seed shell and sawdust with high volatile value for a corn stalk will result in a composite with high ignition potential and emission of lesser smoke.

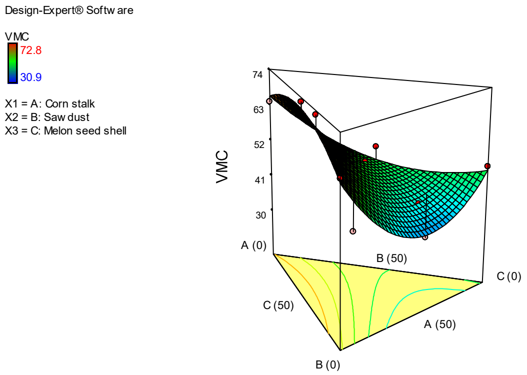


Fig. 6: Volatile Matter Content of the Samples

High ash content of sample indicates presence of high mineral matter. The ash content obtained were 1.151% melon seed shell, 1.8% corn stalk and 4.121% sawdust as shown in Fig. 7. The ash content of all the samples analysed was lower than 6%, that is, the value beyond which slagging of ash would occur with biomass fuels according to Hahn, (2004). Thus, it is likely that when these biomass combinations are used as fuel no slagging would occur.

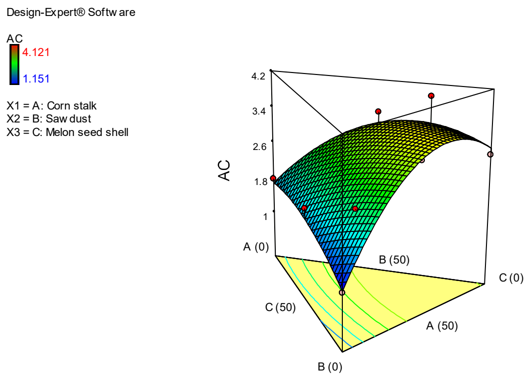


Fig 7: Ash Content of the Samples

From the results obtained, melon seed shell recorded the highest fixed carbon content of 2.918%, corn stalk has the lowest with 1.8204% fixed carbon as depicted in Fig 8. While these values are greater than the 1.41% for corn cobs as reported by Thabuot *et al*. (2015), the calorific values of the composite will be high. Increasing the percentage composition of melon seed shell will proportionately increase the fixed carbon content of the composite.

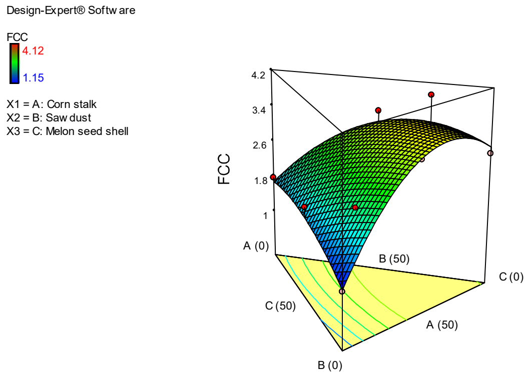


Fig. 8: Fixed Carbon Content of the Samples

The result of the calorific values obtained shows that corn stalk exhibits highest calorific value of 32,636 Kcal/kg, while sawdust and melon seed shell have the least calorific value among the samples with 28,652 Kcal/kg as indicated in Fig 9. These values are similar to calorific values of 3113.15 Kcal/kg for Areca leaves briquette as reported by Deepak and Jnanesh, (2015) and 31,886.04 Kcal/kg to 31,136.771 Kcal/kg of orange peels and corn cobs as reported by Aliyu *et al*., (2020). The decrease in calorific value may be due to the blending of biomass with a non-combustible substance such the starch used as binder which does not contribute to the total heat value released.

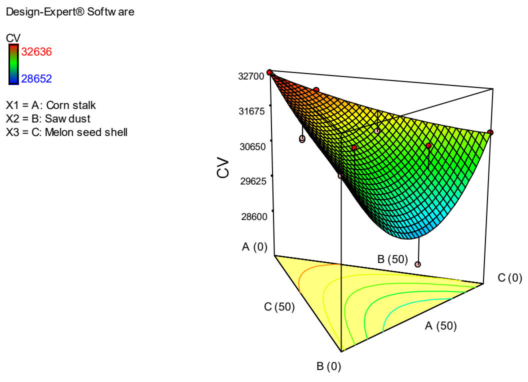


Fig. 9: Calorific Value of the Samples

Results of the Ultimate Analysis of the Samples

The organic carbon content of the biomass materials ranged from 64.553% for melon seed shell to 78.281% for corn stalk as indicated in Fig 10. The composite shows organic carbon content of about 78.28%, thus, the higher the carbon content of a biomass fuel the more likely that the samples would have higher heating value (Sanger *et al*., 2011).

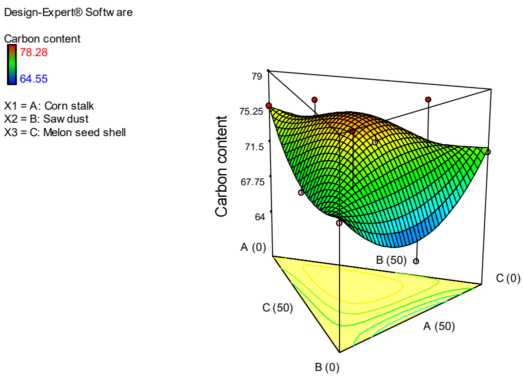


Fig. 10: Carbon Content of the Samples

The nitrogen content of the species studied ranged from 0.817% for corn stalk and sawdust to 1.482% for melon seed shell as shown in Fig 11. Nitrogen content is a good indicator of the amount of nitrogen based toxic components that can be formed during combustion. During combustion of wood fuel, nitrogen is oxidized into nitrogen oxide (NO_2). Exposure to nitrogen oxides increases the risk of respiratory infections as it is highly toxic and irritating to the respiratory system (Sillman, 2003). When NO_2 and volatile organic compounds react in the presence of sunlight, they form a photochemical smog, which is a significant form of air pollution (Sillman, 2003). The nitrogen content of samples was slightly higher than the limits set by the Austria national standard for pellet and briquettes, Austria ÖNORM M7135 (i.e. Nitrogen content ≤ 0.6%).

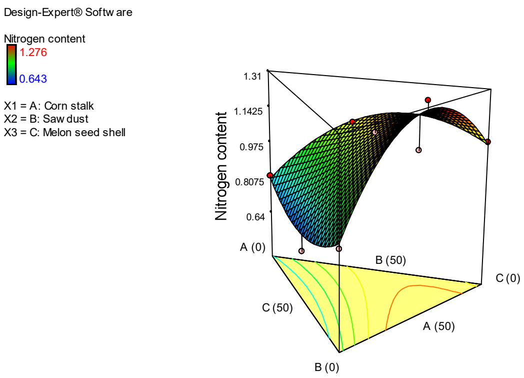


Fig. 11: Nitrogen Content of the Samples

The hydrogen content of the samples studied ranged from 4.764% (melon seed shell i.e 16.667% Corn Stalk, 41.667% Sawdust and 41.667% Melon Seed Shell) to 6.957% (corn stalk, i.e 50% Corn Stalk, 25% Sawdust and 25% Melon Seed Shell) as shown in Fig 12, The composite typically, comprises 5% to 6% of the biomass dry matter. High hydrogen content in briquettes leads to a high heating value.

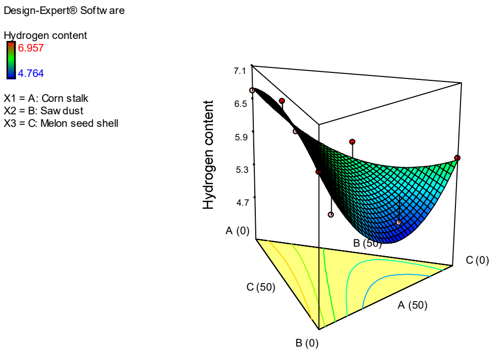


Fig. 12: Hydrogen Content of the Samples

The composite oxygen content of about 20.01% was obtained as shown Fig 13. The lesser the oxygen the better the briquette, this is because as oxygen content increases, moisture holding capacity increases and binding ability decreases. However, this value is lower than oxygen values reported for briquettes produced from rice straw and Sugarcane leaves by Jittabut (2015).

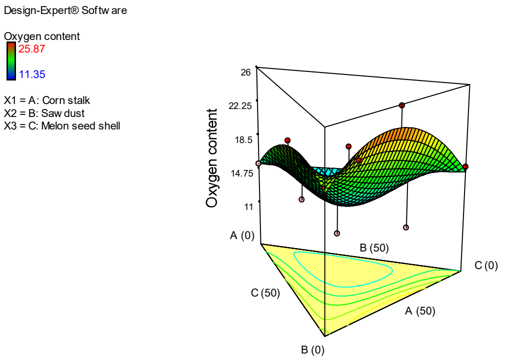
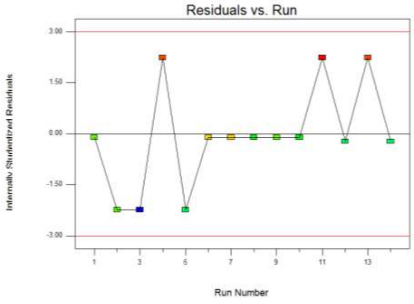
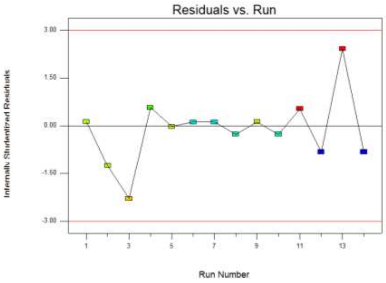


Fig. 13: Oxygen Content of the Samples

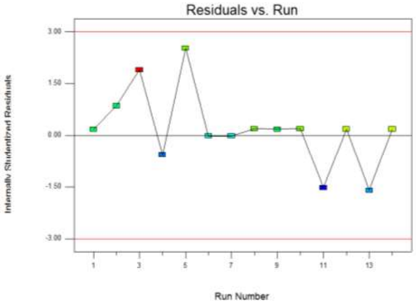
The residual versus the experimental run order shown in Fig. 14 a-d shows that the experimental runs exhibit a greater percentage of lurking, thereby validating the established correlation between the process variables and the biomass ultimate parameters studied. These plots allow to check for lurking variables that may have influenced the response during the experiment. Trends indicate a time-related variable lurking in the background. Blocking and randomization provide insurance against trends running the analysis. Consequently, Nitrogen content is more consistent or lurked across the run with minimised residuals while carbon content exhibits least lurking effect and high recurring residuals.



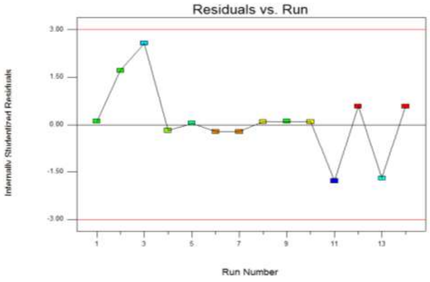
(a) Effect of run on carbon content



(b) Effect of run on Nitrogen content



(c) Effect of run on Oxygen content



(d) Effect of run on hydrogen content

Fig. 14: Effect of runs on the ultimate analysis of the biomass samples

The standardized error of the design is used in evaluating the design validity in the formulation of composite briquette; the plot indicates absence of point of critical error indicating the design levels significantly represent the composite estimate of the biomass as shown in Fig 15.

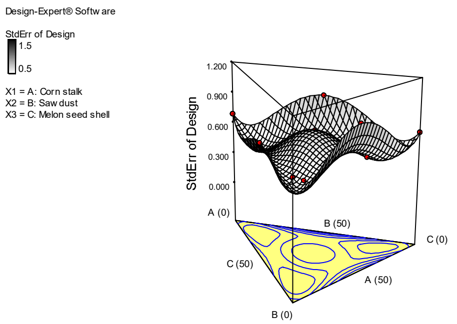


Fig. 15: Standard error plot of the composite design

Conclusion

Biomass residues of Corn Stalk, Melon Seed Shell and Sawdust have shown from the investigation conducted to possess desirable properties for a good briquette. The various formulations of the samples have high calorific value with sample 12 (comprising of 41.667% Corn Stalk, 41.667% Sawdust and 16.667% Melon Seed Shell) having the highest calorific value of 32481.781Kcal/Kg. Also from the results of the proximate analysis, ash content was found to be low thus reducing the chance of slagging when the biomass is used as fuel. The results obtained from the ultimate analysis further confirms the briquettes having good fuel properties as they conform to standards and previous works although some little variations were noticeable. Utilizing biomass wastes such as these as alternative source of fuel will not only add to the energy generation of the country but will also go a long way in solving many ecological problems caused by the use of fossil fuels and environmental degradation through human activities.

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Synthesis of Carbon Nanotubes using Catalytic Chemical Vapour Decomposition of Acetylene over Co-Mo bimetallic Catalyst supported on Magnesia

***Buhari, S. A.[1]; Abdulrahman, A. S.[2]; Abdulkareem, A. S.[3]; Lawal, S. A.[1] & Akintunde, I. B.[2]**

[1]Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria.
[2]Department of Materials and Metallurgical Engineering, Federal University of Technology, Minna,
[3]Department of Chemical Engineering, Federal University of Technology, Minna, Nigeria.

E-mail address: shehubuhari32@gmail.com

Abstract

This research work investigates the utilization of acetylene as a precursor for the synthesis of multi-walled carbon nanotubes (CNTs) over bimetallic Co-Mo catalyst supported on magnesia (MgO) via catalytic chemical vapour deposition (CCVD) technique. The CCVD equipment requires the use of catalyst and support in addition to a carbon source (acetylene) and nitrogen gas for CNTs growth. The bimetallic Co-Mo catalyst supported on MgO was prepared by the wet impregnation method, which was placed in the quartz boot inside the CVD equipment. The catalyst sample with the highest yield of 93.22 % was prepared from 16 g support mass, stirring speed of 1500 rpm, stirring time of 20 minutes, drying temperature of 120℃ and drying time of 10 hours. The catalyst was characterized using high-resolution scanning electron microscopy (HRSEM) and X-Ray diffraction spectroscopy (XRD) to determine the catalyst crystallinity, morphology and elemental composition. The catalyst developed was utilized for the synthesis of CNTs by chemical vapour deposition method (CVD) with acetylene as the carbon source and nitrogen as the carrier gas while the CVD furnace was programmed to heat at 10℃ per minute. The effects of synthesis parameters (calcination temperatures, reaction time, and gasses flow rates) on the yield of the CNTs were examined with 2^4 factorial experimental design. The highest yield of 89.09 % of CNTs was obtained at a temperature of 700℃, 250 mL/min and 200 mL/min flow rate for acetylene and nitrogen, respectively. The XRD patterns of the as-synthesized CNTs revealed the development of graphitized carbon, the high-resolution scanning electron microscopy (HRSEM) micrographs indicated the formation of fairly uniform and evenly dispersed carbon nanotubes were grown on the support, while the high-resolution transmission electron microscope (HRTEM) confirm the formation of CNTs with a particle size between 31.21 and 45.03 nm. Also, the HRTEM results further revealed the increase in diameter of CNTs when the temperature is raised from 700℃-800℃. This study establishes the production of CNTs from acetylene precursor over bimetallic Co-Mo catalyst supported on MgO in a CVD reactor.

Keywords: Synthesis, Bi-metallic alloy, Catalytic Chemical Vapour Deposition, Catalyst, CNTs

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Introduction

There have been rapid developments in the synthesis and characterization of nanostructured materials especially carbon nanotubes (CNTs) that lied within the nanometre scale from precursor materials since it was first discovered (Iijima, 1991). Carbon nanotubes are unique nanostructured materials with distinct tubular structures and large length to diameter ratios that have received notable attention due to their unique structural, mechanical, thermal, optical, chemical and electronic properties in the fields of science, engineering and medicine (Yang *et al*. 2016). These have drawn the attention of researchers in the field of science and technology to research in this area of study. Significant scientific studies have revealed the potential of CNT applications such as supercapacitors, reinforcements in high-performance composites, hydrogen storage, catalyst support, selective adsorption agents, field emission devices, artificial implants, biosensors, catalyst, diagnostic tools, preservative. CNTs have also been explored for biomedical applications,