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PRODUCTION OF BIOCHAR FOR SOIL ENRICHMENT: PARAMETRIC AND SENSITIVITY ANALYSIS ON THE YIELD OF SPINACH *(MARATUS CALCATUS)*

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Abstract

This thesis is based on the use of biochar for soil enrichment and its parametric and sensitivity analysis on the yield of spinach. A saw dust based biochar was used to carry out the experiment, the saw dust was dried, sorted by particle size distribution and pyrolysed at different temperatures (300^0c, 350^0c and 400^0c) with different holding time (30 minutes, 60 minutes and 90 minutes), this was done in other to the best or optimum temperature at which a biochar with high

Keywords:
Biochar, Pyrolysis, and Soil Analysis

Introduction

Agriculture has to address and the same time curb the challenges ensuring food safety through increased income and productivity, adapting to climate change mitigation. This challenge, worsening global pressure on normal resources, mainly on water, will need essential changes in our food classification. To treat these challenges, feeding systems have to be simultaneously, additional effective and flexible at each level from the farm to the world wide level. They have to develop more effectively in reserve employment and become more capably to adapt to variations and impacts. For example,

nitrogen and carbon content could be gotten, the optimum temperature and holding time was discovered to be biochar produced at 350c at a holding time of 90 minutes. The ultimate and proximate analysis of the biochar produced at 350^{0}c was found to have moisture content of 4.32, the ash content was 26.12, the volatile matter was discovered to be 35.32, and the fixed carbon was 34.34. The ultimate analysis result carried out showed that the carbon content was 72.45%, hydrogen was 2.66%, Oxygen present was 13.02%, the nitrogen content was 3.60% which indicated a 100% increment as compared to raw saw dust (1.41%), the biochar had no sulphur content in it(0.00%). The BET analysis indicated the biochar increased in surface area after it was subjected to pyrolysis (surface area = 591.0m2/g, pore volume = 0.1747cc, pore size = 6.077nm). The SEM analysis of the biochar was done and the scanning revealed the porous structure of the biochar and the large surface area which was essential to the retaining of nutrients in the soil. XRD revealed the amorphous nature of the biochar with its elemental composition, the FT-IR revealed the functional groups present in the biochar. A soil analysis was embarked on before the planting and after harvesting the spinach, the soil analysis clearly indicated that there was a sharp increase in the soil organic matter, phosphorus, calcium, magnesium, potassium, nitrate and the soil Ph, the parameters used in determining the yield of the spinach as compared to the control were germination time, harvest time, mass of spinach after harvesting, shoot and length of spinach. The experiment revealed the composition of biochar and organic fertilizers as a treatment prove to be more efficient in enriching the soil for better yield of the spinach.

Livestock and crop production are the most essential source to make living in Africa for nearly 61% of the working inhabitants. More than one third of the overall area of Africa is appropriate for agricultural improvement and development. Therefore, it is necessary to inform the farmers or peasants of the importance of biochar to improve soil and increase productivity by improving water and nutrient retention capacity and thereby decreasing over dependence on chemical fertilizers.

The motivation to study biochar came from the possibility to solve many of the challenges fronting the today's world: waste administration, renewable energy, soil declination and climate change. Different stages for the extraction of renewable energy from feedstocks, biochar build up soil fertility and food availability rather than act as a challenging benefit. If suitably understood and applied, biochar has the possibility for generating several win conditions with no demerits.

The concept to us e of biochar as a sol amendment may seem recent but it really comes from the study of very ancient soils in the basin of Amazon. It is known that "Terra preta" or black soil of the Indians was designed by indigenous people since thousand years ago when they amassed charcoal and different wastes, nutrient trash like animal bones and fish bones. Until today, black soil or "Terra Preta" soils remain more fertile than neighboring or surrounding unmodified soil. Researchers see that the biochar in these soils is the one that keeps them so fertile over such extensive stages in an environment that rapidly filters nutrients out of the soil and where organic materials decomposes so quickly.

Crop growth and productivity are strongly influenced by various biotic and abiotic factors such as pests, weeds, drought, high salinity, extreme temperature, etc. and the soil quality. Soil is also contaminated by heavy metals through various human activities, which affect plant growth and development and ultimately brings low yielding cropping systems. Mining is one of the important sources of heavy metal contamination in soil. The strength of soil is directly related to nutrient availability. Plants require a number of soil nutrients like nitrogen (N), phosphorus (P), and potassium (K) for their growth, but soil nutrient levels may decrease over time after crop harvesting, as nutrients are not returned to the soil. In India, the soil of many regions is not only deficient in macronutrients like NPK but also in secondary nutrients (e.g. sulfur, calcium, and magnesium) and micronutrients (e.g. boron, zinc, copper, and iron). Thus, to fulfill the shortage, a large amount of chemical fertilizers is added to the soil; however, only a small percent of water-soluble nutrients are taken up by the plants and the rest are converted into insoluble forms, making continuous application necessary. The extensive use of chemical fertilizers has led to the degeneration of the environment causing infinite problems. It not only lowers the nutrient composition of the crops but also impairs the soil fertility in the long run.

Besides fertilizers, pesticides are also known to be mitigating factor agriculture, and the adverse effects of pesticides on the environment are truly responsible for influencing the microbial properties of soil. High inputs of fertilizers and pesticides and their long persistence in the soil adversely affect the soil microflora, thereby disturbing soil.

What is Biochar?

Biochar is a stable form of carbon created by heating biomass in a low or no oxygen environment. When used as a soil amendment, biochar has an extremely porous carbon structure which allows for effective water and nutrient storage, as well as providing a habitat for high quantities of soil microbes. Biochar forms a dynamic substrate, so it provides numerous benefits, including increasing nutrient availability, increasing soil water retention, improving crop yield, and sequestering carbon for hundreds to thousands of years. Biochar applications have been proposed to increase the productivity and quality of some soils.

However, biochar research has been concluded by many studies that biochar's effectiveness depends largely on the biomass feedstock and the soil to which it is applied. This study proposes to expand current knowledge in comparison of various biochar feed stocks, as well nutrient treatments.

MATERIALS AND METHODOLOGY

This chapter gives an extensive knowledge of the biochar production, the proximate, ultimate, BET, SEM, FTRI, CEC procedures and the field experimental design .it Highlights the names of the apparatus and equipments used to achieve the experimental purpose. The ultimate and proximate analysis were carried out to know the percentage of ash content, volatile matter, moisture content, fixed carbon and the elements present in the biochar.

EQUIPMENT AND APPARATUS USED

EQUIPMENTS

The list of equipments and processes involved in the production of biochar from saw dust which was later used for soil amendment are shown in the Table 3.1 below.

Table 2.1: List of Equipments

S/N	*EQUIPMENT/MATERIALS*	*SOURCE*
1.	*Heating Furnace*	*STEP B Laboratory FUTMINNA*
2.	*Oven*	*WAFT Laboratory FUTMINNA*
3.	*Gas Cylinder*	*STEP B Laboratory FUTMINNA*
4.	*Stop watch*	*WAFT Laboratory FUTMINNA*
5.	*Crucibles*	*WAFT Laboratory FUTMINNA*
6.	*Weighing Balance*	*WAFT Laboratory FUTMINNA*
7.	*Saw Dust*	*Sawmill, Maitumbi, Minna*
8.	*SA3100 Surface analyser*	*STEP B Laboratory FUTMINNA*

Equipments and materials for Ultimate Analysis

1. Digestion unit
2. Analytical Scale
3. Fumes hood
4. Glass wares

Chemicals and Solutions

1. Sulphuric Acid
2. Distilled water
3. Copper sulphate (catalyst)

Material Preparation

Saw dust was selected for this experiment and it was obtained from the saw mill at Maitumbi, Minna, Niger State. The saw dust was sun dried for 3 days to ensure homogeneity. Afterwards size reduction was carried out by grinding. The grinded sample was further sieved with 500um (0.5mm) sieve. Putting of the sample in the sieve was done mechanically to ensure effectiveness and uniformity. The process was then repeated severally to ensure the particles attained the desired sizes. The sample was then taken to STEP Laboratory for pyrolysis.

Pyrolysis of Saw dust

The saw dust was re-dried in an oven at a temperature of 80^{o}C for an hour. A crucible containing nitrogen gas in its cylinder was connected to the heating furnace in order to keep the system un-reactive and stable. The heating furnace was heated at an increasing rate of 10^{o}C/min 450^{o}C for one hour to complete the pyrolysis process (Adeniyi, 2014). At the end of the pyrolysis process the biochar was brought out and allowed to cool for about 30 minutes.

PROXIMATE ANALYSIS

The proximate analysis of the biomass is essential in determining the chemical composition of the biomass and to provide their various combustion characteristics. The proximate analysis are divided into four constituents namely: Moisture content, ash content (inorganic matter left after combustion), volatile matter (the gases emitted during the thermal decomposition of the biomass in an inert atmosphere) and fixed carbon (calculated by the difference).

Moisture Content Analysis

The moisture content analysis was carried on the biochar produced in order to know the level of moisture (water) in the biochar. An empty crucible weight was put in an oven for 30 minutes at 100^{0}c to eliminate any trace of moisture, the crucible was put in a desicator to cool down and then was reweighed, the weight was noted. 1g of the sample was measured out into the crucible and then weighed. The sample was the placed in the oven set at 105^{0}c and left for 1hour. The crucible and its content were then removed and placed in a desicator to cool down and then reweighed.

Moisture content (%) $= W3 - W1/W2 - W1 \times 100\%$

Where W1= Weight of clean dry crucible (g),

W2= Weight of crucible + Wet Sample (g)

W3= Weight of crucible + dry sample

Ash Content Analysis

1.0g of the dried sample of biochar was measured and heated in a furnace at 500^{o}C for 30minurtes by following the previous weighing procedures and heating was carried out in a furnace and left in a desicator to cool down to room temperature and weighed. This weight was recorded as the final weight of ash by using the following equation in grams (g).

Ash content (%) $= weight\ of\ ash / initial\ weight\ of\ dry\ sample \times 100$

Volatile Content Analysis

The volatile matter of the biochar was determined using the Meynell Method. 1.0 g of the residual dry sample each from moisture content determination was placed (spread evenly) on an empty crucible, after weighing the empty crucible and it was covered and placed in a furnace heated at 700°C for 15minutes to drive off the volatiles. The resulting samples was further heated at 600°C for 10 minutes, placed in the desicator and allowed tom cool and then calculated using the following equation below:

$$volatile\ matter(\%) = loss\ in\ weight\ due\ to\ removal\ of\ volatile\ matter / weight\ of\ sample\ taken \times 100$$

Fixed Carbon

The fixed carbon analysis gives a measure of what is left out of the biomass when moisture, volatiles and ash have been removed. The fixed carbon of the biochar was calculated using the following equation:

$$fixed\ carbon(\%) = 100 - (moisture\ content + volatile\ matter + ash\ content)$$

ULTIMATE ANALYSIS

Elemental components of the biochar were determined by an elemental analyser. A given weight of (1.0g) was burned at a raise temperature in an oxygen atmosphere, so the carbon was converted to CO_2 and the hydrogen to H_20, sulphur into $S0_2$ and the Nitrogen into N_2. The first three compounds were detected quantitatively by an IR detector, while N_2 was determined by a thermal conductivity detector.

Carbon and Hydrogen Contents

Big-Pregle method was used to determine the carbon and hydrogen content. To determine the carbon and hydrogen content: 1g of the biochar was placed in quartz tube and burnt off through the absorbent magnesium percolate to absorb water and sodium hydroxide to absorb carbon dioxide. The amount of water and carbon dioxide were determined from the difference between the weight before and after absorption of water. The hydrogen and carbon (%) were evaluated thus as: $\%C = a(0.2727) / g \times 100$

While for Hydrogen content: $\%H = b(0.2727) / g \times 100$

Brunauer-Emmett-Teller (BET) Analysis

The adsorption capacity of the biochar produced was necessary to determine and this was carried out using the BET analysis to determine surface area and pore volume of the produced biochar. The biochar sample was dried at 110^oC for one hour and out-gassed at 300^oC under vacuum for two hours prior to measurement. The sample was measured on a Beckman Coulter SA3100 surface area analyser (STEP B FUTMINNA) at the temperature of liquid nitrogen (196^oC)

SEM ANALYSIS

The SEM Analysis is a test process that scans a sample with an electron beam to produce a magnified image for analysis and it's used very effectively for microanalysis and failure analysis of solid inorganic material. The signals generated during the SEM analysis produce a two dimensional image and reveal information about the biochar including the external morphology (texture), chemical composition when used with the EDS feature and orientation of materials making up the sample. The EDS component of the system is applied in conjunction with SEM analysis to determine elements in or on the surface of the biochar for qualitative information.

CATION EXCHANGE CAPACITY ANALYSIS (CEC)

Cation exchange capacity has a significant influence on the physical and chemical behaviour of soil and this is measured by displacing all the bound cations with a concentrated solution of another cation and then measuring either the displaced cations or the amount of cation that is retained. 2.0g of biochar was placed in a 250ml flask and 100ml of ammonium solution (ph=7) was added and shook thoroughly and allowed to stand overnight. The solution was filtered with light suction using a funnel and it was re-filtered with an additional ammonium solution (ph=7), Ca^{2+} , Na^{+}, Mg^{2+}, K^{+} were checked for using ammonium chloride (NH_4Cl) and ammonium hydroxide (NH_4OH).

X-Ray Diffraction (XRD) Analysis

X-ray diffraction analysis carried out was important in the determination of structure of the biomass carbon used in this research. 1.0g sample of the biochar was put into a circular disc then placed on spring cover which was clamped on a bigger cylindrical disc. The mechanism was such that once the sample was clamped to the bigger disc it holds the sample firmly in place and ready for x-ray diffraction measurement. The sample was placed in the x-ray machine (Siemens D500 X-ray Diffraction system) and the computer linked to the X-ray machine was readjusted for fresh reading. The X-ray machine shuttle was switched on. The computer reading was readjusted to 0 to 80 degree.

FIELD EXPERIMENTAL DESIGN OF BIOCHAR APPLICATION

The field experiment was designed to test whether the use of biochar for soil amendment can reduce the application rate of chemical fertilizer while at the same time maintaining a high crop yield (spinach). The control (no biochar) has three rows and the portion with biochar has three rows too. The field was prepared and managed according to standard practices including cultivation. The biochar was completely with the top soil at a depth of 10cm. The field experimental design is shown in the figure below:

Figure 2.5.1: Experimental design

<u>Treatments</u>

Rate of biochar application

T_1 = Control (without biochar and fertilizer)

T_2 = with Biochar only at 20g per bed

T_3 = with chemical Fertilizer only (recommended)

$T_4 = T_2 + T_3$

Treatment 1 (T_1)	Treatment 4 (T_4)	Treatment 2 (T_2)
Treatment 2 (T_2)	Treatment 3 (T_3)	Treatment 1 (T_1)
Treatment 3 (T_3)	Treatment 2 (T_2)	Treatment 4 (T_4)
Treatment 4 (T_4)	Treatment 1 (T_1)	Treatment 3 (T_3)

MEASUREMENT ANALYSIS

Top soil samples, 10cm in depth were collected from the field before planting and at harvest. For each of the collected samples, soil properties including soil Ph, soil organic matter, available phosphorus, nitrogen as nitrate and cation exchange capacity were determined at the WAFT laboratory, FUTMINNA. The measurement of the land used for planting was put into consideration; the size of the land used was 3m^2 by 3m^2, the spinach were planted in 10cm apart and the soil was tilled and mixed with biochar

Planting seeds, watering and harvesting

The seed was pressed into the soil until it was between 10cm and 20cm below the soil surface. Plants were watered six days a week unless soil saturation was too high. Between 5ml and 30ml of tap water was added to plant manually. When the soil was oversaturated such that additional water was likely to pass through into the soil without being absorbed, the plants were not watered. At the end of the 35-day period, plants were harvested by pulling the plant up by the roots and replacing as much soil as possible from the roots. Each plant had its height recorded, as well as dry mass for both roots and shoots, and wet weight for both roots and shoots.

Water Holding Capacity.

As mentioned above, there is a strong positive correlation between water holding capacity and total microbial activities in the soil (Zhang & You, 2013). The water holding capacity of the control soil and mixtures of control soil with the biochar were tested. The soil and biochar mixtures were all tested biochar, all soils were mixed until homogeneity was attainted prior to testing. The analysis of the soil sample (control) with the mixture of soil sample and biochar were carried out at the WAFT laboratory, this was done before the planting took place and after the harvesting was done.

RESULTS AND DISCUSSION

Introduction

This chapter contains the results obtained from the Proximate and Ultimate analysis of the biochar carried out at the WAFT laboratory FUTMINNA, the FTRI (Fourier transform infra red), the BET carried out at the STEP B laboratory FUTMINNA, the XRD (x-ray diffraction pattern), the CEC (cation Exchange Capacity) and the SEM analysis. All these analysis were key in investigating the form of the biochar used for the soil amendment.

Proximate and Ultimate Analysis

Ultimate Analysis at different temperatures

Sample	Carbon(C)%	Nitrogen(N)%	Hydrogen(H)%	Oxygen(O)%	CEC(c/mol/kg
Biochar-300C	66.73	2.85	2.97	13.62	15.30
Biochar-350C	72.45	3.60	2.66	13.02	13.45
Biochar-400C	81.46	1.69	1.94	10.32	13.10

The ultimate analysis of the biochar at different temperatures were investigated to know the optimum temperature at which a better and more stable biochar could be produced. From the table 4.1. we could infer that the biochar produced at a temperature of 350C had a higher carbon content which implies that carbonization degree is enhanced by increasing temperature (Chaun et al 2004; Chen et al 2012). The reduction in hydrogen and oxygen content was due to the weaker bonds inside the biochar matrix (Demibras 2004). There was a high percentage of nitrogen in biochar produced at 350C which indicates that wood derived biochar had good potential for net Nitrogen immobilization in the soil (Fungai *et al* 2013). These results generally showed that at elevated temperature more recalcitrant carbon structure was formed inside the biochar matrix, from the ultimate analysis carried out, the Biochar produced at 350C was more suitable to be used for soil enrichment with its high carbon, nitrogen and cation exchange capacity content. The CEC is a measure of the ability of materials to adsorb cations such as Ca^{2+}, Mg^{2+} or k^{+}. However, Cely et al 2015 showed that the CEC of biochar is greatly dependent on the pyrolysis temperature and properties of the raw material. The greater CEC of the Biochar was due to the higher charge density per unit surface area , the formation of carboxyl groups, a more porous structure or a combined result of the three factors (Sun et al, 2014). The higher CEC value of biochar indicates its stronger ability to hold essential nutrients as well as greater its resistance against the acidification of soil (Mukherjee et al, 2011). The Biochar produced at 300^{0}C had a higher CEC and would be more beneficial in soil amendment/enrichment in agronomy. The biochar used in this experiment had a very high nutrient composition compared to the feedstock (saw dust), these properties made the biochar of very essential value in agronomy and can thus be used as soil amendments especially in combination with organic and inorganic fertilizers.

3.1.1 Proximate Analysis

Sample D	moisture Content (wt%)	Ash Content (wt%)	Volatile matter (wt%)	fixed carbon (wt%)
Saw dust	11.65	2.3	53.50	32.55
Biochar	4.32	26.12	35.22	34.34

Ultimate Analysis

Sa Sample (w%	Carbon (C) (w%)	Hydrogen (H) (w%)	Oxygen (O) (w%)	Nitrogen (N) (w%)	Sulphur (S) (w%)
Saw dust	51.40	6.70	36.86	1.41	0.00

Biochar	72.45	2.66	13.02	3.60	0.00

From the table 4.1 and 4.2 the result of the proximate and ultimate analysis carried out on the saw dust and biochar indicates the properties of the biomass material used for this experiment which enabled us to know how it would have an impact when applied to the soil and its effect on the yield of spinach. After the saw dust was collected, it was dried at a temperature of about 60C for three days (3) before proceeding to carry out proximate analysis on it. Then proximate analysis carried out on the raw saw dust denoted that the saw dust still had a moisture content of about 11.65% (before pyrolsis) which is high compared to the moisture content after it was pyrolysed, the ash content of the saw dust was 2.3%, this low ash content could be attributed to the fact the saw dust had not been subjected to heat compared to the ash content of the biochar. The volatile matter of the saw dust is very high due to the fact the moisture content of the saw dust is high, the higher the moisture content the higher the volatile matter in a material. The fixed carbon which is a summation of moisture content, ash content and volatile matter subtracted from 100% was found to be 32.55 which is low compared to the fixed carbon of biochar.

The moisture content, ash content, volatile matter, fixed carbon of the biochar were obtained as follows 4.32%, 26.12%, 35.22%, 34.34% compared to Wan Azlina et al 2014 of 5.21%, 31.34%, 51.39% 14.29%, the differences in the percentages was due to the different biomass material, drying temperature and procedures being used for the experiment, the drying temperature used differs from each biomass material. The low moisture content of the biochar is advantageous to the soil because it would help in water retention capacity which would invariably boost the microbial activities in the soil and this is very helpful to spinach growth. The ash content is a merit in increasing the ph of soil, ash is known to contain high level of calcium which helps in increasing ph of a solution and spinach growth has been studied to thrive better on soil ph that is high. The fixed carbon in biochar signifies the amount of carbon left after the saw dust has been pyrolysed, this would also help to add nutrients to the soil and sequester the carbon in the soil to prevent green house effect.

The ultimate analysis was carried out on both the saw dust and the biochar and there was a significant difference in the composition of both materials.

The carbon, hydrogen, oxygen, nitrogen and sulphur of the saw dust are 51.40%, 6.70%, 36.86%, 1.41 compared with the values obtained from the biochar, 72.45%, 2.66%, 13.02%, 3.60%, we could infer that the carbon in the biochar is higher than that of the saw dust due to the fact that it had been subjected to immense heat, the nitrogen composition of the biochar was found to be higher than that of the saw dust because some of the nitrogen gas were captured by the biochar during pyrolysis which resulted in about 200% increment in the nitrogen content of the biochar. The nitrogen composition is very essential to boosting soil fertility because it is needed mainly by plants and this nitrogen can be released in a more sustainable way into the soil when biochar is applied.

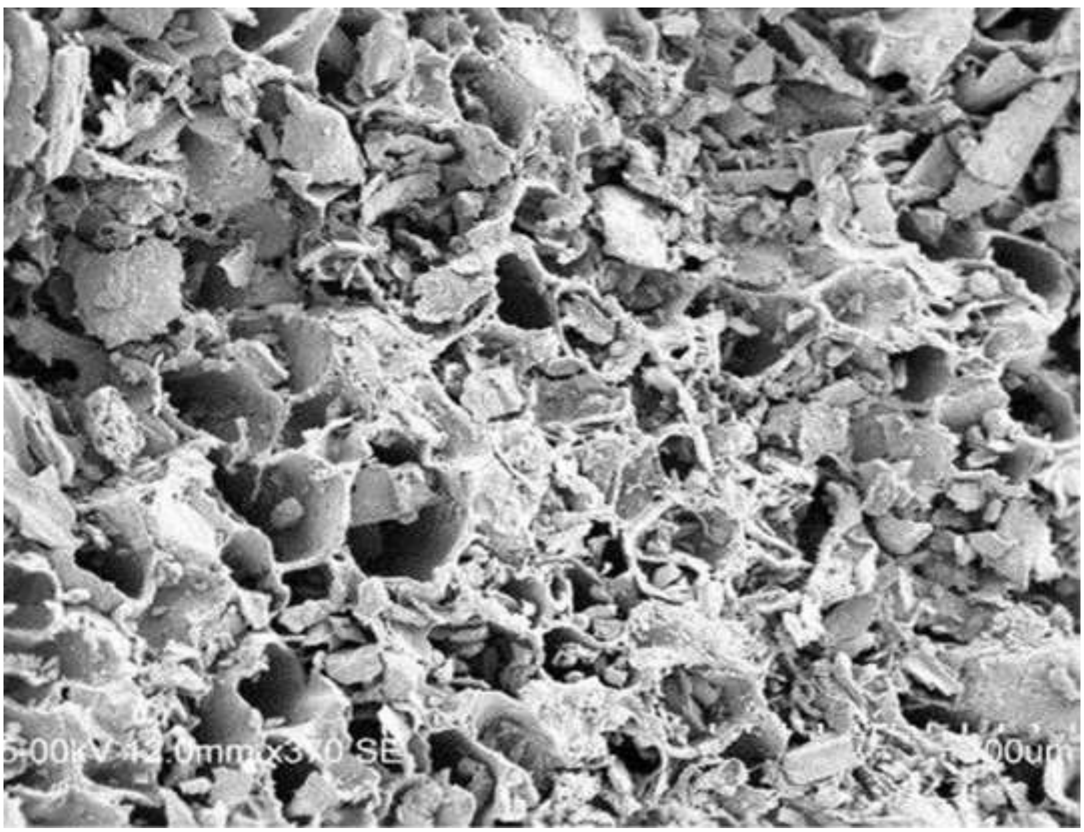
3.2 BET Analysis

Sample	Surface area(m^2/kg)	Pore volume(cc/g)	Pore size(nm)
Raw Sawdust	1.384	0.879	1.787
Biochar	591.0	0.1747	6.077

The BET analysis for the more suitable biochar (Biochar at 350C) and raw saw dust were carried out to investigate the surface area properties of both materials to see the changes. It was observed that the surface area of biochar was increased massively compared to the surface area of raw saw dust (from 1.384m2/kg to 591.0m2/kg), this occurred as a result of the carboinzation at that temperature, when biomass is subjected to immense heat, they tend to have more pores which results to higher surface area. Greater surface area is very essential in soil enrichment because it helps in improving soil properties and increases soil retention capacity to a greater extent (Shaaban *et al.* 2013).

The above graph indicates the Fourier Transform Infrared (FTIR) spectra result, the fourier transform infrared works to convert the raw data from the broad-band light source to actually get the level of absorbance of each wavelength. The x-axis or horizontal axis on the graph denotes the infrared spectra , which plots the intensity of infrared spectra. The peaks from the above graph are called absorbance bonds and correspond with the various vibrations of the sample’s atoms when it is being exposed to the infrared region of the electro-magnetic spectrum. For mid range, the wave number on the infrared spectrum is plotted between 4,000 to 500 cm-1. The y-axis or the vertical axis represents the amount of infrared light absorbed or transmitted by the biochar being analysed. The functional groups were identified based on the peaks from the graph above, in addition, the rate of weakening and disappearance of peaks of functional groups present on the biochar surfaces at higher temperature such as –OH and C-H groups is consistent with a significant mass loss (Jin et al, 2016).

SEM ANALYSIS



The biochar was subjected to scanning electron microscope (SEM) to have a clear understanding of the structure and size distribution of the biochar, the SEM image was taken under a magnification of Fv400 (x5000), the figure above shows the structure of the biochar after it was pyrolysed. The morphology of the biochar was determined by the scanning electron microscope and the graded composition of the biochar was analysed by the energy disperse X-ray dispersion. The EDX showed the elemental composition of the biochar, the biochar contained C, O, N, Si, Ca and Mn. The SEM analysis showed the biochar had larger pores and lower surface area after it was subjected to intense heat, which indicates that the size distribution (pore size) was largely dependent on the temperature of pyrolysis. The image above also revealed presence of porous structure on the surfaces but some pores were filled by volatile matter. The presence of volatiles in the pore structure of biochar has been reported in rice husk and elm saw dust biochar (Wang et al. 2014).

X-RAY DIFFRACTION PATTERN (XRD)

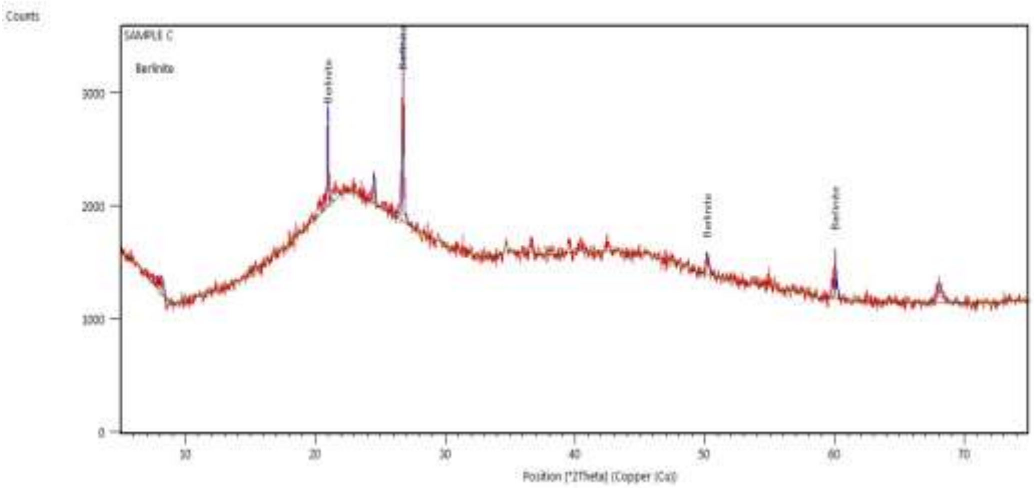


Figure 4.4: X-ray diffraction pattern for the pyrolysed saw dust (biochar.

From the figure 4.4 above, the highest peak is at an angle of 20.10^0 and 26.12^0 (2θ-axis) and this was as a result of the pyrolysis temperature that caused partial cellulose degradation (Keiluweit *et al*. 2010). However, the peak at 2θ-axis indicated the development of atomic order in the carbonized sample at a high temperature. The absence of sharp peaks denoted the amorphous texture of the biochar sample (Tongpothorn *et al*. 2011). It was previously reported that the formation of aromatic structures began after the formation of aromatic structures began after the complete disintegration of the nanocomposite structure during the charring process (Paris *et a*l. 2005)

SOIL ANALYSIS BEFORE AND AFTER EXPERIMENT

Before Experiment

Treatments	soil organic matter (%)	phosphorus(p) mg	potassium(k) mg	Magnesium(mg) mg	calcium (Ca) mg	Nitrate(N) mg	Ph
Treatment 1	2.9	16	202	340	1950	16	5.6
Treatment 2	2.6	21	222	431	1721	33	5.3
Treatment 3	3.1	26	180	440	2471	27	5.6
Treatment 4	3.4	20	195	404	1982	38	6.0

The soil analysis of the portion of land used for this experiment was carried out, the analysis was carried out before the planting was done and after the harvesting was carried out. The soil analysis was done on the five treatments in which the spinach was planted, it could be deduced that the soil organic matter, phosphorus, potassium, magnesium, calcium, nitrate and ph of the soil all varied because leaching might have occurred leaving some portion of the land unfertile or weak in nutrients.

After experiment

Treatments	soil organic matter (%)	phosphorus(p) mg	potassium(k) mg	Magnesium(mg) mg	calcium (Ca) mg	Nitrate(N) mg	Ph
Treatment 1	3.5	28	188	313	1802	14	5.1
Treatment 2	3.2	25	201	442	1921	41	5.9
Treatment 3	3.9	33	174	406	2411	18	5.2
Treatment 4	5.5	42	223	396	2114	39	6.4

The soil analysis was carried out the harvesting was done and there was a very clear distinction in the way the nutrients varied as against the analysis carried out before planting was done. The treatment with the combination of biochar and recommended fertilizer (Treatment 4) prove to be more effective in soil enrichment than the treatments with biochar alone and fertilizer alone, this is because biochar is known to act as a good support to fertilizer not only as an soil improver. From the table above, we could also see that the treatment with biochar alone also had a very positive impact on the soil as it improved the soil ph from 5.3 to 5.9, the nitrate also increased from 33mg to 41mg which occurred as a result of the level of nitrogen in the biochar applied to the soil, the calcium level in the soil before application of biochar was 172mg but there was a sharp increase of calcium level after harvesting was done(1921mg), which indicates a positive outcome of the application of biochar to enrich soil.

CONCLUSION

The pyrolsis of saw dust was carried out at different temperatures and holding time, the proximate and ultimate analyses were carried out as well. The saw dust pyrolysed at 350^{0}C prove to have a higher nitrogen value (3.60) which aids in soil enrichment, the carbon content of this biochar is relatively high (72.45) which would deductively help in carbon sequestration. The biochar (350^{0}C) was used on the field on the course of this experiment. The BET, FTIR, CEC, XRD and SEM analysis were done on the biochar to determine its properties. The X-ray diffraction revealed the nature of the biochar to be amorphous and had the presence of elements such as carbon, oxygen, magnesium and potassium, the BET analysis of the biochar clearly indicated that greater surface area of a material was largely dependent on pyrolysis, this large surface area is advantageous to in soil amendment to provide an enabling environment for nutrients and microbials to be easily absorbed and retained for plant growth.

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