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Analysis of Some Selected Wastes Generated from Bioresource Development Centre, Abagana and Environ to Ascertain their Suitability in Biofuel Production

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ABSTRACT

This research investigated the properties of five different wastes to ascertain their suitability in biofuel production. The wastes investigated were: mung beans shell (MB), black beans shell (BB), castor seed shell (CA), African velvet seed shell (AV), and eucalyptus leaf (EU). For comparison, the properties of danta wood (Nesogordonia papaverifera) sawdust were investigated and the results obtained were compared to those of the wastes. The moisture content, volatile matter content, ash content, fixed carbon content and calorific value of the wastes were analysed using standard methods and compared to that of the sawdust. Some selected metals were analysed in the sawdust and the wastes using atomic absorption spectroscopy. The elemental composition of the wastes and sawdust were obtained using EDX. SEM and FTIR analyses of the materials were carried out. The result obtained showed that the moisture content of the wastes (4.912% to 12.427%) was lower than that of the sawdust (31.479%). Ash content of the wastes (6.315 to 17.399) was higher than that of the sawdust (1.070%). black beans shell showed the lowest volatile matter of 8.265%, followed by the sawdust (16.610%) while the volatile matter of other wastes ranged from 22.824% to 28.376%. the fixed carbon content of the sawdust (50.841%) was lower than that of the wastes which ranged from 57.719% to 66.272%. The AAS analysis showed the wastes have higher concentration of metals : Zn (0.3ppm to 0.48ppm), Cu (0.9ppm to 2.2ppm), Fe (6.5119 to 19.115ppm), Mg (5.633ppm to 8.844ppm) K (4.72 to 8.29ppm), Na (3.81 to 5.33ppm), Ca (20.77 to 230.95ppm), Pb (ND to 0.176ppm), Cr (ND to 0.95ppm) than the sawdust Zn (0.048ppm) Cu (0.299ppm), Fe (1.507ppm), Mg (4.713ppm) ,K (2.700ppm), Na(4.345ppm), Ca(23.75ppm) Pb(0.215ppm),Cr(0.780ppm). The elemental composition of the wastes shows low concentration of the elements in the wastes, while SEM result revealed the porous and fibrous nature of the used biomasses. FTIR result revealed the presence of many functional groups in the briquettes. The results of the analysis showed that the analysed wastes can serve as a good feedstock for biofuel production due to the low elemental compositions, low ash content and low moisture content and high fixed carbon but the sawdust will serve as a better qualities. However, incorporating them into sawdust will help improve their qualities.

INTRODUCTION

The conversion of biomasses to biofuel is an important area of interest in the world today. Biomass is a renewable source of energy. According to Onchieku *et al.*, (2012), biomass accounts for about 14% of the total world energy compared to coal (12%), natural gas (15%), and electric energy (14%). Millions of tons of biomasses are generated annually. Due to some agricultural activities going on in some Federal Ministries and Government Agencies in Nigeria like National Biotechnology Development Agency, Bioresource Development Centres and Ministry of Agriculture and engagement of most rural dwellers in agricultural activities, a lot of wastes are being generated annually (Umeocho *et al.*, 2024). Its availability throughout the year at zero cost has made it a good source of renewable energy. Theses wastes, when not managed properly, can be a source of health concern and global sustainability challenge. Adeyi (2010) defined agricultural wastes as all forms of plant-derived or animal-derived material that are considered useless either because they have no known positive economic importance or because they are not grown/raised for any specific purpose. This includes woods, herbaceous plants, crops and forest residues, animal wastes etc. In Nigeria, large quantities of these wastes are produced annually and are vastly underutilised and poorly managed. Proper management of agro waste is important for controlling environmental pollution. Solid wastes, when improperly deposited, can impair the quality and availability of water; contaminate the soil; cause unpleasant odours; and endanger public health (IPCC, 2013, Bond *et al.*, 2013). According to Eze-Ilochi and Oti (2017), when biomass is employed in energy production (briquette formation), the energy consumption and the quality of final product depend on both the properties (chemical and physical) of the biomass and the briquetting processes employed. The intent that led to this research is the need to promote environmental safety, ensure proper management of waste generated in this area, provide alternative source of energy for domestic cooking and barbequing in the area and reduce the tension caused by rising fossil fuel prices especially now that fuel subsidy has been removed by the Nigerian Government.

2. METHOD

The sawdust was sourced from timber shade, Umuokpu Awka. The mung beans seed shell, black beans shell, Castor seed shell and the eucalyptus leaf were sourced from Bioresource production unit and farm. The African velvet seed shell was sourced from a nearby dump site to Bioresources Development Centre, Abagana, Njikoka Local Government area.

2.1 Materials preparation

The materials were air dried for about three weeks to reduce their moisture content, chopped into small sizes and pulverized. They were sieved with a standard laboratory of 2.8 mm mesh sieve to get particle sizes of 2.8 mm. Figure 1 shows the wastes used for the analysis.

a. Mung beans shell b. African velvet shell

c. Black beans shell d. Eucalyptus leave

e. Castor seed shell

Figure 1: Biomasses used for the research

2.2 Digestion of the materials

The materials were digested following the procedures of Eze-Ilochi and Oti (2017). 2.0g of each of the ground samples was weighed into different Teflon crucibles. Then the following were added into each of the crucible: $10cm^3$ of Aqua regia (mixture of HCl and HNO_3 in the ratio of 3:1), $10cm^3$ of water and $5cm^3$ of hydrofluoric acid. The mixture was thoroughly stirred. The crucibles were properly covered and put into an oven set made up to $200cm^3$ mark in a 200ml volumetric flask after cooling. Atomic Absorption spectrometer (AAS) was used in analysing the following metals in the mixtures: Zn, Cu, Fe, Mg, K, Na, Ca, Pb and Cr.

2.3 SEM/EDX

The elemental composition and the morphology of the materials were analyzed using SEM/EDX Phenom pro X Scanning Electron Microscope, at a voltage of 15kV and magnifications of 500 (134µm), 1000 (269µm) and 2000 (537µm).

2.4 Fourier Transform Infra-Red spectroscopy

The FTIR was performed on the wastes to determine the organic components of the materials using Agilent technology FTIR machine, model Cary 630.

2.5 Proximate Analysis

The following analyses were carried out

2.5.1 Moisture Content

The procedure of ASTM E1871-82 (2006) was used in determining the moisture content of the samples. Each 2g sample was carefully measured into different beakers of known weight and kept in an oven at 105^oC for 5hours to enable the sample to dry (to constant weight). The beakers were transferred to a desiccator, allowed to cool to room temperature and weighed. The moisture content was calculated using the following formula:

$$\text{MC} = \frac{initial\ weight\ of\ sample - final\ weight\ of\ sample}{initial\ weight} \text{x}100$$

2.5.2 Volatile matter

The procedure of ASTM E872-82 (2006) was used in determining the volatile matter content of the samples. The residual dry samples from moisture content determination were weighed and heated at 400°C in a furnace for 2 h. The samples were removed from the furnace, cooled and re-weighed. The volatile matter was calculated using

$$\text{VM (\%)} = \frac{W3 - W\,4}{W3} \text{ X } 100$$

W_3= Weight of the residual Sample,
W_4 = weight of the sample after cooling.

2.5.3 **Ash Content**

Determination of Ash Content: Ash content is the measure of total amount of minerals present in substance. It is the measure of the minerals left after an absolute combustion of a briquette. The ash content was determined following the procedure of ASTM E1755-01 (2007). Each 2 g dry sample was measured into different beakers of known weights. The beakers and their contents were placed in a furnace and heated at 590°C for 3 h. Then they were put in a desiccator to cool and weighed. The ash content was calculated using:

$$\text{AC (\%)} = \frac{W5}{W6} \text{ X } 100$$

Where W_5 = weight of ash
W_6 = initial weight of dry sample.

2.5.4 Fixed carbon

The fixed carbon was calculated using the method of Garcia *et al.*, (2012), using the formula

$$\%Fc = 100 - (\%Ac + \%Vm + \%Mc)$$

Where Ac- ash content, Vm = volatile matter, Mc = moisture content.

2.5.5 Calorific Value

An oxygen bomb calorimeter, model XRY-IA was used in determining the calorific values of the raw materials.

3. RESULT AND DISCUSSION

3.1 Metal concentration of the materials.

Table 1 and figure 2 show the metal concentration of the materials. Some heavy metals such as Cu, Zn, Fe and Mn are needed for proper growth of plants Sablok, (2019). However, the presence of heavy metals in high amount in plants can be a source of concern due to their non-biodegradable nature. These heavy metals can as well be a source of pollution when they are presence in biomasses used in energy production. It can be seen from the result of metal concentration that the sawdust had lower concentration of the analysed metals than the biomasses. Calcium was found as a major element in all the materials, while Cr and Pb was found as trace elements in all the materials. MB had Fe and Ca as major elements, Cu, Mg, Ca and Na as minor elements and Zn, Pb and Cr as trace elements. BB had Ca as major element, Na, K, Mg and Fe as minor elements and Zn, Cu, Pb and Cr as trace elements. AV had Ca as major element, Fe, Mg, K, and Na as minor elements and Zn, Cu, Pb and Cr as trace elements. CA had Ca and Fe as major elements, Cu, Mg, K, Na as minor elements and Zn, Pb and Cr as trace elements. EU had Ca and Fe as major elements, Cu, Mg, K and Na as minor elements and Zn, Pb and Cr as trace elements.

Table 1: Metal concentration of the materials.
Mean metal concentration of the materials.

MATERIALS

METALS (PPM)	MB	BB	AV	CA	EU	SAWDUST
Zn	0.33±0.0001	0.48±0.00	0.2932±0.00	0.47±0.00	0.33±0.039	0.04±0.0004
Cu	2.25±0.0001	0.90±0.00	0.6461±0.0001	1.68±0.0011	1.31±0.00	0.29±0.0003
Fe	10.39±0.00	9.05±0.0001	6.5119±0.00	12.08±0.0003	19.11±0.00	1.50±0.00
Mg	7.26±0.0001	7.16±0.0001	5.6334±0.0003	8.84±0.0008	6.55±0.014	4.71±0.0001
K	7.60±0.00	6.96±0.0004	6.9094±0.0004	8.29±0.00	4.72±0.013	2.70±0.0001
Na	4.05±0.0001	3.81±0.00	5.3325±0.0001	4.46±0.00	4.95±0.029	4.34±0.00
Ca	203.95±0.0005	117.36±0.0005	56.2273±0.0004	20.77±0.00	230.61±1.45	23.70±0.00
Pb	0.17±0.0001	ND	0.1769±0.0003	0.69±0.0013	0.91±0.00	0.21±0.0001
Cr	ND	0 .9561±0.00	0.7632±0.00	0.86±0.00	0.85±0.00	0.70±0.0007

MB= MUNG BEANS, BB = BLACK BEANS, AV = AFRICAN VELVET, CA = CASTOR, SEED SHELL, EU = EUCALYPTUS LEAF.

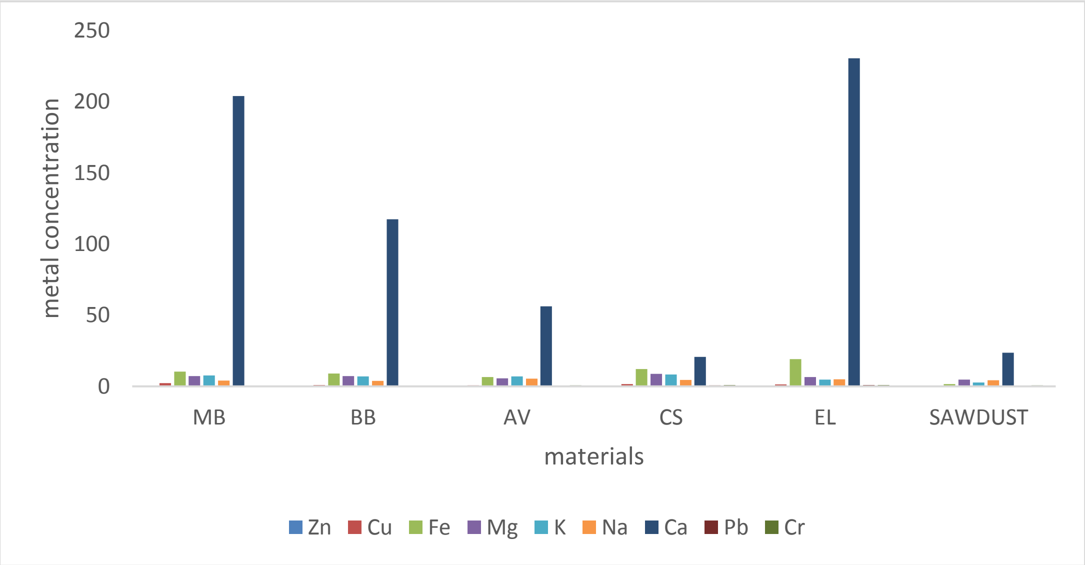

Figure 2: Metal concentration of the materials

Sawdust had Ca as major elements, Fe, Mg, K and Na as minor elements and Zn, Cu, Pb and Cr as trace elements. Ash forming elements like Ca, K, Mg, Na and Fe were found higher in all the biomasses than in sawdust. According to Eze-Ilochi and Oti, (2017) alkali metals will mainly form ash during combustion as they do not undergo complete combustion. It is expected that the biomasses will deposit higher ash content during combustion due to the higher concentration of the metals. Cu, Cr and Pb which are toxic, when released to the environment during combustion and inhaled, were found to be below the permissible limit (10mg/kg for copper, I.3mg/kg for chromium and 2mg/kg for Pb) in both the biomasses and the sawdust, (WHO,1996). Pb, when presence in high concentration in plants can disrupt the functioning of enzymes or pigments in plant tissues by replacing the essential nutrient which will in turn lower crop yield and may lead to stunted growth in such plants (Kushwaha *et al.*,2015). The result of metal concentration of the materials show that they can be used as a feedstock in biofuel production.

The results of the one-way ANOVA test show a p-value of 0.000. This indicates a statistically significance difference in metal concentration among the materials. Thus, further investigation was conducted to identify which of the metals have significantly different concentrations. This was done using the multiple comparison test of Tukey's HSD. The concentration of Zn, Cu, Fe, Mg, K, Na, Pb, and Cr were found to be statistically significantly different from Ca (the mean difference produced p-values less than 0.05 level of significance). However, there were no significant differences observed among the concentrations of other metals across the materials.

3.2 SEM/EDX analysis

Table 2, Elemental composition of the materials

Elements	MB		BB		AV		CA		EU		SAWDUST	
	At conc	wt conc	At conc	Wt conc	At conc	Wt Conc	At conc	Wt conc	At conc	Wt conc	At conc	Wt conc
Carbon	74.89	67.86	87.77	82.94	85.55	80.08	76.48	69.88	90.15	85.71	83.67	79.10
Nitrogen	21.20	22.40	9.67	10.66	11.26	12.29	20.12	21.44	7.30	8.09	13.95	15.38
Potassium	1.38	4.06	0.57	1.76	0.38	1.16	1.12	3.33	0.02	0.07	0.08	0.25
Calcium	0.45	1.35	0.27	0.86	0.22	0.70	0.24	0.74	0.22	0.70	0.00	0.00
Magnesium	0.69	1.26	0.27	0.86	0.24	0.45	0.43	0.79	0.20	0.38	0.22	0.42
Aluminium	0.29	0.60	0.28	0.60	0.27	0.57	0.21	0.44	0.67	1.44	0.30	0.64
Sulphur	0.24	0.57	0.08	0.21	0.14	0.34	0.25	0.60	0.09	0.22	0.34	0.86
Phosphorus	0.22	0.51	0.13	0.32	0.15	0.37	0.42	1.00	0.08	0.21	0.27	0.66
Silicon	0.22	0.46	0.44	0.97	1.30	2.85	0.22	0.47	0.80	1.79	0.38	0.84
Chlorine	0.17	0.46	0.13	0.35	0.10	0.28	0.18	0.48	0.12	0.32	0.42	1.18
Sodium	0.26	0.46	0.22	0.40	0.29	0.53	0.21	0.38	0.17	0.32	0.37	0.67
Titanium	0.00	0.00	0.06	0.23	0.00	0.00	0.03	0.13	0.00	0.00	0.00	0.00
Iron	0.00	0.00	0.00	0.00	0.09	0.39	0.08	0.34	0.17	0.75	0.00	0.00

The elemental composition of the raw materials shows that all the biomasses analysed have high composition of carbon. According to Nasrin *et al.*, (2011), the calorific value of biomass depends on the percentage of carbon and hydrogen which are main contributors to the heat energy value of biomass material. Therefore, energy content or calorific value of the briquettes produced from such biomass may also be determined by this element's composition.

Nitrogen is another element that has high concentration in all the biomasses. Nitrogen is harmless in free form (N_2) but can be a source of worry when combined with oxygen to form any of the nitrogen oxides (NO, NO_2 and N_2O). NO and NO2 are emitted during various combustion processes. NOX contributes to the formation of ozone and particulate matters (SMOG). In combustion of biomass, the NOX formed may depend on the nature of the biomass, the amount of nitrogen present in the biomass and the amount of oxygen available to oxidize nitrogen species.

Sulphur, when present in fuel, can lead to environmental pollution. It is one of greenhouse gasses that can bring about acid rain when released to the atmosphere. It can also expose inhalers to health risk. The result of the sulphur content shows that sulphur is present in the materials at a very low concentration. The result is comparable to the findings of Eze- Ilochi and Oti, (2017) who found the total sulphur content of all the analysed biomasses ranging from BDL to 0.01% except for coal with total sulphur content of 0.6%.

Other ash forming elements such as Al, Fe, K, Mg, P, Na, Mn, Cl, Si and Ti were found to be present in the biomasses in a very small amount (< 1). According to Vassilev, *et al.*, (2012) the presence of ash forming elements at high concentration in biomasses can cause: increased volatilization and formation of many dangerous components, enhanced fine particle emission, high quantity of water-soluble fraction, low ash fusion temperature, high amount of active and low-temperature melts with low viscosity, increased deposit formation, sintering, agglomeration, fouling, slagging. Corrosion and abrasion and other technological, environmental and health problems. The SEM results of the materials are represented in Figure 3 to 8.

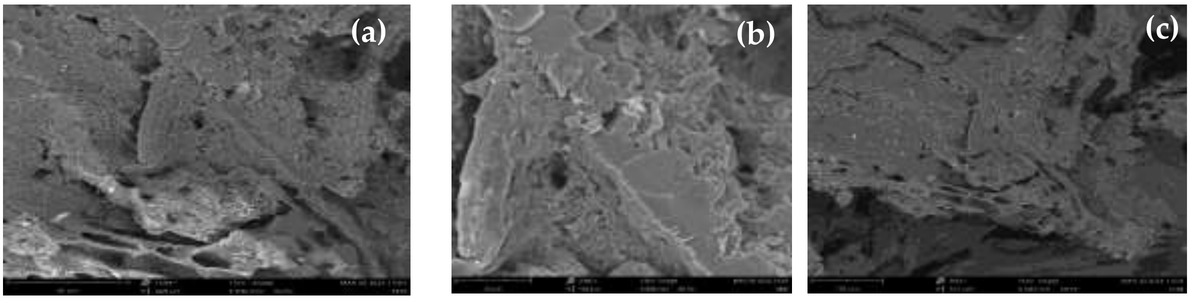

Figure 3: SEM Micrograghs of sawdust (a: SEM image of sawdust at 100µm, b: SEM image of sawdust at 80µm, c: SEM image of sawdust at 30µm)

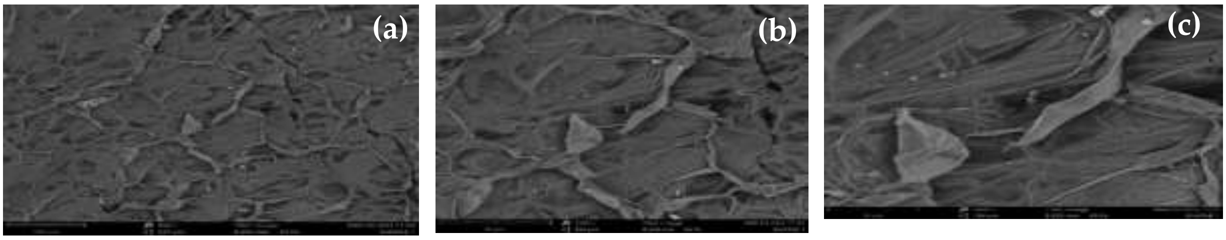

Figure 4: SEM Micrograghs of Mung beans shell (MB) (a: SEM image of MB at 100µm, b: SEM image of MB at 80µm, c: SEM image of MB at 30µm)

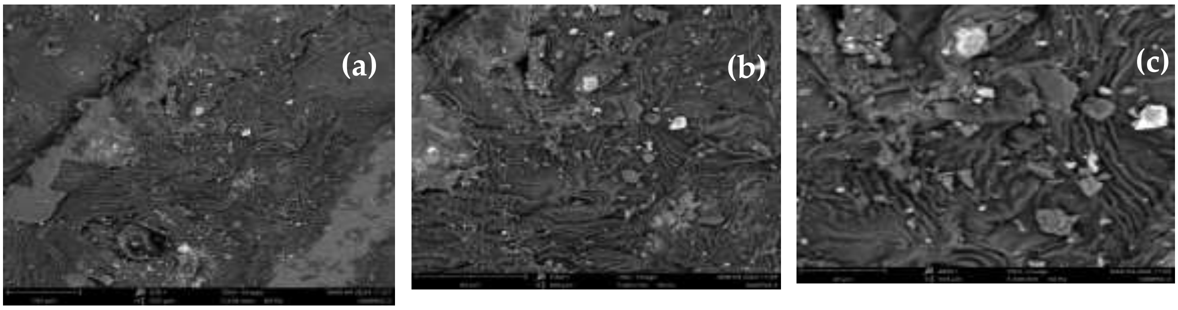

Figure 5: SEM Micrograghs of Black beans shell (BB). (a: SEM image of BB at 100µm Fig 5b: SEM image of BB at 80µm Fig 5c: SEM image of BB at 30µm

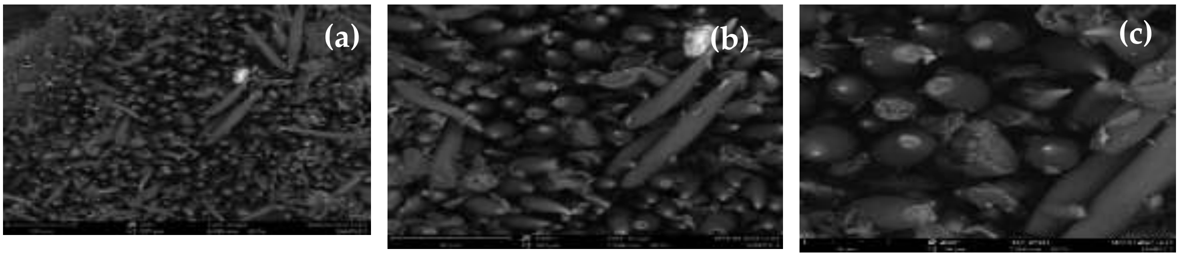

Figure 6: SEM Micrographs of African velvet seed shell (a: SEM image of AV at 100µm Fig 6b: SEM image of AV at 80µm Fig 6c: SEM image of AV at 30µm)

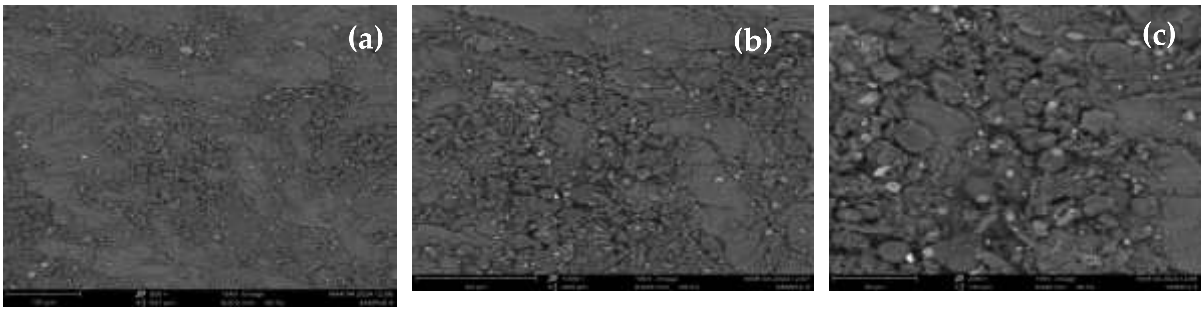

Figure 7: SEM Micrographs of Castor seed shell (a: SEM image of CA at 100µm, b: SEM image of CA at 80µm, c: SEM image of CA at 30µm)

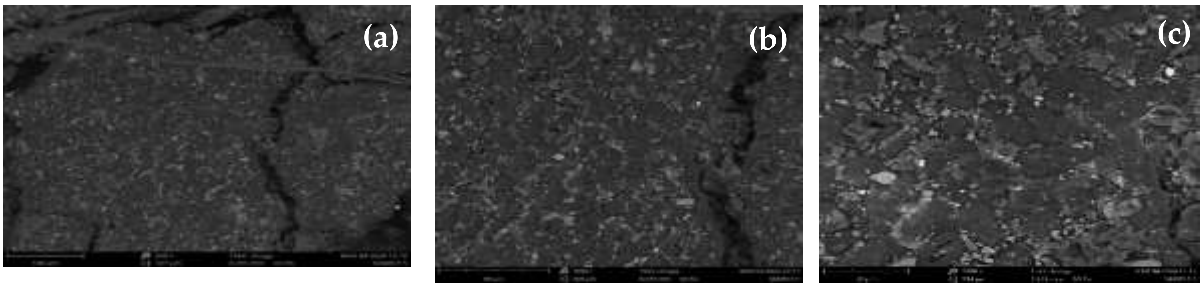

Figure 8: SEM Micrographs of Eucalyptus leaf. (a: SEM image of EU at 100µm, b: SEM image of EU at 80µm, c: SEM image of EU at 30µm)

The morphology of a material is an important factor that significantly influences the physical and chemical properties of the material. The morphology of the biomasses employed in this research were analysed for better understanding of their physicochemical properties. It can be seen from the SEM results (Figures 3a – 8c) that the sawdust has more porous fibres than the other biomasses. African velvet seed shell showed very large granulated particles. Mung beans and black beans shell showed long fibrous lignocellulosic structure. The morphology of castor seed shell showed large granulated structure. The morphology of eucalyptus leave showed short fibrous and coarse structure. All these observed features are typical of biomass. The morphology of the materials helps in predicting their agglomeration properties before briquetting (Jayappa and Narayana, 2012). The SEM image observed for the materials are comparable with the report of Eze-Ilochi and Oti (2017) for Bambara nut shell, wild cassava peel, sugarcane bagasse, groundnut shell, bush mango nut shell and empty fruit bunch, Raju et al., (2014) for sawdust residues, almond leave and coco peat and Jayappa and Narayana, (2012) for castor seed, ground nut shell, sawmill dust and tamarind fruit shell.

3.3 FTIR Results

Table 4 shows that the peaks were more than five for each material showing the materials are not simple organic compounds or inorganic compounds. Akowuah *et al*., (2012) stated that the presence of chemical groups influences the ash content, binding properties and calorific value of agricultural wastes. The analysis detected a peak at 3200 – 3400 which was attributed to O-H intramolecular and intermolecular stretching in lignin, cellulose and hemicellulose (Popescu *et al*.,2007). It was observed in all the materials in except AV. C-H stretch of alkane with peak at 2850 - 3000 was assigned to asymmetrical methyl and methylene stretching in lignin, cellulose and hemicellulose (Popescu *et al*.,2007) and was observed in all the materials except in BB. The peak at 1370 – 1390 was observed in BB and assigned to lignin and hemicellulose asymmetric methyl and methylene stretching (Popescu *et al*.,2007).

The peak at 1750 - 1815 was observed in uncarbonized sawdust, CA and BB and it was assigned to hemicellulose C=O stretching in unconjugated ketone, carbonyl and aliphatic groups. Extractives: C=O stretching in ester carbonyl. (Zhou *et al*., 2015; Zhang *et al*., 2016).

Table 4: The FTIR results of the materials.

100% Us	100%Cs	100% MB	100% BB	100%AV	100%CA	100%EU	FUNCTIONAL GROUP
3332.2	3343	3332	-	3231.2	-	3321.1	Normal polymeric OH stretch
					-	1684.8	Ketones
2888.71	2922.2	2888.7		2922.2	2885.0	2914.8	Alkanes and alkyl. Strong C-H stretch
			1371.7				Methyl C- H asym/sym bend. CH3C-H bend
2840.2	-	2840.2	-	-	2829.1	-	O-H stretch (carboxylic acid)
-	-	2169.3 2064		-	1919.6		Isothiocyanate
-	-	-			1718.3		C=O stretch (ketones)
1725	-	-	1729.5	1707.1	-	-	Aldehyde
1606.5	1580.4	1606.5	1599.0	1591	-	-	C = C -C Aromatic ring stretch
-	1423.8	1412.7	1412.7	-	1513.3	-	Aromatic C-C stretching, deformation of C-H
-	-	-	-	-	1408.9	-	Ar – CH (C-O stretch
					1364.2		Nitro compound
-	-	-	-	-	1241.2	-	Ar – CH (C-O Stretch)
1315.8		1315.8	1319.5	-	1304.6	1315.6	C-H wagging
1028.7	1025.0 1237.5	-	1239.7	1237.5	1028.7	1028.7 1022.9	Aromatic C-O- stretch (esthers)
1099.6	-	-	1095.8	1155.3	-	-	C-O -C stretch, alcohol (ms)
764.1	-	764.1	758	282.7	767.8 816.3	779.0	R-Cl (alkyl halides)
-	-	-	-	-	674.6	-	C-Br
2169	2109.7	-	-	-	-	2102.2 c-=c stretch	Alkynes

The peak at 750 – 850 was observed in all the materials except MB. It was assigned to cellulose Cl – H deformation (Zhang *et al*., 2016). The peak at 1085 – 1150 was observed in uncarbonized sawdust, BB and AV. It was assigned to cellulose and hemicellulose C-O-C stretching, Lignin aromatic C-H in plane deformation (Popescu *et al*., 2007; Traore et al., 2018). The peak at 1020 – 1075 was observed in uncarbonized sawdust, carbonized sawdust, BB, AV, CA and EU. It was assigned to holocellulose and lignin C-O stretching (Zhang *et al*., 2016). The peak at 1000- 1350 was observed in all except carbonized sawdust and AV. It was assigned to CH_2 wagging (Popescu *et al*.,2007; Traore *et al*., 2018). The peak at 1180 – 1260 was observed only in CA. It was assigned to polysaccharides C-O stretch and O-H in plane (Acquah *et al*., 2016). The peak at 1580 – 1615 was observed in uncarbonized sawdust, carbonized sawdust, MB, BB and AV. It was assigned to lignin and extractives aromatic ring vibrations (Zhou *et al*., 2015; Zhang *et al*., 2016).

The peak at 1423 – 1513 was observed in carbonized sawdust, MB, BB and CA. it was assigned to lignin C= O stretching and aromatic skeletal vibration, Carbohydrate CH and OH bending. (Chen et al., 2012, Zhou *et al*., 2015, Funda *et al*., 2020, Popescu *et al*., 2007) The FTIR table showed that different compounds which were initially present in uncarbonized sawdust sample disappeared after carbonization. Kan *et al*., (2016), stated that a lot of reactions, like aromatization, isomerization, dehydration and charring, take place during the carbonization of materials. This implies that carbonization can result to the formation of aromatic structures in the carbonized sawdust. Table 4 shows the presence of aromatic C-C stretch in the carbonized sawdust at 1421. This is in line with the findings of Rana *et al*., (2021) who observed that at increased temperature (400 - 1000), during the carbonization of a biochar, the peaks appeared at (753 -908 and 3040 – 3005) which favoured the formation of aromatic structures. The analysed samples have mutual bands. The observed functional groups in the biomasses are in line with the findings of Ozomadu *et al.*, (2021).

3.4 Proximate analysis

Table 5: Mean proximate analyses results of the materials

PARAMETERS	MUNG BEANS SHELL	BLACK BEANS SHELL	AFRICAN VELVET SHELL	CASTOR SEED SHELL	EUCALYPTUS LEAF	SAWDUST
Mean Mc (%)	7.1796±0.00	8.064±0.007	12.427± 0.035	5.610± 0.060	4.912±0.049	31.479±0.00
Mean Ac (%)	8.255±0.002	17.399±0.01	6.315±0.001	8.295±0.002	8.429±0.002	1.070±0.001
Mean Vm (%)	22.976±0.001	8.265±0.012	22.924±0.01	28.376±0.002	27.330±0.005	16.610±0.01
Mean Fc (%)	61.573±0.000	66.272±0.174	58.334±0.000	57.719±0.000	59.329±0.000	50.841±0.00
Calorific value (MJ/Kg)	18.60±0.00	16.44±0.00	16.91±0.00	17.82±0.00	18.10±0.00	20.30±0.01

KEY: MC= moisture content, AC= Ash content, VM= Volatile matter and FC= Fixed carbon content, CV = Calorific value, MB = mung beans, BB = Black beans, AV = African velvet, CA = Castor seed shell, EU = Eucalyptus leaf.

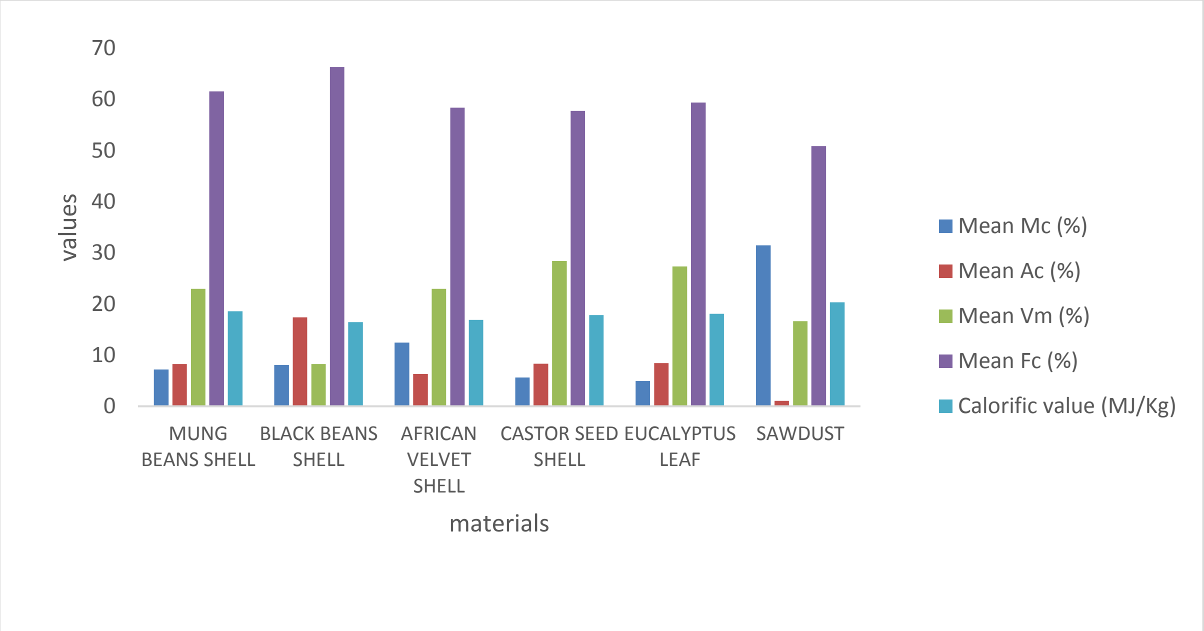

Figure 9: Comparative proximate analysis and calorific value of selected biomass materials. The figure shows the mean moisture content (Mc), ash content (Ac), volatile matter (Vm), fixed carbon (Fc), and calorific value for mung bean shell, black bean shell, African velvet shell, castor seed shell, eucalyptus leaf, and sawdust.

The results showed that the moisture content of the biomasses was 7.1796±0.00% for mung beans shell, 8.064±0.007% for black beans shell, 12.427± 0.035% for African velvet shell, 5.610± 0.060% for castor seed shell, 4.912±0.049% for eucalyptus leaf and 31.479±0.00 for the sawdust. The moisture content of the wastes was lower than that of the sawdust. According to Eze-Ilochi and Oti, (2017), moisture content is an undesirable characteristic as it reduces the energy value of materials. Lower moisture content of the wastes shows that they will serve as a better feedstock for biofuel (briquette) production. Ash content of the biomass was 8.25±0.002% for mung beans shell, 17.39±0.006% for black beans shell, 6.317±0.001% for African velvet shell, 8.29±0.002% for castor seed shell, 8.42±0.005% for eucalyptus leaf and 1.070±0.001% for the sawdust. Ash is a by-product of combustion and therefore is not desired in large quantity. The ash content of a good fuel is expected to be low.

The ash content of the biomass was higher than that of the sawdust. This could be as a result of higher concentrations of the analysed metals in the wastes than in sawdust. Black beans shell showed the lowest volatile matter of 8.265±0.012%, followed by the sawdust (16.610±0.01%) while the volatile matter of other biomass was 22.924±0.00% for African velvet shell, 22.976±0.00% for mung beans shell, 27.330±0.005 for eucalyptus leaf and 28.376±0.002% for castor seed shell. High volatile matter content of the wastes poses them as a good food feed stock for biofuel production. According to Oyelaran and Tudunwada, (2015), the higher volatile matter content of the wastes shows that they will ignite more readily and burn fast. The fixed carbon content of the sawdust was (50.841±0.00%) and was lower than that of the biomass which was 61.57±0.00% for mung beans shell, 66.27±0.174% for black beans shell, 58.33±0.00% for African velvet shell, 57.719±0.00% for castor seed shell and 59.32±0.00% for eucalyptus leaf. Higher fixed carbon is an indication that the wastes will serve as a good feedstock in biofuel production.

Calorific value is an important factor in determining the energy efficiency of a biomass. This can be affected by the moisture content and carbon content of the material (Nasrin *et al.,* 2011). The calorific value was 18.60MJ/kg for mung beans shell, 16.44MJ/kg for black beans shell, 16.91MJ/kg for African velvet shell, 17.82MJ/kg for castor seed shell, 18.30MJ/kg for eucalyptus leaf and 20.30MJ/kg for the sawdust. The higher calorific value of sawdust shows that it will release more heat during combustion than other analysed materials. According to Akpenpuun *et al.,* (2020), the calorific value of briquettes is one of the most influential factors affecting the burning rate of a briquette. The higher the calorific value, the easier and better burning efficiency. An analysis of variance (ANOVA) test was performed to assess the variation in proximate analysis among the materials

The significance level was set at $\alpha = 0.05$. The F-statistic was found to be 58.582, with a corresponding p-value of 0.000. This indicates a statistically significant difference in proximate analysis among the materials. Following the significant findings of the ANOVA test, a multiple comparison test was conducted to identify specific differences between pairs of proximate analysis parameters in various materials. The significance level was set at $\alpha = 0.05$. Any proximate analysis pair with a p-value less than 0.05, indicates significant difference. Significant difference was observed between the following pairs of proximate analysis of the materials: Moisture content and fixed carbon content, Ash content and volatile matter, Ash content and fixed carbon content, Volatile matter and fixed carbon content, and Fixed carbon content and calorific value.

CONCLUSION

The agricultural wastes employed in this research can serve as a good feed stock for biofuel production for domestic cooking owing to their good combustion properties. The metal content and elemental composition of the biomasses contributed to their high ash content. Their metal concentrations were higher than of the sawdust. Low sulphur content and low concentration of other analysed elements in the materials proved them to be eco-friendly FTIR analyses of the materials revealed the presence of many organic compounds in the briquettes which could be the reason for high volatile matter content.

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