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PROXIMATE ANALYSIS OF THE PROPERTIES OF SOME SOUTHWESTERN NIGERIA SAWDUST OF DIFFERENT WOOD SPECIES

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ABSTRACT

In view of the ever increasing costs and the negative environmental impacts of petroleum-based fuels and enormous amount of sawdust generated yearly in southwestern Nigeria. This study was undertaken to assess the suitability of sawdust of different wood species as source of energy by determining their chemical properties via proximate analysis. The results showed that the moisture contents (%MC) of the sawdust samples ranged between 7.92 - 15.96% with Entada gigas and Piptadeniasrum africanum giving the least and maximum, respectively; the ash contents (%Ash) ranged between 0.08% and 5.09% with Triplochoton scleroxylon being the least and Adansonia digitata giving the maximum; the volatile matter contents (%VM) ranged from 9.58% for Entada gigas to 18.44% for Vitellaria paradoxa; and the fixed carbon contents ranged between 77.51% and 93.59% with Funtumia elastic and Triplochiton scleroxylon having the least and maximum, respectively. The chemical properties showed that the sawdust of the different wood species would be suitable as source of energy for energy generation in thermal plants, comparing with those of Nigerian coal species.

Key words: Sawdust**;** wood species; proximate analysis; chemical properties; southwestern Nigeria.

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1. INTRODUCTION

As a result of increasing global concern regarding environmental impacts, especially climate change, from the use of fossils and, the need for an independent energy supply to sustain economic growth and development, there is currently a great deal of interest in renewable energy in general. Odunlami et al. (2018) reported the implications of the use of fossil fuels. McKendry (2002) reported that biomass is one of the most common and easily accessible renewable energy resources and gives opportunity as a feedstock for bioenergy. A wide range of biomass resources-crop residues, wood wastes from forestry and industry, residues from food and paper industries, municipal solid wastes and dedicated energy crops such as short-rotation perennials- can be utilized to generate electricity, heat, and combined heat and power.

Nigeria is endowed with abundant forest reserves, most of which are located in the southwestern part of the country. There has been significant increase in the number of sawmills in this region of the country with Lagos, Oyo, Ogun, and Ondo States having the largest numbers. This is as a result of the need to satisfy the growing demands for wood for building and other construction purposes. There are several species of these forest products (Okedere et al, 2017). Trees from the forests are processed at sawmills to produce construction, building, and furniture materials. After these perceived useful products have been taken, heap of sawdust produced is left behind.

As rightly noted by Stout and Best (2001), a transition to a sustainable energy system is urgently needed for developing countries. Therefore, it is illogical to believe that several kinds of biomass resources, agricultural residues - rice husk, corn stover, cotton stalk, groundnut husk etc - have become one of the most promising choices as fuels due to its availability in substantial quantities as waste annually as reported by Wilaipon (2007) and McKendry (2002). Agricultural residues are to be left on farmlands and allowed to decay to release natural nutrients back to the soil. By this, there will be less use of artificial nutrients that have adverse effects on soil - sustainability in the use of agricultural land. Only sawdust is seen as a waste on sustainable basis if and only if the trees producing are replanted. In Nigeria forest is kept sustainably, hence huge sawdust as a waste annually. Elehinafe et al, (2017) pointed out that Nigeria could invest in generation of energy from this perceived waste instead of indiscriminate burning of sawdust to stop battling with the problem of insufficient energy required to meet the demands of the growing population and economy.

Elehinafe et al. (2017) assessed the comparative suitability of sawdust of different wood species for utilization as energy resource by determining their calorific values. Results showed that the calorific values of the sawdust samples with about 15% moisture content ranged between

11.29 and 26.10 MJ/kg with Irvingia grandifolia and Nauclea diderrichii giving the least and maximum, respectively. Up to 13 of the identified wood species have calorific values between 20 and 26 MJ/kg that are comparable to those of coal and may be adopted as energy resources.

Notably, Oladeji (2010) reported that, if biomass is to be used efficiently and rationally as fuel, they must be characterized by determining it parameters such as the moisture content, ash content, volatile matter, and fixed carbon among others. Therefore, this study assessed the chemical properties of sawdust of wood species in southwestern Nigeria by proximate analysis. It also sought to compare the results with of coal species as reported in the literature.

2. MATERIALS AND METHOD

2.1. Pretreatment of sawdust samples of the different wood species

The samples of the sawdust of 100 wood species investigated were collected at selected sawmills in the cities of southwestern Nigeria. For proper identification, the twigs of the parent trees were taken to the herbarium of Botany Department, Obafemi Awolowo University, Ile-Ife, Nigeria. The sawdust samples were properly sun-dried until the moisture contents were low enough in the range of 10 to 16 %, appropriate moisture levels for solid fuel, as recommended by ASTMD2016-25 (Debdoubi *et al*., 2004). Enzymatic treatment was not needed as shown in Ayeni et al., (2018).

2.2. Determination of the properties of the sawdust samples by proximate analysis

The targeted properties of the sun-dried sawdust samples are: moisture contents, ash contents, volatile matter contents and fixed carbon contents in percentages. Moisture contents, ash contents, and volatile matter contents were experimentally determined in Obefemi Awolowo University, while fixed carbon contents were calculated by difference (Debdoubi *et al*., 2004).

2.3. Determination of moisture contents of the sawdust samples

The SG91 Gallenkamp oven in Obefemi Awolowo University was used to determine the moisture contents of the sawdust of the wood species. The sawdust samples were pre-weighed in two test pieces of 2 g each, with an AB54-S Metler Toledo balance. The oven was set at a controlled temperature of 105^{o}C and the pre-weighed samples were made to undergo drying for 10 minutes as recommended by ASTMD2016-25 (Debdoubi *et al*., 2004). They were removed and allowed to cool in a desiccator. The heating and cooling were repeated until constant weights were achieved. The moisture contents were calculated using equation 1.

$$\%MC = \left(\frac{M_i - M_f}{M_i}\right) x\ 100\% \quad (1)$$

where,

M_i = initial weight of the sawdust sample (before drying)

M_f = final weight of the fuel wood sample (after drying)

2.4. Determination of ash contents of the sawdust samples

The BF51314C Box Muffle Furnace in Obefemi Awolowo University was used to determine the ash contents of the sawdust samples. The samples were pre-weighed in two test pieces of 2 g each with an AB54-S Metler Toledo balance. The ash content is the residue after a sawdust sample has been burnt. This was determined using ASTMD-5142 procedure as recommended reported by Debdoubi *et al*. (2004). The pre-weighed samples were burnt in a muffle furnace at 550 ± 25 ^{o}C for 4 hours. They were removed and allowed to cool in a desiccator to obtain the weight of the ash. The final weights of the samples were taken with the aid of AB54 Mettler Toledo analytical balance. The ash contents were calculated by equation 2.

$$\%Ash = \left(\frac{W_f}{W_i}\right) x\ 100\% \quad (2)$$

where,

W_i = initial weight of the fuel wood sample (before burning)

W_f = final weight of the fuel wood sample (after burning)

2.5. Determination of volatile matter contents of the sawdust samples

The BF51314C Box Muffle Furnace in Obefemi Awolowo University was also used to determine the volatile matter of the sawdust samples. The samples were pre-weighed in two test pieces of 2 g each, with an AB54-S Mettler Toledo balance. The volatile matter is the condition of the material at which when heated in the absence of air under prescribed condition, liberated as gases and vapours. The volatile matters were determined based on the procedure recommended in ISO562/1974 (Debdoubi *et al*., 2004). The pre-weighed samples were made to undergo dry oxidation in muffle furnace at 550 + 25 °C for 10 minutes. They were then removed and allowed to cool in a desiccator. This was repeated one more time and allowed to cool in desiccator. The final weights of the samples were taken with the aid of Mettler Toledo analytical balance. The volatile matters were calculated as given by equation 3.

$$\%VM = \left(\frac{Z_i - Z_f}{Z_i}\right) x\ 100\% \qquad (3)$$

where,

Z_i = initial weight of the fuel wood sample (before dry oxidation)

Z_f = final weight of the fuel wood sample (after dry oxidation)

2.4. Determination of the fixed carbon contents of the sawdust sample

The fixed carbons of the sawdust samples were determined by using the following relationship (Debdoubi *et al*, 2004) as shown in equation 4.

$$\%FC = 100\% - \%Ash - \%VM \qquad (4)$$

where,

%Ash = determined ash contents

%VM = determined volatile matters

3. RESULTS AND DISCUSSIONS

One hundred (100) different sawdust samples from 100 different wood species were sourced and identified to know their botanical names. The results of the properties of the sawdust samples by proximate analysis are presented in Table 1. The properties of the sawdust samples were limited to moisture contents (MC), volatile matter contents (VM), ash contents (Ash) and fixed carbon contents (FC) in percentages. The results presented were also discussed.

The results showed that the sawdust samples have far lower %MC (7.92 - 15.96%) compared to those of Nigerian coal species which have %MC of between 32.5 to 42.7% (Ugwu, 2012). The study of Yang *et al.* (2005) proved that moisture content is a very significant property which can adversely affect the burning characteristics of solid biofuels. Aina *et al.* in 2009 also reported that, moisture content is one of the main parameters determining solid biofuels quality for lower moisture contents implies higher calorific value. Moisture content affects both the internal temperature history within the solid, due to endothermic evaporation, and the total energy that is needed to bring the solid up to the pyrolytic temperature (Zaror and Pyle, 1982). From Table 1, moisture contents of the sawdust samples ranged between 7.92 % and 15.96%. They all belong to the category of low moisture fuels (~6% to 16%) meaning that they would be suitable as fuels for energy generation (Parmar *et al*., 2008). Sun-drying of the identified sawdust samples before the determination of their %MC could make them to fall under the category of low moisture fuels.

The investigated sawdust samples of the different wood species have lower %VM which ranged between 9.58 and 18.44% when compared to that of coals whose %VM ranged between 32.5 and 42.7% (Ugwu, 2012).Volatile matter represents the constituents of hydrogen oxygen and carbon present in a solid biomass that when heated change to vapour, usually a mixture hydrocarbons (Chaney, 2010). Volatile matter content has been proven to affect the thermal characteristic of solid fuels (Van and Koppejan, 2008) and this is also influenced by the structure and bonding within the solid fuel. As reported by Chaney (2010) that, low-grade fuels, such as dung, tend to have a low volatile content resulting in smouldering combustion which De Souza and Sandberg (2004) found as a heterogeneous flameless combustion process which occurs on the surface or within the porous solid fuel. They went further to state that, it results in incomplete combustion which gives rise to significant amount of smoke and toxic gases being emitted.

Ash is the non-combustible component of biomass. The sawdust samples had lower %Ash (0.08% to 5.09%) than those of Nigerian coal species whose %Ash ranged from 3.9% to 26.0 % (Ugwu, 2012). Livingston (2005) demonstrated that heating values are negatively related to ash content, with every 1% increase in ash concentration decreasing the heating value by 0.2 MJ/kg. In addition, the ash and its inorganic elements produced during combustion may cause a number of problems to the power plants through slagging, corrosion, and fouling (Monti *et al*., 2008). In their study, Kim *et al.* (2001) showed that ash has a significant impact on the heat transfer to the surface of the fuel, as well as the diffusion of oxygen to the solid fuel surface during char combustion. The values of ash content observed in this study are good and acceptable. Loo and Koppejan (2008) reported that, the higher the fuel's ash content, the lower its calorific value.

Table 1 Properties by proximate analysis of wood species in Southwestern Nigeria

S/N	Botanical Name	%MC	%Ash	%VM	%FC_
1	*Albizia gummifera*	11.03	1.95	12.64	85.41
2	*Pterygota macrocarpa*	10.01	2.52	10.76	86.72
3	*Irvingia grandifolia*	10.63	1.59	12.33	86.08
4	*Crassocephalum biafrae*	9.32	0.20	11.99	87.81
5	*Daniella oliveri*	10.61	0.63	12.33	87.04
6	*Parkia biglobosa*	10.29	2.37	11.28	86.35
7	*Daniella ogen*	9.93	0.82	10.90	88.28
8	*Cola acuminata*	12.08	3.25	14.04	82.71
9	*Bambusa vulgaris*	9.43	1.65	12.73	85.62
10	*Entada gigas*	7.92	5.09	9.58	85.11
11	*Ficus thionningii*	11.45	0.60	14.29	85.11
12	*Uapaca heudelotii*	10.22	2.07	13.00	84.93
13	*Symphonia globulifera*	12.50	1.22	13.59	85.19
14	*Cola millenii*	11.86	4.45	12.29	83.26
15	*Prunus dulcis*	9.29	0.98	13.27	85.75
16	*Entandrophragma cylindricum*	15.09	3.58	17.55	78.87
17	*Irvingia excelsa*	10.27	2.08	15.09	82.85
18	*Milicia excels*	10.58	0.38	13.49	86.13
19	*Delonix regia*	14.02	4.98	18.78	76.24

20	*Ficus carica*	9.51	1.59	11.77	86.64_
21	*Astonia boonei*	12.15	0.95	13.11	85.94
22	*Newbouldia laevis*	11.75	1.26	13.32	85.42
23	*Cassia fistula*	12.99	4.33	14.28	81.39
24	*Brachystegia leonensis*	10.57	3.01	14.99	82.00
25	*Musanga cecropiodes*	11.03	0.60	12.65	86.75
26	*Asteromyrtus symphyocarpa*	9.51	1.02	10.95	88.03
27	*Poga oleosa*	10.06	3.09	15.05	81.86
28	*Tectona grandis*	11.39	3.95	13.11	82.94
29	*Pycananthus angolensis*	9.39	0.60	10.80	88.60
30	*Gmelina arborea*	14.98	0.97	18.00	81.03
31	*Parkia biglobasa*	11.32	0.08	16.59	83.33
32	*Anthocleista vogelii*	10.26	1.50	11.95	86.55
33	*Afromosia elata*	8.63	2.28	9.75	87.97
34	*Isoberlina doka*	10.48	1.70	12.94	85.36
35	*Mitragyna ciliata*	13.90	3.02	15.54	81.44
36	*Blighia sapida*	12.12	1.21	12.98	85.81
37	*Nauclea diderrichii*	9.52	0.36	10.48	89.16
38	*Cissus adenopoda*	10.19	0.74	12.47	86.79
39	*Antrocaryon micraster*	11.91	0.60	14.42	84.98
40	*Garcinia kola*	11.09	1.01	14.01	84.98
41	*Lecaniodiscus cupanioides*	10.63	0.94	12.96	86.10
42	*Nesorgodonia paparivera*	10.46	0.50	13.34	86.16
43	*Erythrophylium sp.*	12.10	3.03	12.28	84.69

Table 1 Properties, by proximate analysis, of wood species in Southwestern Nigeria (Cont'd)

S/N	Botanical Name	%MC	%Ash	%VM	%FC
44	*Khaya ivorensis*	10.10	1.03	10.46	88.51
45	*Ficus mucuso*	8.90	3.01	17.48	79.51
46	*Anogeissus leiocarpus*	11.41	0.42	12.94	86.64
47	*Chrysophyllum africanum*	10.60	4.00	16.18	79.82
48	*Pterocarpus erinaceus*	14.23	0.81	11.08	88.11
49	*Adansonia digitata*	9.44	5.09	12.22	82.75
50	*Vitellaria paradoxa*	10.49	0.38	18.44	81.18
51	*Mangifera indica*	15.61	0.70	12.52	86.78
52	*Cylicodiscus gabunensis*	11.01	1.01	11.48	87.51
53	*Antiaris Africana*	10.08	2.70	11.64	85.66
54	*Triplochoton scleroxylon*	10.90	0.08	6.33	93.59
55	*Hildegardia barteri*	9.58	0.59	12.66	86.75
56	*Hymenocardia acida*	10.22	1.12	14.21	84.67
57	*Gliricidia sepium*	12.54	0.98	11.27	87.75
58	*Diospyros crassiflora*	10.58	3.02	15.05	81.93
59	*Terminalia ivorensis*	13.10	2.57	13.00	84.43
60	*Spondias mombin*	11.04	1.63	11.29	87.08
61	*Pterocarpus osun*	10.53	4.10	13.95	84.61
62	*Bombax buonopozense*	8.95	2.42	16.83	83.63
63	*Chasmanthera dependens*	13.09	0.94	13.43	82.23
64	*Mansonia altissima*	10.36	1.79	12.17	84.78
65	*Napoleona vogelii*	10.15	2.07	11.59	85.76

66	*Pinus ponderosa*	11.01	0.66	11.03	87.75
67	*Citrus limon*	10.44	2.71	17.47	86.26
68	*Funtumia elastic*	15.24	5.02	13.01	77.51
69	*Quecus robur*	12.00	0.40	12.48	86.59
70	*Terminalia glaucescens*	10.73	1.90	10.77	85.62
71	*Swieteni sp.*	9.80	2.14	18.77	87.09
72	*Citrus aurantifolia*	14.32	0.52	13.46	80.71
73	*Bytraria marginata*	11.58	1.10	11.74	85.44
74	*Azadirachta indica*	10.61	0.93	10.20	87.33
75	*Macaranga barteri*	10.02	1.08	10.07	88.72
76	*Sterculia rhinopetala*	8.40	2.30	14.44	87.63
77	*Berlinia grandifolia*	12.64	2.87	11.88	82.69
78	*Bombax ceiba*	10.34	0.55	11.27	87.57
79	*Theobroma cacao*	11.14	0.19	13.03	88.54
80	*Terminalia superb*	10.47	0.78	13.95	86.19
81	*Lovoa trichlioides*	10.25	1.10	11.67	87.23
82	*Citrus medica*	14.13	2.00	17.10	80.90
83	*Percuguaria daemia*	10.44	0.79	12.63	86.58
84	*Zanthozylum leprieuril*	11.43	2.96	13.20	83.84
85	*Elaeis guinensis*	10.04	0.60	11.07	88.33
86	*Citrus paradise*	8.60	0.69	11.10	88.21
87	*Ricinodendron heudelotti*	10.50	0.99	12.39	86.62

Table 1 Properties, by proximate analysis, of wood species in Southwestern Nigeria (Cont'd)

S/N	Botanical Name	%MC	%Ash	%VM	%FC
88	*Raphia Africana*	16.04	2.45	17.88	79.67
89	*Phoenix dactylifera*	10.22	0.45	11.09	88.46
90	*Hevea brasiliensis*	10.94	0.24	12.11	87.65
91	*Cocos nucifera*	15.04	1.70	16.37	81.93
92	*Strychnos spinosa*	10.60	0.11	11.13	88.76
93	*Ceiba pentandra*	10.04	2.55	11.00	86.45
94	*Piptadeniasrum africanum*	15.96	0.61	17.04	82.35
95	*Cordia milleni*	10.61	0.51	10.85	88.64
96	*Cola nitida*	11.12	3.10	12.18	84.72
97	*Cleistopholis patens*	9.28	0.93	11.11	87.96
98	*Strombosia pustulata*	11.03	0.49	12.15	87.36
99	*Artocarpus altilis*	11.43	0.64	15.70	83.66
100	*Anacardium occidentale*	10.04	1.20	11.33	87.47

The sawdust samples had higher %FC which ranged between 77.51% and 93.59%. The sawdust samples had higher %FC than those of Nigerian coal species which ranged between 20.0% and 46.3% (Ugwu, 2012).The fixed carbon of a fuel which is the percentage of carbon available for char combustion. This is not equal to the total amount of carbon in the fuel (the ultimate carbon) since an amount is released as hydrocarbons in the volatiles. Characterization methods have been developed for solid fuels and it was discovered that chemical energy is stored in the fuels in two forms including fixed carbon and volatiles (McKendry, 2002). This study showed that biomass store chemical energy more in form of fixed carbons than volatiles. Fixed carbon gives a rough estimate of the heating value of a fuel and acts as the main heat generator during burning. Compared with coals, biomass is characterized by higher fixed carbon contents which are the main heat generator (Obernberger *et al*., 2006). The more the fixed carbon a fuel contains the more reactive the fuel indicating that biomass is easier to ignite and burn (Lewandowski and Kicherer, 2010) compared with coal types.

4. CONCLUSIONS

The findings of this study have shown that, sawdust samples of different wood species would make good biomass fuel. The proximate characteristics of the sawdust samples assessed in this study showed that the sawdust samples have low moisture contents, low ash contents high fixed carbon contents. There is also an indication that, the sawdust is environmental friendly and will help reduce the health hazard associated with the use of fuel wood and reduce deforestation. The survey has revealed that sawdust of different wood species usually generated in large quantities in saw-mills in Nigeria and usually burned as waste can be converted into fuel used domestically and industrially for energy and heat generation.

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