Nigerian Research Journal of Engineering and Environmental Sciences 5(1) 2020 pp. 340-353

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Characterization and Evaluation of Energy Potential and Combustion Emissions of Tropical Wood Wastes at Sawmill Dumpsites

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ARTICLE INFORMATION

Article history:
Received 19 Feb, 2020
Revised 10 Apr, 2020
Accepted 14 Apr, 2020
Available online 30 June, 2020

Keywords:
Characterization
Energy
Combustion
Emissions
Wood waste

ABSTRACT

Sawmill dumpsites are characterised by combustion of wood wastes which pollutes the environment. In this study, five tropical species of wood wastes were collected from sawmill dumpsites in Asaba Metropolis and used for experimental analysis. The samples were chopped into particle sizes of 0.3 to 0.5 micrometres and analysed in accordance to ASTM standards. The analyses include the calorific value (CV), proximate and ultimate analyses. Data generated from the analyses was used to evaluate the potential carbon iv oxide (CO_2) and sulphur iv oxide (SO_2) emissions. From the results, it was observed that the wood samples can be used for energy purposes due to high CV ranging from 30,516.81 kJ/kg to 30,738.38 kJ/kg. The proximate analysis showed low moisture content of 7.26% to 7.70%. The ash content ranged from 0.76% to 1.92%, The ultimate analysis showed high carbon content which validated the results of the calorific value. The SO_2 level from the combustion analysis ranged from 0.08% to 0.10%. This result revealed that the wood samples can be used for boiler applications. The combustion evaluation analysis showed that CO_2 emission to the atmosphere ranges from 18.87% to 23.60% for dry basis analysis. These results revealed that wood waste is still preferable than burning fossil fuel because CO_2 emissions from wood waste is offset by growing trees.

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1. INTRODUCTION

The abundant biomass resources, specifically wood chips, wood pellets in Nigeria could become a cheap renewable energy resource. Dosunmu and Ajayi (2002) reported that wood pellets and wood chips have substantially higher fuel heat content per dollar compared to many fossil fuels. Biomass is a renewable energy resource that occurs naturally. It may be harvested without significant depletion if properly managed.

In Nigeria, logging activities in the forests and wood processing at the various wood processing industries generate a huge volume of wood wastes annually across cities in the country. The figure for wood wastes generated from Nigerian sawmills was reported to be about 5.2 million tonnes per year (Dosunmu and Ajayi 2002).

Akinola and Fapetu (2015) reported that biomass resources are in different forms but wood is adjudged the most common. In Richard et al. (2002) and Baskar et al. (2012), energy generation and utilisation from wood waste were reported to enhance economic development, encourage green economy and gradually replace the use of fossil fuel such as coal, gasoline, natural gas and oil for energy purposes. According to Ogwu et al. (2014), the conversion of wood wastes through the process of briquetting will go a long way in reducing waste disposal problems in majority of the wood processing industries such as the sawmills. El-Saeidy (2004) in his study also proposed the transformation of loose biomass (i.e. wood waste generated at sawmills) into briquettes as an effective way to solving issues associated with open burning at sawmills. He further reported that briquetting would contribute towards the promotion of energy from waste wood while mitigating environmental degradation. Bourguignon (2016) stated that rather than open burning, these wastes can be converted to useful energy such that heat is generated for power (electricity), hot water for heating and cool media for cooling.

Duncan (2017) in his research stated that in recent years, the use of waste wood for heat and electricity generation has rapidly grown. Wood waste is everywhere both in developed and developing countries. Tropical wood wastes are abundant in Nigeria. These wastes are generated in sawmills and are openly burned. Gases emitted during open burning (combustion) at sawmill are greenhouse gases (Bourguignon 2016). These include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Duncan (2016) further reported that the supporters of wood waste suggest that it represents a relatively economical and easy way of supplying renewable energy which is beneficial to the forest industries and to global climate. Aina (2016) also stated that biomass energy such as wood waste can reduce the net emissions of carbon dioxide and other greenhouse gases. However, to its critics, wood waste emits more greenhouse gases during combustion than the fossil fuel which it intends to replace. Furthermore, it is worthy of note that in Nigeria, the knowledge and application of wood wastes as an energy generation source is still at a very low level compared to other developing and developed countries. Akhator et al. (2017) reported that while wood species such as spruce and willows on account of their energy content and properties are specially grown, and harnessed for energy generation in most parts of Europe, the same cannot be said of Nigeria as salient information on the type of wood species in the country for energy production are not known.

Consequently, this study intends to characterize the five tropical wood wastes in terms of their calorific value and their physico-chemical properties from sawmills in Asaba, Delta State, Nigeria. The results from the physico-chemical properties will be used to evaluate the combustion CO_2 and SO_2 emissions from the wood wastes. This is aimed at providing valuable information on energy potential of wood waste species in Asaba that will aid in formulating long term policies, and plan effective ways of exploiting and utilizing wood waste for energy generation.

2. MATERIALS AND METHODS

2.1. Material Collection

Five different samples of wood wastes samples were collected from sawmill dumpsites in Asaba Metropolis, Nigeria. These samples are Yukumo, Danta (*Nesogordonia kabingaensis*), Alstonia (*Alstonia scholaris*), Afara (*Terminalia superba*) and Okwen (*Brachystegia nigerica*).

2.2. Material Preparation

After collection of the samples, they were sundried for 3hrs and thereafter chopped into a particle of 0.3 to 0.5 micrometre. The prepared samples were used for the experimental analysis.

2.3. Analysis

Analyses were carried out in accordance to ASTM standards. The analyses include the calorific value, moisture content, proximate and ultimate analyses. ASTM-D 4442, for direct moisture content, ASTM-E 872, for volatile matter, and ASTM-E 1755, for ash content in wood samples were used. Data generated from the analyses was used to evaluate the possible CO_2 emissions that emanates from the combustion of the wood waste samples.

2.3.1. Calorific value

The calorific value of the wood samples was determined using an oxygen bomb calorimeter. Equation 1 was used to calculate the calorific value of the samples.

$$\mathrm{CV}\left(\frac{\mathrm{kJ}}{\mathrm{kg}}\right) = \frac{\mathrm{E\Delta T - \Phi - V}}{\mathrm{g}} \quad (1)$$

Where, E = Energy equivalent of the calorimeter = 13,039.308 (kJ/^{o}C), ΔT = Change in temperature (^{o}C), Φ = 2.3 × length of burnt wire (kJ), g = mass of sample (kg), V = volume of alkali in calorimeter (kJ)

2.3.2. Moisture content

The formula used for determining the moisture content is given in Equation 2.

$$\%\ \mathrm{MC} = \frac{(\mathrm{g-x})}{\mathrm{g}}\, x\ 100 \quad (2)$$

Where g = Weight of sample, x = Weight of dry matter and (g – x) = Loss in weight

2.3.3. Proximate analysis

The proximate analysis carried out consists of the ash content, volatile matter as well the fixed carbon. The formulas used for determining the constituent of the proximate analysis are as follows:

$$\%\ \mathrm{Ash} = \left(\frac{\mathrm{x}}{\mathrm{g}}\right) x\ 100 \quad (3)$$

Where, g = weight of sample and x = weight of ash

$$\%\ \mathrm{Volatile\ matter} = \left(\frac{\mathrm{x-y}}{\mathrm{g}}\right) x\ 100 \quad (4)$$

Where, g = weight of sample, x = Weight of dry matter and y = Weight of residue

$$\%\ \mathrm{Fixed\ carbon} = 100 - \ (VM + Ash + MC) \quad (5)$$

2.3.4. Ultimate analysis

The ultimate analysis provides information on the elemental chemical constituents of the samples such as carbon, hydrogen, oxygen, nitrogen and sulphur. This analysis helps to determine the quantity of air required for complete combustion, the volume and composition of combustion gases and heat of combustion of the wood samples which depends primarily on its carbon and hydrogen content. Ultimate analysis was carried

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out using specialized laboratory equipment, such as carbon, hydrogen, nitrogen, sulphur (CHNS) analyzers. This analysis was carried out at the Energy Research Centre, University of Nigeria, Nsukka. The formula used for determining the constituent of the ultimate analysis is according to Jenkins et al., (2008).

$$\% \text{ Carbon} = \frac{(B-T)\times M\times 0.003\times 100\times 1.33)}{g} \quad (6)$$

Where, B = Blank Titre, T = Sample Titre and g = Weight of sample

$$\% \text{ Nitrogen} = \frac{(\text{T xMx0.014xDF})}{\text{g}} x\ 100 \quad (7)$$

Where, M = molarity of the acid used, g = Weight of sample, T = Titre value and DF = Dilution factor

$$\% \text{ Sulphur} = \frac{\text{x}*0.1373}{\text{g}} x\ 100 \quad (8)$$

Where, g = weight of sample and x = weight of $BaSO_4$

$$\% \text{ Hydrogen} = \frac{\text{wt of H2O} \times 0.1119 \times 100}{\text{wt of pellet}} \quad (9)$$

Where 0.1119 is a constant derived from empirical equation in Leibig-Pregle method (Onochie et al., 2017)

$$\% \text{ Oxygen} = 100 - (\text{ C} + \text{H} + \text{N} + \text{S} + \%\text{ Ash}) \quad (10)$$

2.4. Combustion Performance

In determining the combustion of the wood waste samples, the chemical formula is required. Since each of the wood samples contains the carbon, hydrogen, oxygen, nitrogen and sulphur, then the chemical formula for the wood samples will be $C_a H_b O_c N_d S_e$. The combustion analysis was determined using Equation (11).

$$C_a H_b O_c N_d S_e + x O_2 + x (79/21)\ N_2 \longrightarrow pCO_2 + qH_2O + rSO_2 + sN_2 \quad (11)$$

3. RESULT AND DISCUSSION

3.1. Calorific Value

The result of the characterization and combustion analysis are presented in Figure 1. It was observed that the wood samples have high calorific value ranging from 30,516.81 kJ/kg to 30,738.38 kJ/kg. Listing the wood samples in ascending order of their calorific values are Yukumo < Danta (*Nesogordonia kabingaensis*) < Alstonia (*Alstonia scholaris*) < Afara (*Terminalia superba*) < Okwen (*Brachystegia nigerica*). The high calorific value showed that wood samples can be used for heating purposes such as application in boilers for processing. This result agrees with the observations of Huhtinen (2009) who reported that the calorific value of wood does not vary much from one species to another.

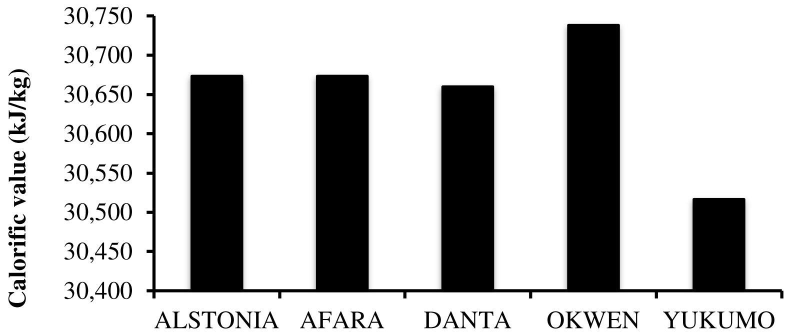

Figure 1: Calorific value of wood samples

3.2. Proximate Analysis

The result of the proximate analysis is graphically represented in Table 1. The percentage moisture content of the various wood samples showed that Okwen has the lowest moisture content and Danta wood sample has the highest moisture content. However, the result varies from 7.26% to 7.70% moisture content. According to Bureau of Energy Efficiency as reported in Onochie et al. (2017), good moisture content ranges between 8-12%. Hence, considering the low percentage moisture content of the fuel wood samples, it is established that these wood waste samples can be utilized for energy purposes. In Brammer and Bridgwater (2002) as reported by Huhtinen (2009), relatively low moisture content favours thermo-chemical conversion because high moisture content reduces the conversion systems efficiency and also reduces the energy content of wood wastes during combustion. Yang et al. (2005) reported that heat would be required to vaporize the moisture content. The high percentage volatile matter of the wood samples ranged from 89.46% to 90.09%. This showed that there would be ease of ignition during combustion of the wood waste. Olsson et al., (2005) and Holt et al., (2006) reported that the higher the proportion of volatile matter, the more suitable is the wood waste for thermal conversion. Again, the percentage ash content as presented showed that the fuel wood samples have low ash content which was between 0.76% and 1.49%. The percentage ash content as reported in Bureau of Energy Efficiency, recommended 5 to 40 percent for boilers (Onochie et al., 2017). In order words, it is suitable even in boiler application. In Loo and Koppejan (2008) it was reported that the higher the ash content in a fuel the lower its heating value. The fixed carbon also ranged from 1.66% to 1.85%. Similar ranges of percentage volatile matter, ash content and fixed carbon have been reported for several wood species by Akinola and Fapetu (2015) and Akhator et al. (2017).

Table 1: Proximate analysis of samples

Wood samples	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)
Alstonia	7.37	1.04	89.74	1.85
Afara	7.29	1.92	89.09	1.7
Danta	7.7	0.76	89.77	1.77
Okwen	7.26	0.95	90.09	1.7
Yukumo	7.39	1.49	89.46	1.66

3.3. Ultimate Analysis

The ultimate analysis of the wood samples is presented in Table 2. The result in Table 2 showed that the percentage sulphur of the wood waste samples was generally low ranging from 0.08% to 0.10%. The carbon content of the fuels also validates the results from the calorific value analysis. It was also observed that the wood samples contained low percentage nitrogen and sulphur contents as required by DIN 51731 (1996).

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This imply that very low levels of NO_x and SO_x will be emitted if the wood wastes are used in thermal conversion processes.

Table 2: Ultimate analysis of the wood samples

Component	Wood sample				
	Alstonia	Afara	Danta	Okwen	Yukumo
Carbon (%)	47.08	45.49	46.16	46.94	42.28
Nitrogen (%)	0.55	0.46	0.38	0.46	0.45
Sulphur (%)	0.10	0.08	0.08	0.10	0.08
Hydrogen (%)	4.76	4.59	4.62	4.73	4.18
Oxygen (%)	40.14	42.09	41.06	40.51	45.62

3.4. Chemical Analysis of Samples

From the results of the ultimate analysis in Table 2, the equivalent chemical composition [$C_a H_b O_c N_d S_e$] by mass of each of the wood samples was determined. Thus, data containing the various elements (carbon, hydrogen, oxygen, nitrogen and sulphur) was used to evaluate the unknown variables (a, b, d, e and f) so as to determine the chemical formula of each sample.

3.4.1. Chemical formula of Alstonia wood sample

i. *For Carbon:*
   $12a = 47.08$; $a = 3.9233$
ii. *For Hydrogen*:
   $1b = 4.76$; $b = 4.76$
iii. *For Oxygen*:
   $16d = 40.14$; $d = 2.50875$
iv. *For Nitrogen:*
   $14e = 0.55$; $e = 0.0392$
v. *For Sulphur*:
   $32f = 0.10$; $f = 0.003125$

Therefore, the chemical formula of the Alstonia wood sample is $C_{3.9233} H_{4.76} O_{2.50875} N_{0.03923} S_{0.003125}$. The calculation for Afara, Danta, Okwen and Yukumo wood samples are same as above and their chemical formulas are $C_{3.791} H_{4.59} O_{2.63063} N_{0.0329} S_{0.0025}$; $C_{3.791} H_{4.59} O_{2.63063} N_{0.0329} S_{0.0025}$; $C_{3.9117} H_{4.73} O_{2.5318} N_{0.0329} S_{0.003125}$ and $C_{2.6425} H_{4.18} O_{2.8513} N_{0.0321} S_{0.0025}$ respectively. The summary of chemical formula for the various fuel pellets is shown in Table 3.

Table 3: Chemical formula of wood samples

Fuel wood samples	Chemical formula
Alstonia	$C_{3.9233} H_{4.76} O_{2.50875} N_{0.03923} S_{0.003125}$
Afara	$C_{3.791} H_{4.59} O_{2.63063} N_{0.0329} S_{0.0025}$
Danta	$C_{3.8467} H_{4.62} O_{2.56625} N_{0.0271} S_{0.0025}$
Okwen	$C_{3.9117} H_{4.73} O_{2.5318} N_{0.0329} S_{0.003125}$
Yukumo	$C_{2.6425} H_{4.18} O_{2.8513} N_{0.0321} S_{0.0025}$

3.5. Combustion Performance Analysis

3.5.1. Alstonia wood sample

The stoichiometric equation for the combustion of Alstonia [$C_{3.9233} H_{4.76} O_{2.50875} N_{0.03923} S_{0.003125}$] is given by Equation (12).

$$C_{3.9233}H_{4.76}O_{2.50875}N_{0.03923}S_{0.003125} + y_1\,[O_2 + (79/21)N_2] \rightarrow p_1CO_2 + q_1H_2O + r_1SO_2 + [t_1 + y_1\,(79/21)]N_2 \quad (12)$$

Balancing the constituents on both sides of the combustion equation yields the final stoichiometric combustion for Alstonia wood sample [$C_{3.9233}H_{4.76}O_{2.50875}N_{0.03923}S_{0.003125}$] and is given by:

$$C_{3.9233}H_{4.76}O_{2.50875}N_{0.03923}S_{0.003125} + 3.86205[O_2 + (79/21)N_2] \rightarrow 3.9233CO_2 + 2.38H_2O + 0.003125SO_2 + 14.567894285714N_2 \quad (13)$$

For wet and dry basis analyses:
Wet basis:
If the products of combustion are:

$$3.9233CO_2 + 2.38H_2O + 0.003125SO_2 + 14.567894285714N_2$$

Therefore, the total amount of substance of wet products:
= 3.9233 + 2.38 + 0.003125 + 14.567894285714 = 20.87432 kmol

Equation (14) is used to determine the percentage composition of the gases.

$$\%\text{ composition of component} = \frac{\text{Amount of substance of component}}{Total\ amount\ of\ substance\ of\ all\ components} \quad (14)$$

Therefore, the percentage composition of wet gases is as follows:
CO_2 produced by Alstonia Wood Sample = $\frac{3.9233}{20.87432} \times 100$ = 18.795%
H_2O produced by Alstonia Wood Sample = $\frac{2.38}{20.87432} \times 100$ = 11.402%
SO_2 produced by Alstonia Wood Sample = $\frac{0.003125}{20.87432} \times 100$ = 0.015%
N_2 produced by Alstonia Wood Sample = $\frac{14.567894285714}{20.87432} \times 100$ = 69.79%

Dry basis:
The total amount of substance of dry products:

= 3.9233 + 0.003125 + 14.567894285714 = 18.49432 kmol

Therefore, the percentage composition of dry gases is as follows:
CO_2 produced by Alstonia Wood Sample = $\frac{3.9233}{18.49432} \times 100$ = 21.214%
SO_2 produced by Alstonia Wood Sample = $\frac{0.003125}{18.49432} \times 100$ = 0.017%
N_2 produced by Alstonia Wood Sample = $\frac{14.567894285714}{18.49432} \times 100$ = 78.77%

The percentage composition of wet gases is as follows: CO_2 is 18.795%; H_2O is 11.402%; SO_2 is 0.015% and N_2 is 69.79%. The percentage composition of dry gases is as follows: CO_2 is 21.214%; SO_2 is 0.017% and N_2 is 78.77%. This is represented in Figures 2 and 3. Figures 2 and 3 illustrate the percentage composition of wet and dry gases in Alstonia wood. For the wet analysis, the exhaust gases in focus are CO_2 and SO_2. The potential CO_2 emission of Alstonia wood is 18.795% and SO_2 emissions is 0.015%. Other gases present during combustion of the wood include nitrogen and water vapour which had level of 69.79% and 11.402% respectively. Again, in Bureau of energy efficiency as reported in Onochie et al. (2017), it was stated that excess amount of sulphur (0.5% above) in fuel causes high rate of corrosion in boilers. Thus, the results showed that the sulphur dioxide in the Alstonia wood is very low and good enough for combustion in boilers.

The dry basis analysis showed the amount of CO_2 and SO_2 in the absence of water vapour. The percentage composition of CO_2 and SO_2 in the Alstonia wood revealed 0.017% and 21.214% respectively. The SO_2 content also falls below the value reported in Bureau of energy efficiency. This means that at both wet and dry analyses, Alstonia wood sample is good enough for combustion in boilers while the CO_2 emission will be used up by growing trees.

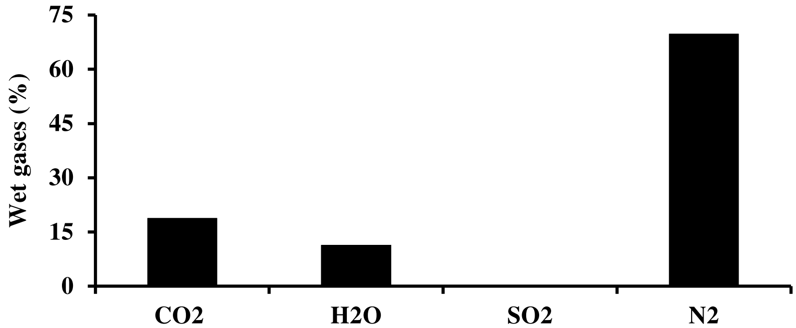

Figure 2: Potential CO_2, SO_2 and other gases of Alstonia wood on wet basis

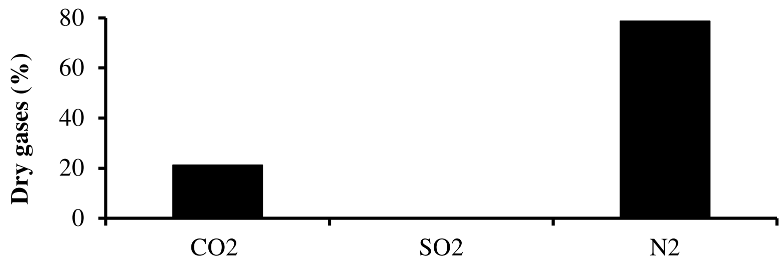

Figure 3: Potential CO_2, SO_2 and N_2 gases of Alstonia wood on dry basis

3.5.2. Afara wood sample

The stoichiometric equation for the combustion of Afara wood sample [$C_{3.791}$ $H_{4.59}$ $O_{2.63063}$ $N_{0.0329}$ $S_{0.0025}$] using air as the oxidant is given by Equation (15).

$$C_{3.791}\ H_{4.59}\ O_{2.63063}\ N_{0.0329}\ S_{0.0025} + y_2\,[O_2 + (79/21)N_2] \rightarrow p_2CO_2 + q_2H_2O + r_2SO_2 + [t_2 + y_2\,(79/21)]N_2 \quad (15)$$

For wet and dry basis analyses:

The calculation for the combustion of Afara is the same as that of Alstonia. The percentage composition of wet gases is as follows: CO_2 is 19.16%; H_2O is 11.60%; SO_2 is 0.01% and N_2 is 69.11%. While the percentage composition of dry gases is as follows: CO_2 is 22.50%; SO_2 is 0.017% and N_2 is 77.48%. This is presented and shown in Figures 4 and 5.

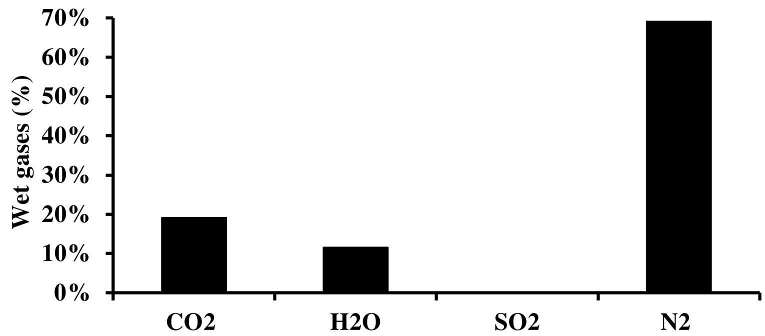

Figure 4: Potential CO_2, SO_2 and other gases of Afara wood on wet basis

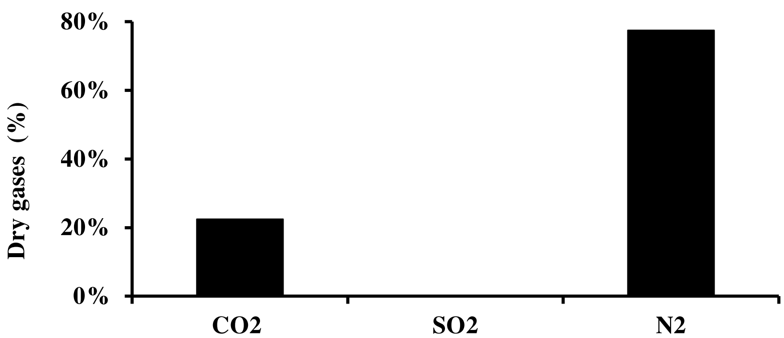

Figure 5: Potential CO_2, SO_2 and N_2 gases of Afara wood on dry basis

In the wet analysis, the potential CO_2 emission is 19.16% and SO_2 emissions is 0.01%. Other gases present during combustion of the wood include nitrogen and water vapour which has 69.11% and 11.60% respectively. The results again showed that the sulphur oxide in the Afara wood is very low and good enough for combustion in boilers. The dry basis analysis showed the amount of CO_2 and SO_2 in the absence of water vapour. The percentage composition of CO_2 and SO_2 in the Afara wood revealed 22.50% and 0.01% respectively. The SO_2 content again falls below the value reported in Bureau of energy efficiency. This means that at both wet and dry analyses, Afara wood sample is also good enough for combustion in boilers while the CO_2 emission will be used up by growing trees.

3.5.3. Danta wood sample

Again, the stoichiometric equation for the combustion of Danta wood sample [$C_{3.8467}\,H_{4.62}\,O_{2.56625}\,N_{0.0271}\,S_{0.0025}$] using air as the oxidant is given by:

$$C_{3.8467}\,H_{4.62}\,O_{2.56625}\,N_{0.0271}\,S_{0.0025} + y_3\,[O_2 + (79/21)N_2] \rightarrow p_3CO_2 + q_3H_2O + \\ + r_3SO_2 + [t_3 + y_3\,(79/21)]N_2 \quad (16)$$

For wet and basis analyses:

The calculation for the combustion of Danta is the same as that of Alstonia. The percentage composition of wet gases is as follows: CO_2 is 19.06%; H_2O is 11.44%; SO_2 is 0.01% and N_2 is 69.49%. While the percentage composition of dry gases is as follows: CO_2 is 21.52%; SO_2 is 0.01% and N_2 is 78.47%. This is presented and shown in Figures 6 and 7.

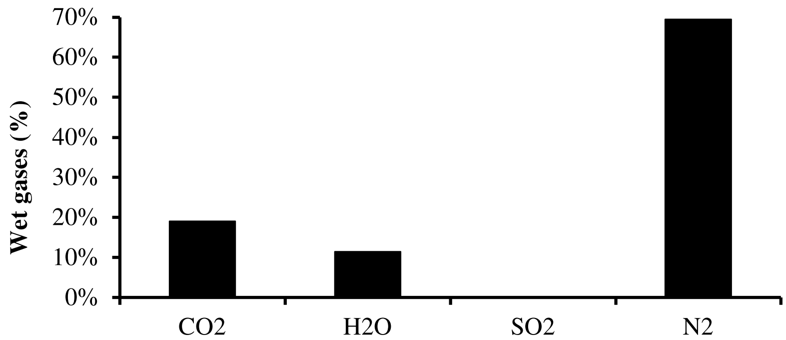

Figure 6: Potential CO_2, SO_2 and other gases of Danta wood on wet basis

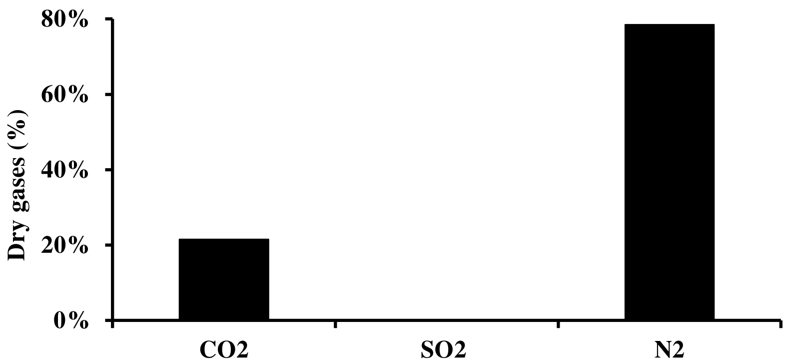

Figure 7: Potential CO_2, SO_2 and N_2 gases of Danta wood on dry basis

Figure 6 and 7 shows the percentage composition of wet and dry gases in Danta wood. Again, for the wet analysis, the potential CO_2 emission is 19.06% and SO_2 emissions is 0.01%. Other gases present during combustion of the wood include nitrogen and water vapour which has 69.49% and 11.44% respectively. The results again showed that the sulphur oxide in the Danta wood is also very low and good enough for combustion in boilers. However, in the dry base analysis, the percentage composition of CO_2 and SO_2 in the Danta wood revealed 21.52% and 0.01% respectively. The SO_2 content again falls below the value reported in Bureau of energy efficiency. This means that at both wet and dry analyses, Danta wood sample is also good enough for combustion in boilers while the CO_2 emission will be used up by growing trees.

3.5.4. Okwen wood sample

The stoichiometric equation for the combustion of Okwen wood sample [$C_{3.9117} H_{4.73} O_{2.5318} N_{0.0329} S_{0.003125}$] using air as the oxidant is given by:

$$C_{3.9117}\ H_{4.73}\ O_{2.5318}\ N_{0.0329}\ S_{0.003125} + y_4\,[O_2 + (79/21)N_2] \rightarrow p_4CO_2 + q_4H_2O + \\ + r_4SO_2 + [t_4 + y_4\,(79/21)]N_2 \quad (17)$$

For wet and dry basis analyses:

Again, the calculation for the combustion of Okwen is the same as that of Alstonia. The percentage composition of wet gases is as follows: CO_2 is 18.87%; H_2O is 11.4%; SO_2 is 0.02% and N_2 is 69.70%. While the percentage composition of dry gases is as follows: CO_2 is 21.30%; SO_2 is 0.02% and N_2 is 78.69%. Again, this is presented and shown in Figures 8 and 9.

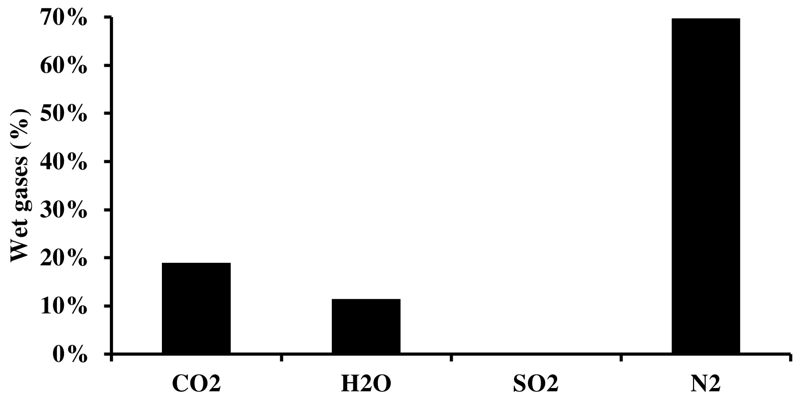

Figure 8: Potential CO_2, SO_2 and other gases of Okwen wood on wet basis

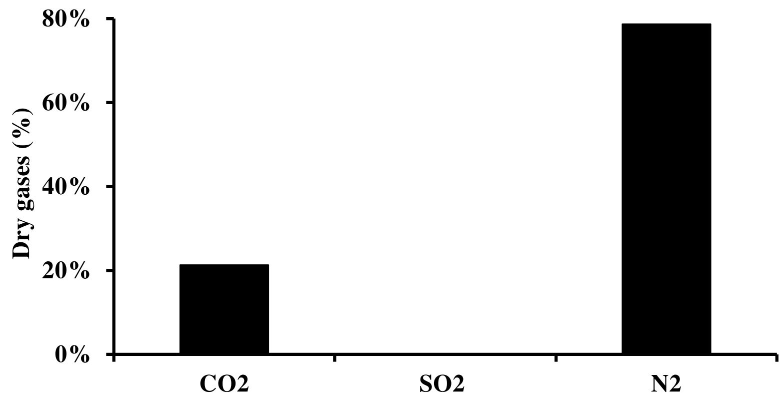

Figure 9: Potential CO_2, SO_2 and N_2 gases of Okwen wood on dry basis

Figure 8 and Figure 9 shows the percentage composition of wet and dry gases in Okwen wood. Again, for the wet analysis, the potential CO_2 emission is 18.87% and SO_2 emissions is 0.02%. Other gases present during combustion of the wood include nitrogen and water vapour which has 69.70% and 11.41% respectively. The results again showed that the sulphur dioxide in the Okwen wood is also very low and good enough for combustion in boilers. However, in the dry basis analysis, the percentage composition of CO_2 and SO_2 in the Okwen wood revealed 21.30% and 0.02% respectively. The SO_2 content again falls below the value reported in Bureau of energy efficiency. This means that at both wet and dry analyses, Okwen wood sample is also good enough for combustion in boilers while the CO_2 emission will be used up by growing trees.

3.5.5. Yukumo wood sample

The stoichiometric equation for the combustion of Yukumo wood sample [$C_{2.6425}H_{4.18}O_{2.8513}N_{0.0321}S_{0.0025}$] using air as the oxidant is given by:

$$C_{2.6425}H_{4.18}O_{2.8513}N_{0.0321}S_{0.0025} + y_5\,[O_2 + (79/21)N_2] \rightarrow p_5CO_2 + q_5H_2O + \\ + r_5SO_2 + [t_5 + y_5\,(79/21)]N_2 \quad (18)$$

For wet and dry basis analyses:
The percentage composition of Yukumo wood sample for wet gases is as follows: CO_2 is 19.89%; H_2O is 15.73%; SO_2 is 0.02% and N_2 is 64.36%. While the percentage composition of dry gases is as follows: CO_2 is 23.60%; SO_2 is 0.02% and N_2 is 76.37%.

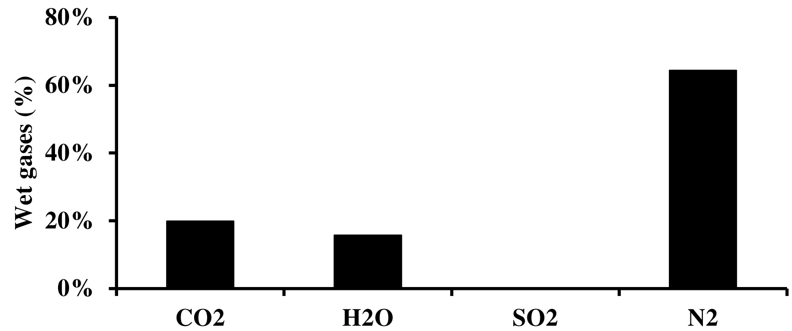

Figure 10: Potential CO_2, SO_2 and other gases of Yukumo wood on wet basis

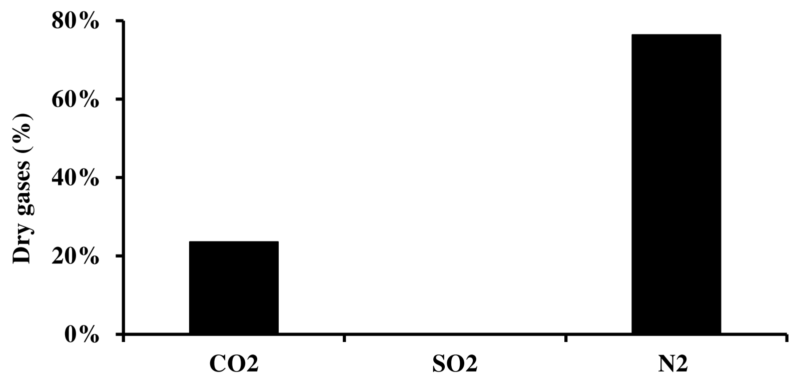

Figure 11: Potential CO_2, SO_2 and N_2 of Yukumo wood on dry basis

Figures 10 and 11 show the percentage composition of wet and dry gases in Yukumo wood. Again, for the wet analysis, the potential CO_2 emission is 19.89% and SO_2 emissions is 0.02%. Other gases present during combustion of the wood include nitrogen and water vapour which has 64.36% and 15.73% respectively. The results again showed that the sulphur oxide in the Yukumo wood is also very low and good enough for combustion in boilers. However, in the dry basis analysis, the percentage composition of CO_2 and SO_2 in the Yukumo wood revealed 23.60% and 0.02% respectively. The SO_2 content again falls below the value reported in Bureau of energy efficiency. This means that at both wet and dry analyses, Yukumo wood sample is also good enough for combustion in boilers while the CO_2 emission will be used up by growing trees.

4. CONCLUSION

This study is based on the characterization and CO_2 and SO_2 emission of five tropical wood wastes in Asaba metropolis, Nigeria. From the results and findings, it was revealed that the five wood samples have high calorific value, hence could serve for energy purposes. The proximate analysis results showed low moisture content which is considerably low compared to other biomass resources from literature. The percentage ash content revealed that the wood samples can be very good for combustion in boilers for energy utilization purposes. The ultimate analysis results showed high carbon content which validates the calorific value results. The wet and dry basis for the exhaust products from the combustion analysis of various wood samples shows that SO_2 is very low, ranging between 0.01 to 0.02%. The combustion performance analyses (dry and wet basis) revealed that CO_2 emission during combustion ranges from 18.795% to 23.60%. In order words, the potential CO_2 emission, therefore, in ascending order is Alstonia < Okwen < Danta < Afara < Yukumo. This study revealed that wood biomass can be used for energy utilisation due to its high calorific value and low moisture content and it is still preferable in terms of burning fossil fuel because CO_2 emissions released during combustion of wood waste is offset by growing trees.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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