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Evaluation of Briquettes Produced from Four Selected Sawdusts Combination at Quaternary Levels

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Abstract

The objective of this paper is to evaluate briquettes produced through quaternary level combination of four types of common sawdusts from major wood sources. This was achieved by producing seven briquettes made up of four primary sawdusts and three from combinations of all primary saw dusts in rations of 25% each, 60/40 rations of A and B and C and D and vice versa (i.e. 40/60 %). The sawdust samples are from four different wood species; Terminalia superba (Afara), Khaya ivorensis (Mohagany), Anogeissus leiocarpus (Marke) and Isoberlina doka (Ububa/Doka). The samples of the sawdust were collected from selected sawmills in Kaduna, Nigeria. Proximate analysis was applied when evaluating the produced briquettes. The results of proximate analysis for the seven sawdust briquette samples tested shows the range of values as; moisture content is 4.3 – 5.0%, ash content (0.7 – 4.2)%, volatile matter (81.5 – 90.8)% and fixed carbon (7.7 – 18.0)%. Calorific Values (CV) are within the range of (17.202 – 18.933) MJ/Kg. The results of proximate analysis of all seven sawdust briquette produced shows that heterogeneous sawdust samples at quaternary levels (or perhaps even at higher levels) of combination do not necessarily produce briquette with much higher CV, as show in difference between the highest and lowest CVs obtained with a difference of 1.072 MJ/kg.

Keywords: Biomass energy; sawdusts; quaternary level; mixing ratio.

I. Introduction

Traditionally, wood in form of fuel wood, twigs and charcoal has been the major source of energy in Nigeria, accounting for about 51% of the total annual energy consumption; the other sources of energy include natural gas (5.2%), hydroelectricity (3.1%), and petroleum products (41.3%) [1]. The use of firewood and misuse of the existing energy resources (agricultural residues) is creating a human and environmental crisis in developing countries which is resulting in deforestation. As wood fuel supplies diminish, the people who depend on wood fuels are suffering increase in physical or economic burdens in maintaining even a minimal daily fuel supply. Hence there is a need for researchers to come up with alternative fuel to reduce consumption of fuel wood and at the same time meet the supply from diminishing demand. With the principles of biomass, energy from the immediate environment like agricultural waste, sawmill or carpentry waste can be used to create energy sources in the form of briquettes [2].

Briquetting is the process of compaction of residues into a product of higher density than the original raw materials. It is also known as densification [3]. The use of fuel wood for cooking has health implications especially on women and children who are disproportionately exposed to the smoke apart from environmental effects. The decreasing availability of fuel woods has necessitated that efforts be made towards efficient utilization of agricultural wastes. These wastes have acquired considerable importance as fuels for many purposes, for instance, domestic cooking and industrial heating. These wastes can be processed in a form whereby they are well compacted and hardened in form that they burn for a longer time. The production of briquettes will enable enterprises to key into the carbon credit redemption mechanism through the clean development mechanism (CDM) under the Kyoto Protocol of United Nation Framework For Climate Change (UNFCC) to earn carbon credits which will serve as a form of subsidy on the project.

Various research work was previously carried out to evaluate the properties of briquettes made from sawdust of different fuel wood variety. The briquettes were produced using various parameters such as; mixing ratios of two or more types wastes, particle size, different binders, different compaction pressures from low to high pressures, all with the aim of achieving desired objectives in characteristics of briquettes produced to meet various applications. Such characteristics include ash content (AC), volatile matters (VM), moisture content (MC), fixed carbon (FC) and more importantly the calorific value (CV).

In a study in by [4], the sawdust of a major hardwood species, Albizia zygia was densified into briquettes and a comparative analysis of the physical properties between the sawdust briquettes and the solid wood of the same species were carried out. The results obtained showed that the briquettes produced using 100% sawdust of Albizia zygia had a heat value and the percentage dry matter of 4.723 $Kcal^{-1}$ and 92.90% respectively compared to the values 4.014 $Kcal^{-1}$ and 76.24% for the solid wood of the same species. It was concluded that stable briquettes with higher calorific value can be produced that will be suitable for both domestic and industrial energy production for heat generation.

Reference [5] carried out proximate analysis to determine potential utilization of sawdust as biomass fuel in Malaysia. The result shows that the sawdust has MC of 8.25%, FC of 14.04%, VM of 76.23% and 1.49% of AC.

In the work of [6], briquettes were produced out of the mixtures of sawdust from Teak, Masonia, Iroko and Afara woods. This mixture of sawdust was sieved into three different grain sizes and were added two grain sizes of palm kernel shell and paper pastes in various ratios. It was observed that the optimum performance and calorific value, the appropriate percentage paper paste should range between 20% and 25%.

Furthermore, in [7], evaluation of the fuel potential of six tropical hardwood species were conducted. Fuel properties were determined using standard laboratory methods. The result indicates that the gross calorific value (GCV) of the species ranged from 20.16 to 22.22 MJ/kg and they slightly varied from each other.

Reference [8] determined the chemical properties of samples of sawdust from 100 wood species using proximate analysis in Nigeria. The results showed least values for MC, AC, VM and FC to be 7.92%, 0.08%, 9.58% and 77.51% respectively. It was concluded that the range of sawdust are suitable as an alternative source of energy. In another earlier research, [9] carried out physicochemical characterization of a wood sawdust using proximate analysis in India. The analysis shows MC, AC, VM and FC to be 3.07%, 3.38%, 80.87% and 12.68% respectively. However, the study did not specify wood species of the sawdust.

In this study, an attempt is been made to combine sawdust at quaternary level (i.e. combining four types of sawdust) using various ratio of mixing and compacted a high pressure of 30 - 50 bars to achieved self-bonding of the mixture (i.e. without the use of a binders).

II. Materials and Methods

A. Materials

Materials use for this research include Bomb calorimeter IKA C2000 Basic, Phillip Harris Oven, VITCO Muffler Furnace (TC 344), the sawdust samples, Setra (BL-410S) digital scale and WITCO Hydraulic Press (40T).

B. Methods

The samples of the sawdust of four wood species investigated were collected from selected sawmills at Mahuta Timber Market in Kaduna, Nigeria. The four sawdust samples are; Terminalia superba (Afara), Khaya Ivorensis (Mohagany), Anogeissus leiocarpus (Marke) and Isoberlina doka (Ububa/Doka). The sawdust samples were properly sun-dried for two days 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 [10].

A pre-treatment on the feedstock was carefully conducted through manual sorting to remove impurities such as pieces of wood, metal and any other unwanted materials. Then the four samples of sawdust were sun dried in open air for two days to bring down the moisture content to within 8-16 %. The sawdust samples were sieved using a screen to obtain a suitably small and uniform size of 4mm diameter.

1) Preparations of Seven Briquette Samples

Steel mold was fabricated and used to produce the briquettes samples at a pressure of 32 tons using WITCO Hydraulic Press at Prosan Engineering Limited, Kakuri-Kaduna and sustaining the pressure for 15 minutes. The combination of the seven briquette samples produced are given in Table I.

Table I. Sawdust Materials

Sample No.	Source Material For Briquette
BR1	Terminalia superba (Afara) sawdust only.
BR2	Khaya Senegalese sawdust only.
BR3	Anogeissus leiocarpus (Marke) sawdust only
BR4	Isoberlinia doka (Ububa/doka) sawdust only.
BR5	Mixture ratio by volume of 25% each of Terminalia S, Khaya S, Anogeissus L and Isoberlinia D sawdusts.
BR6	Mixture ratio by volume of 60% (Terminalia S and Khaya S) sawdusts Plus 40% (Anogeissus L and Isoberlinia D) sawdusts.
BR7	Mixture ratio by volume of 40% (Terminalia S and Khaya S) sawdusts Plus 60% (Anogeissus L and Isoberlinia D) sawdusts.

2) Determination of Moisture Content

The Phillip Harris Oven was used to determine the moisture contents (MC) of the sawdust of the wood species. The oven was set at a controlled temperature of 105°C and the pre-weighed samples were made to undergo drying for 10 minutes as recommended by ASTMD2016-25 [8]. The samples 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 (1).

$$MC = \left[W_1 - \left({}^{W_2}/_{W_1}\right)\right] \times 100\% \qquad (1)$$

Where, W_1= initial weight of the briquette sample (before drying) and W_2= final weight of the briquette sample (after drying)

3) Determination of Ash Content

The ash content is the residue after a sawdust sample has been burnt. This was determined using ASTMD-5142 procedure as recommended reported by reference [10]. The pre-weighed samples were burnt in a muffle furnace at about 550°C for 4 hours. The samples 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 the Setra (BL-410S). The ash contents were calculated using (2).

$$AC = \left[W_1 - \left({}^{W_2}/_{W_1}\right)\right] \times 100\% \qquad (2)$$

Where, W_1= initial weight of the briquette sample (before burning) and W_2= final weight of the briquette sample (after burning)

4) Determination of Volatile Matter

The volatile matters were determined based on the procedure recommended in ISO562/1974 [10]. The pre-weighed samples were made to undergo dry oxidation in a muffle furnace at 550°C for 10 minutes. They were then allowed to cool in a desiccator. The final weights of the samples were taken with the aid of Setra (BL-410S) digital weighing scale. The volatile matters were calculated as given by (3).

$$VM = \left[W_1 - \left({}^{W_2}/_{W_1}\right)\right] \times 100\% \qquad (3)$$

Where, W_1= initial weight of the briquette sample (before dry oxidation) and W_2 = final weight of the briquette sample (after dry oxidation)

5) Determination of the Fixed Carbon Contents

The fixed carbons (FC) of the briquette samples were determined by using (4) [10].

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

Where, Ash = determined ash contents and VM = determined volatile matters

6) Determination of Calorific Value

The calorific value (CV) was determined using an oxygen Bomb Calorimeter (IKA C2000 Basic) which is connected to an industrial size oxygen supply. The apparatus comprises of the bomb calorimeter housing with thermometers. The bomb cover with crucible holder and circuit was removed and placed on the stand. The samples were weighed in the crucible using an electrical digital weighing scale to masses ranging between 0.8g to 1.2g. The sample within the crucible was then placed on to the holder and a resistance wire (platinum wire) connected across to complete the circuit. A cotton wick was then secured onto the center of the resistance wire and connected to the sample in the crucible. The whole set up was put into the bomb after cleaning it with distilled water. The cover was tightened, then placed into the calorimeter housing. The samples were numbered in the control and the experiment was started. After about 20 minutes, the lower heating value was displayed on the control panel display screen.

III. Discussion of Results

A. Moisture Content

The results of the moisture content (MC) shows BR1-BR4 have values of 5.0%, 5.0%, 4.0% and 4.6% respectively. While BR5-BR7 have values of 5.0%, 4.3% and 4.7% respectively. All results obtained have a range of 4.3% - 5.0% as illustrated in Fig. 1. This is lower than results obtained in [8] which reported MC with range of 7.92 - 15.96%.

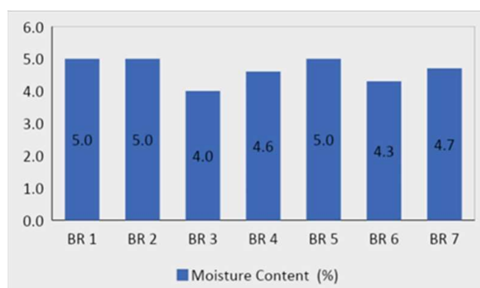

Fig. 1. Moisture content for the seven briquettes

Reference [11] reported that the acceptable operating MC for briquetting is 8-12%. It is reported that MC among other factors influence wood density such that the more the moisture per unit mass of wood, the less its fuel or energy output.

B. Ash Content

The results of the Ash Content (AC) shows BR1-BR4 have AC values of 1.5%, 0.7%, 4.2% and 2.0% respectively.

While BR5, BR6, and BR7 show AC values of 2.1%, 0.5% and 2.4% respectively. All seven sawdust samples' AC results has a range of 0.7-4.2% as shown in Fig. 2. This compares favorably with results obtained with a range between 0.08% and 5.09% [8].

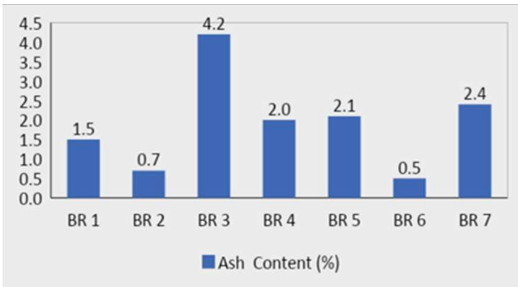

Fig. 2. Ash content for the seven briquettes

Lower AC is an indication of good quality briquette, as the AC of briquettes produced in this study is around the acceptable 4% tolerance level of ash content for fuel [12]. Higher AC in a fuel usually leads to higher dust emissions, air pollution, and affects the combustion volume and efficiency of combustion [13].

C. Volatile Matter

Volatile matter is a mixture of short and long chain hydrocarbons such as combustible or incombustible gasses released during burning. These gasses strongly affect the combustion behavior of briquettes. Lower volatile matter is an indication that the briquettes might not be easy to ignite, but once ignited they will burn smoothly, while high volatile matter results in high combustibility at low ash content.

The results of the Volatile Matter (VM) test shows samples BR1-BR4 have values of 90.8%, 87.0%, 84.0% and 84.8% respectively. While BR5, BR6, and BR7 show values of 83.4%, 81.5% and 82.0% respectively. All results obtained have a range between 81.5% - 90.8%. This compares favorably with range of 77.51% - 93.59% as obtained by [8]. The values obtained in this study as shown in Fig. 3 is higher than 85.48% - 87.55% obtained by [14] for briquettes produced from three hardwood species.

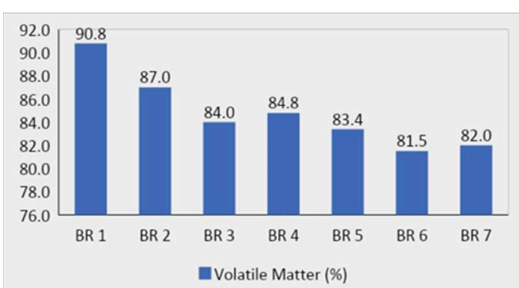

Fig. 3. Ash content for the seven briquette

D. Fixed Carbon

The results of the Fixed Carbon (FC) shows BR1-BR4 have values of 7.7%, 12.3 %, 11.8 % and 13.2% respectively while BR5, BR6, and BR7 shows values of 14.5%, 18.0% and 15.6% respectively. All results obtained has a range of 7.7% - 18.0% which is lower than but compares favorably with results obtained within a range of 9.58% to 18.44% by [8]. However, the fixed carbon as reported in this study is relatively higher than values reported by [15].

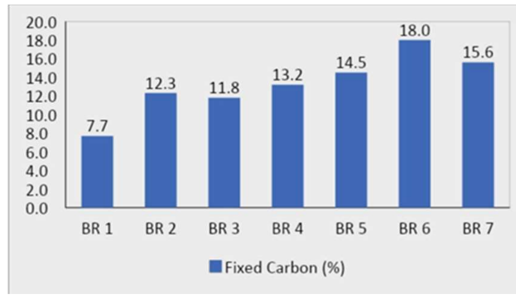

Fig. 4. Fixed carbon for the seven briquette

Fixed carbon gives an indication of the proportion of char that remains after volatile matter is distilled off. It gives a rough estimate of the heating value of a fuel and acts as the main heat generator during burning. It is expected that the high fixed carbon and its smokeless flame will enhance the heat value and combustion duration of briquette. A good quality and efficient fuel briquette is dependent on lower volatile matter and ash content with a higher fixed carbon content.

E. Calorific Value

The results show BR1-BR4 have values of 17.867, 18.274, 17.202 and 17.772 MJ/kg respectively while BR5, BR6, and BR7 show values of 17.933, 17.833 and 17.861 MJ/kg respectively. The range of values obtained lies between 17.202 - 18.933 MJ/kg for the briquettes produced (See Fig. 5).

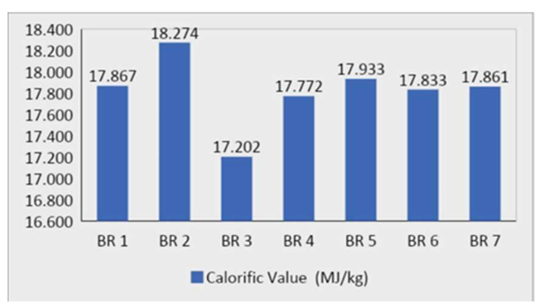

Fig. 5. Calorific value for the seven briquette

IV. CONCLUSION

This study evaluates the calorific value of briquette through a quaternary level combination of four types of common saw dusts from major wood sources. This was achieved by producing seven briquette made up of four primary saw dusts and three from combinations of all primary saw dusts in rations of 25% each, 60/40 and 40/60%. Proximate analysis was applied when evaluating the produced briquettes which shows that the range of values are; moisture content (4.3 - 5.0) %, ash content (0.7 - 4.2) %, volatile matter (81.5 - 90.8) % and fixed carbon (7.7 - 18.0) %, and the calorific values within the range of (17.202 - 18.933) MJ/Kg. The results of the calorific values show that heterogeneous sawdust samples at quaternary levels of combination do not necessarily produce briquette with much higher calorific values.

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