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Effects of Binder Ratio on the Combustion Profile of Bambara Nut Shell Briquettes.

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ABSTRACT: Energy accessibility is a major pre-requisite of growth to any society. In an endeavor to incur efficient firewood alternative to the rural household in Nigeria, this study was carried out to analyse the proximate, physical, combustion and SEM (Scanning Electron Microscope) analysis of the Bambara nut shell at different binder ratio (70:30; 60:40) prepared at moderate pressure and ambient temperature using fabricated briquetting machine. The study revealed that the results obtained for the characterization of Bambara nut shell at the different binder ratio is of better performance, most especially the Bambara nut shell with ratio 60:40 to binder had better characteristics than that of 70:30 ratios. They can serve as better alternative source of energy and they are in relativity with previous studies.

KEYWORDS: Bambara nut shell, Analyse, Briquette, Energy, Renewable

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I. INTRODUCTION

The world's energy production by fossil fuels such as coal, crude oil, and natural gas is insufficient. Fossil fuels, which non-renewable source of energy make about 80% of energy source generally use now and the negative effects of it are detrimental to human health and environment [1]. Production and usage of almost any type of energy have environmental impacts, harvesting of fuelwood, in particular, contributes to deforestation, soil erosion and desertification.

Unavailability of clean energy sources leads to many such problems that are sufficiently highlighted or analyzed. Decentralized solutions offering cheap access to rural energy, employment and income generating opportunities to the rural populations are scarce. While a number of technological approaches and implementation proposals exists, a sustainable renewable energy solutions into rural communities hinges on appropriate business models that include a long term commitment from commercially interested and socially aware partner. Models for such a sustainable approach to renewable energy have not yet been developed [2].

Biomass briquettes may hold the answer for emerging and developing countries, as well as countries that are more established. In many third world nations biomass such as wood, grass, and other plant matter is used in cooking [3].Common name is Bambara groundnut, Bambara nut and the Botanical name is (*Vignasubterranea)* (L.) Verdc, and belongs to the plantea of the family of fabaceae and sub family of Faboidea[4].The aim of this research is to study the effect of binder ratio on the combustion profiles of the Bambara nut shell briquettes. The main objective of the study is to determine the proximate, physical, combustion and SEM analysis of briquettes samples using starch binder at 70g: 30g and 60g:40g ratios. This research is directed towards knowing the significance difference in the performance of Bambara nut shell briquettes based on the binder ratios.

II. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

The Bambara nut shells were collected in Arewa, Kebbi state, Nigeria. Biomass briquettes were produced by crushing the coarse particles of biomass samples after drying and grounded particles were sieved with a 2mm mesh. Water was added as a medium to facilitate good mixing which a critical requirement for the cassava starch used as binder. Samples were prepared with binder ratio 70g: 30g and 60g: 40g respectively before stocking into fabricated hydraulic press briquetting machine. The briquettes produced are of 35mm diameter and 75mm height at moderate pressure of 101.325kN/m^2 and ambient temperature of 68 to 77^o Fahrenheit. The briquettes produced were then air dried for three weeks [5].

Binding agents are usually added to enhance compaction biomass material to improve the quality of the resulting briquettes. Bambara nut shells have a limited degree of elasticity. They have the tendency to spring back or even fall apart when compression is released [6]. In order to reduce its springiness and maintain bulk density, binders are introduced. Cassava starch is chosen as binders in this study because they are naturally abundant in rural communities.

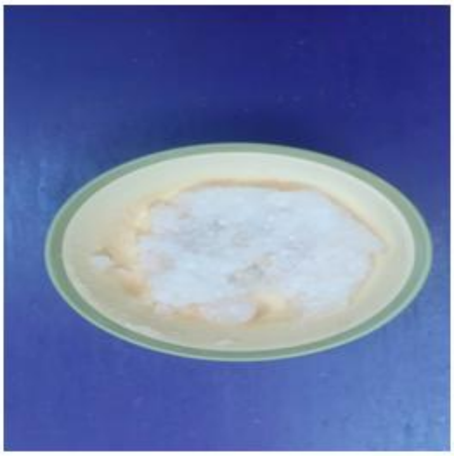

Figure 1.Starch preparation

Figure 2. Nature of briquettes Produced

2.2. Proximate Analysis

2.2.1. Moisture Content

Various methods could be used to determine the moisture content, the moisture content as loss in weight in a drying oven, in this research the percentage moisture content of the briquette samples were determined based on sample weight measurement before and after oven drying. The initial weight of the samples were determined (W_1), and placed in an oven set at 105±3°C for 24hours. The samples were removed and cooled in a desiccator, reweighed (W_2). Percentage moisture content was calculated according to [7] procedure, using equation 1.

Percentage moisture $\frac{w_1-w_2}{w_1}$ x 100 … … … … … … … … … … … … … … … … … ….……………… (1)

Note: W1 = weight of sample before oven drying, (gram)
W2 = weight of oven dried sample, (gram)

2.2.2. Volatile Matter

The briquettes percentage volatile matter content was determined using Lenton furnace. The residue of dry sample from moisture content determination preheated at 300°C for 2hrs to drive off the volatiles, the resulting sample was further heated at 470°C 2hrs, to ensure complete elimination of volatiles, just before the materials turns to ashes, and then cooled in desiccator, based on the [7] procedure. The crucible with known weight and its content was weighed and expressed as the percentage weight loss, the Percentage volatile matter was computed using equation 2.

$$\text{volatile matter} \frac{finalwieght}{originalwieght} \text{ x } 100 \text{ … } (2)$$

2.2.3. Fixed Carbon Content

Fixed carbon was determined by using the data previously obtained in the proximate analysis and according to [8] using the formula was computed using equation 3

%FC = 100 – (%ash + volatile matter) ………………………………………………………… (3)

2.2.4. Ash Content

Ash content of the samples briquettes were determined using a furnace residue from fixed carbon determination were heated in a furnace at 590°C, for two hours and transferred into a desiccators to cool down the materials turned into white ash and weighed. Same procedure was repeated three time at 1hr interval until the weight was constant. The weight was recorded as the final weight of the ash, according to [7]. The percentage ash content was then calculated using equation 4.

$$\text{Ash content} = \frac{weig\ htofas\ h}{originalweig\ \ htofsample} x\ 100 \ldots \ldots \ldots (4)$$

2.2.5. Density

Density as physical property of the briquette is defined as structural packing of the molecules of the substance in a given volume. The density was determined using a weighing balanced in the laboratory by taking the weight of briquette sample and the dimension measurement using vernier caliper based on [9], the volume was evaluated using the relation nr2h and the density was computed using equation 5

$$\text{Density} \left(\frac{g}{cm^3}\right) = \frac{mass}{volume} \ldots \ldots \ldots (5)$$

2.2.6. Compressive Strength

Each sample of the rectangular briquettes with dimension 3.0cm x 2.5cm and thickness of 2.0cm were loaded into the ELE tritest 50 compression machine, and the shear load was determined at 20% at 0.38mm/minute. The load dial per division (R) was noted for every change in strain (AL). The stress (in kN/m2) and % strain was calculated using theformular [9] in equation 6 and 7.

$$\text{Stress} = \frac{force\ \ (F)}{UnitArea} = \frac{loaddialxcalibration\ \ \ \ (CR)}{lengt\ hxbreat\ hofsample} \ldots \ldots \ldots (6)$$

$$= \frac{Rx\ 2.11\ x\ 10KN}{7.5m^2} = \frac{2.81RKN}{m^2} \ldots \ldots \ldots (7)$$

$$\%\ \text{strain}\ \frac{AL}{L_0} x\ 100 \ldots \ldots \ldots (8)$$

(L0 = original thickness of sample)

2.2.7. Calorific Value

Leco AC-350 oxygen bomb calorimeter interfaced with a microcomputer was used to assess the heat values of the briquettes produced. The calorific value was determined following procedure of [10].

2.2.8 Determination of Ignition Propagation

This was determined as highlighted by [11]. One piece of the briquette was graduated in centimeters and ignited using a Bunsen burner. The ignited briquette was allowed to burn until it extinguished itself. The flame propagation rate was estimated by dividing the distance burnt by the time taken in seconds.

2.2.9 Determination of Afterglow Time

The determination of afterglow time was in order to estimate how long the individual briquette was burn before restocking when used in cooking and heating. The procedure of [11] was also used. A piece of oven- dried briquette was ignited and after a consistent flame was established, the flame was blown out. The time, in seconds, within which the glow was perceptible was recorded.

2.2.10. Combustibility Test

About 200g of each set of briquettes was stacked into an improved stove. It was lightened with a match after application of little absolute ethanol to initiate combustion. The fire was allowed to assume a steady combustion. One litre of water in an aluminum pot whose initial temperature was recorded will be placed on the stove and a stop watch was initiated. A digital thermometer was inserted into the water inside the pot and readings taken after every two minutes interval and the corresponding temperatures recorded until water boiled [12].

2.2.11 Scanning Electron Microscopy (SEM) Analysis

SEM analysis with Phenom Pro-X Scanning Electron Microscope (Model No. 800-07334 MVE016477830, Phenom World B.V, Eindhoven, and the Netherlands) was used to determine the morphology of the particles of the biomass materials [13].

III. RESULTS

Table 1. Proximate Analysis of the Samples

Sample	Moisture content (%)	Ash content (%)	Volatile matter (%)	Fixed carbon (%)
B/S (70:30)	10.01±0.12	9.65±0.50	65.20±0.22	25.15±0.10
B/S (60:40)	9.40±2.10	9.21±0.03	64.32±0.26	26.47±0.25

Values are mean standard deviation of triplicate results

Where: B/S (70:30) = Bambara nut shell briquette sample bonded with starch at 30% binder ratio
B/S (60:40) = Bambara nut shell briquette sample bonded with starch at 40% binder ratio

Table 2. Physical Characteristics of the Samples

Sample	Compressive strength (N/mm^2)	Density (g/cm^3)
B/S (70:30)	1.200±0.30	1.210±0.30
B/S (60:40)	1.360±0.06	1.420±0.05

Values are mean standard deviation of triplicate results
Where:B/S (70:30) = Bambara nut shell briquette sample bonded with starch at 30% binder ratio
B/S (60:40) = Bambara nut shell briquette sample bonded with starch at 40% binder ratio

Table 3. The combustion Characteristics of Samples

Sample	Calorific Value (MJ/Kg)	Combustibility test (mins)	Ignition propagation (cm/s)	Afterglow (sec)
B/S (30)	18.72±0.53	20	0.13±0.02	149±0.61
B/S (40)	19.26±0.25	18	0.13±0.74	144±1.40
Charcoal		16		

Values are mean standard deviation of triplicate results
Where: B/S (70:30) = Bambara nut shell briquette sample bonded with starch at 30% binder ratio
B/S (60:40) = Bambara nut shell briquette sample bonded with starch at 40% binder ratio

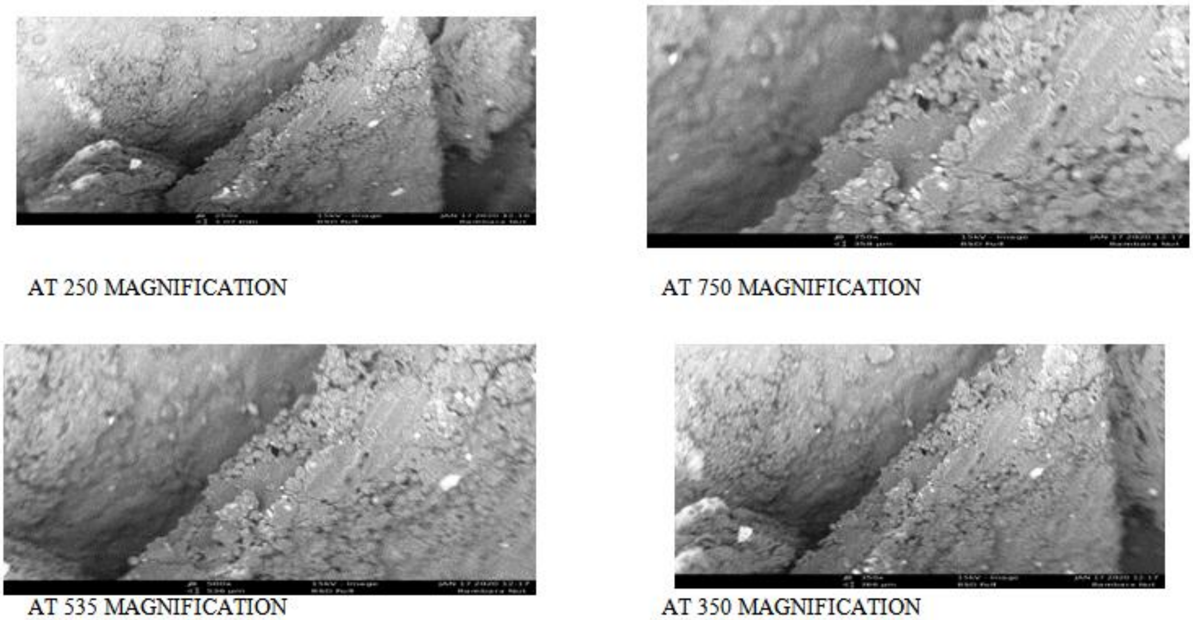

Figure 3. Morphology of Bambara nut shell at different magnifications

IV. DISCUSSION

As observed in table 1., increase in binder has reduced the moisture content of the samples. The moisture content of the briquettes decreased and falls within the range of 10-15% which helps in storage and combustibility [14]. It was observed that B/S (70:30) has higher ash content than B/S (60:40). The briquette with lower ash content is of better performance because ash is an impurity that will not burn; fuels with low ash content are better suited for thermal utilization [15].

The results of volatile matter in table 1.,are 65.20% (B/S 70:30) and 64.32% (B/S 60:40). The high proportion of volatile matter exhibited by B/S 70:30 could be attributed to the high organic matter the sample [16]. The results of the fixed carbon showed that B/S 60:40 has higher fixed carbon of 26.47% which is compare well with 14% of [17] of watermelon peels briquette. The low fixed carbon of the B/S 70:30 indicates prolonged cooking time but with low heat release [16].

The resultsof the density and compressive strength showed that B/S 60:40havehigher density and compressive strength value of 1.42g/cm^3 and 1.36N/mm^2 respectively. It is observed that the higher the density, the higher the compressive strength. The low value of density and compressive strength observed in the B/S 70:30 indicate, it burns at a very short time, less ion terms of packaging, storage and transportation [18]; [19].

The result presented in Table 3 shows the highest and least mean for the heating value of the briquettes produced are 18.72MJ/Kg to 19.26MJ/Kg. It is noted that briquettes of Bambara nut shell briquette (60:40) is better than of Bambara nut shell briquette (70:30)due to the results obtained for both properties that is influenced by the species, moisture content, density and binder ratios [20].

The result presented in Table 3 also shows the highest and least mean for the ignition propagation of the briquettes produced from Bambara nut shell briquette (60:40) and Bambara nut shell briquette are 0.13cm/s and 0.13cm/s respectively while afterglow are 144s and 149s respectively.

The result of combustibility test in Table 3, shows that the Bambara nut shell sample briquette (60:40) took 18 minutes to boil one litre of water and also took 20minutes for Bambara nut sample briquette (70:30) to boil one litre of water under similar condition. These indicates that the burning rate (how fast the fuel burns) and the calorific value (how much heat released) are two combined factors that controlled the water boiling time according to the calorific values obtained for both samples [12].

Figure 3 showed the surface morphology of the Bambara nut shell at different magnifications. The finer the particle size, the easier the compaction during densification and the better the quality of the compacts[21]. From the results, it can be observed that the Bambara nut shell biomass sample have smooth and uniform surface. This could be due to the presence of hemicellulose, lignin and other impurities like wax, and grease covering the biomass sample and protecting the cellulose insidewhile rough surface was observed in soya bean shell biomass sample [22].

V. CONCLUSION

The study revealed that the results obtained for the characterization of Bambara nut shell at the different binder ratio is of better performance, most especially the Bambara nut shell with ratio 60:40 to binder had better characteristics than that of 70:30 ratios. They can serve as better alternative source of energy and they are in relativity with previous studies.

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