PRODUCTION AND CHARACTERIZATION OF FUEL BRIQUETTES FROM BAMBARA NUT SHELL AND SOYA BEAN SHELL

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Abstract

The study revealed the production and characterization of briquettes from Bambara nut shell and soya bean shell using fabricated briquetting machine. The briquettes, comprising of ratio (80g:20g) of the samples and starch were molded and analyzed. Proximate analysis, physical characteristics, combustion characteristics and Scanning Electron Microscopy (SEM) were determined for the briquettes fabricated. The briquettes developed had calorific values of 18.37MJ/Kg for Bambara nut shell briquette and 14.84MJ/Kg for soya bean briquette sample. It took Bambara nut shell briquette sample and soya bean shell briquette 24 minutes and 28 minutes to boil 1litre of water respectively. This study has shown that the briquette produced from Bambara nut shell had better quality than that of soya bean briquette.

Keywords: Bambara nut, Soya bean, renewable, biomass, materials.

1.0 Introduction

Sustainable energy in its broader context can be defined as energy providing affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of the society for which the services are intended, while recognizing equitable distribution in meeting those needs (Davidson, 2002).

The requirement for renewable and sustainable alternative sources of energy are on the rise as a result of depletion of the non-renewable fossil energy resources and the demerit associated with fossil fuels which include; global warming, increasing price and intermittent supply. In light of this, biomass is of great interest because of its availability, low price, carbon dioxide neutral feature, and high potential (Oladosu and Adegbulugbe, 1994).

A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel (Grainger *et al.,* 1981). In the production of briquettes, the materials can be compressed without addition of adhesive, while in others adhesive materials called binders are added to assist in holding the particles of the material together depending on the type of raw material used for the production (Mohammed, 2005).

Common name is Bambara groundnut, Bambara nut and the Botanical name is (*Vigna subterranea)* (L.) Verdc, and belongs to the plantea of the family of fabaceae and sub family of Faboidea (Bamshaiye *et al.*, 2011). Soyabean (*Glycine max*) (L) Merr, is a leguminous crop that is widely enjoyed for consumption by the world in a multitude of forms such as soy sauce, soy milk, tempeh, tofu, and bean sprouts (Hartman *et al*., 2011). Based on review, the studies have focused on the nutritional and anti-nutritional of Bambara groundnut and soya beans.

The aim of this research is to study the combustion profiles of the Bambara nut shell and soya bean shell briquettes. The main objective of the study is to determine the physico-chemical properties, physical characteristics and combustion characteristics using starch binder at 80:20 ratios. This research is directed towards knowing the significant difference in the performance of Bambara nut shell and soya bean shell briquettes.

2.0 Materials and Methods

2.1 Sample Collection and Preparation

The Bambara nut shells and Soya shells were collected in Aliero, 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 is a critical requirement for the cassava starch used as binder. Samples were prepared with six levels of binder ratio viz, 20% for cassava starch binder and 80% of the substrates material before stocking into fabricated hydraulic press briquetting machine.

Binding agents are usually added to enhance compaction biomass material to improve the quality of the resulting briquettes. Watermelon peels have a limited degree of elasticity. They have the tendency to spring back or even fall apart when compression is released (Etonihu *et* *al.*, 2008). 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. Nature of the briquettes

2.2. Physico-chemical 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, and reweighed (W_2). Percentage moisture content was calculated according to (Adekunle *et al.*, 2015) procedure, using equation 1.

$$\text{Percentage moisture } \frac{w_1 - w_2}{w_1} \text{ x } 100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (1)$$

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 turn to ashes, and then cooled in desiccator, based on the (Adekunle *et al.*, 2015) 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.

$$\text{volatile matter} \frac{final\ wieght}{original\ wieght} \text{ x } 100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2)$$

2.2.3. Fixed Carbon Content

Fixed carbon was determined by using the data previously obtained in the proximate analysis and according to (Garcia *et al.*, 2012) 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 (Adekunle *et al*., 2015). The percentage ash content was then calculated using equation 4.

$$\text{Ash content} = \frac{weight\ of\ ash}{original\ \ weight\ of\ sample}\, x\ 100 \ldots\ldots \quad (4)$$

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 (ASTM, 1990), the volume was evaluated using the relation nr2h and the density was computed using equation 5.

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

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 the formular (ASTM, 1990) in equation 6 and 7.

$$\text{Stress} = \frac{force\ \ (F)}{Unit\ \ Area} = \frac{load\ \ dial\ \ x\ calibration\ \ \ (CR)}{length\ x\ breath\ of\ sample} \ldots\ldots \quad (6)$$

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

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

(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 (Obi *et al*., 2013).

2.2.8 Determination of Ignition Propagation

This was determined as highlighted by Oladeji (2010). 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 burnt before restocking when used in cooking and heating. The procedure of Oladeji (2010) 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 (Onuegbu *et al*., 2011).

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 (Imeh *et al*., 2017).

3.0 Results

Table 1. Results of the Proximate Compositions of the Briquettes

Sample	Moisture content (%)	Ash content (%)	Volatile matter (%)	Fixed carbon (%)
B/S (80:20)	10.20±0.30	10.08±0.01	65.49±1.12	24.43±0.20
S/B (80:20)	9.05±0.30	12.54±0.40	73.01±0.62	14.45±0.30

Values are mean standard deviation of triplicate results

Where: B/S (80:20) = Bambara nut shell briquette sample bonded with starch binder at 20% binder ratio.

S/B (80:20) = Soya beans shell briquette sample bonded with starch binder at 20% binder ratio.

Table 2. Physical Characteristics of the Briquettes

Sample	Compressive strength (N/mm^2)	Density (g/cm^3)
B/S (80:20)	1.140±0.25	1.050±0.10
S/B (80:20)	0.890±0.30	0.830±0.11

Values are mean standard deviation of triplicate results

Table 3. Combustion Characteristics of the Briquettes

Sample	Calorific Value (MJ/Kg)	Combu stibility test (mins)	Ignition propagation (cm/s)	Afterglow (sec)
B/S (80:20)	18.37±0.40	24	0.14±0.01	156±1.70
B/S (80:20)	14.84±0.50	28	0.19±0.02	189±3.40
Charcoal		16		

Values are mean standard deviation of triplicate results

Figure 2. Morphology of Soya bean shell

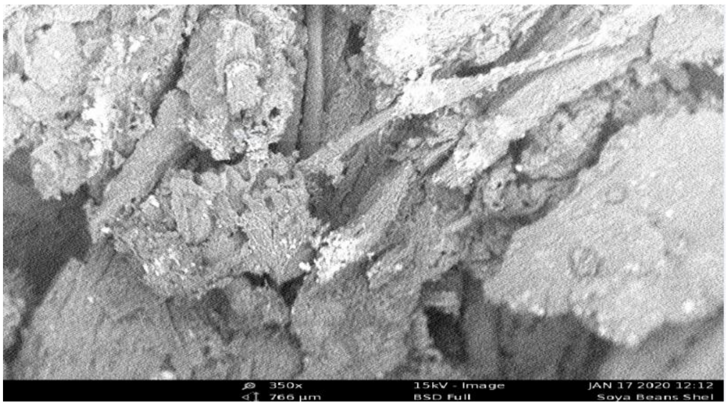
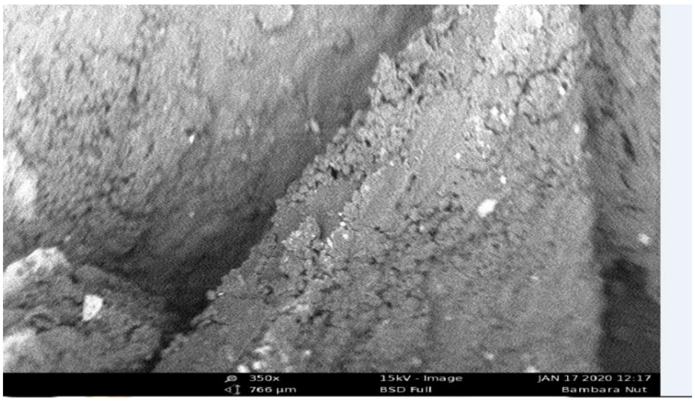


Figure 3. Morphology of Bambara nutshell



4.0 Discussion

It was shown on the table above, the moisture content of the both samples were 10.20% and 9.05% respectively. The values obtained were required values for the storability, proper handling and enhance heating value as recommended by (Wamukonya *et al.*, 1995). Ash is meant to be an impurity in the combustibility of the briquettes, the values of ash content obtained were 9.00% and 8.50% for the both samples respectively. The high ash content in soya bean shell sample will impede combustion and Bambara nut shell sample with low ash content is better suited for thermal utilization (Loo *et al*., 2008) and according to (Garcia *et al*., 2012) general values of ash content may appear in a range from levels below 5-20%. As it was shown on the table above, sample of soya bean of 73.01% has higher volatile matter. Biomass generally contains high volatile matter content range 70%-86% and low char content (Naruephat and Patchree, 2015). The volatile matter from briquettes of both samples is comparable with 75.50% of sugarcane peels briquette reported by Ige *et al*., (2018). It is noted that the higher the volatile matter of a fuel briquette the higher the combustibility of the fuel briquette when the ash content is low (Maninder *et al*., 2012). The fixed carbon of the briquette, gives a rough estimate of the heating value of a fuel and acts as the main heat generator during burning (Akowuah *et al*., 2012). The result of the fixed carbon shows that the briquette produced from soya bean shell sample has a lower fixed carbon content of 14.45% which indicates prolonged cooking time but with low heat release (Olorunnisola, 2007). The briquettes are better with higher fixed carbon because the corresponding calorific value is usually higher as reported by (Praveena, *et al*., 2014).

The compressive strength for the two samples was found to be reasonable with the briquette from sample Bambara nut shell sample having the higher value of 1.140 N/mm^2. The implication of this is that briquette from sample Bambara nut shell sample will suffer less damage during packaging, storage and transportation (Praveena, *et al*., 2014) and above all, it is an indication of good quality briquettes because of the strong inter particle bonds (Onuegbu *et al*., 2011).

The values of 1.04g/cm3 and 0.83±0.02g/cm3 were obtained for the density for both samples. It is expected that it will take a longer time for the sample A briquette to burn and may release less fly ash than the other briquette (Olawale, 2009). The result presented in Table 3 shows the highest and least mean for the heating value of the briquettes produced from Bambara nut shell and soya bean shell ranged from 18.37MJ/Kg to 14.84MJ/Kg. It is noted that briquettes of Bambara nut shell briquette are better than of soya bean shell briquette due to the results obtained for both properties that is influenced by the species, moisture content, density and binder type (Voicea *et al*., 2003).

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 and soya bean shell briquette are 0.14cm/s and 0.19cm/s respectively while afterglow are 156s and 189s respectively.

The result of combustibility test in Table 3 shows that the Bambara nut shell sample briquette took 24 minutes to boil one litre of water and also took 28minutes for soya bean sample briquette to boil one litre of water under similar condition. These indicate 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 (Onuegbu *et al*., 2011).

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 inside while rough surface was observed in soya bean shell biomass sample (Ashori *et al.,* 2012). The finer the particle size, the easier the compaction process during densification and the better performance of the briquette (Karunanithy *et al*., 2012).

5.0 Conclusion

This study has shown that the briquette produced from Bambara nut shell had better quality than that of soya bean briquette. The utilization of these wastes for briquettes production will further serve as a waste management option thereby ensuring environmental cleanliness. The Bambara nut shell briquette and soya bean briquette can be the sustainable alternative energy source.

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