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Ignition and Burning Rate of Sheanut Shell Briquettes Produced at Moderate Temperature and Die Pressure

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Abstract: Energy availability is a crucial requirement to societal development. In an effort to provide a cheap firewood alternative to the rural households in Nigeria, this study was carried out to produce biomass briquette from sheanut shell using a simple extruder briquetting machine. The proximate analysis of the raw and briquetted samples were carried out and were found that these properties were improved as a result of briquetting. The density was found to be 0.46g/cm^3 and the compressive strength was 2120Mpa while the ignition time was 1.70mm/s and the afterglow time was 38sec. It took 1kg of the briquette, 22 mins to boil 2 litres of water while it took kerosene 16mins to boil the same quantity of water. The efficiency based on kerosene was 73.58% which indicates that this agro-waste residue is a good resource for biomass briquetting.

Keywords: Biomass, Briquettes, Firewood, Ignition Time, Sheanut Shell

1. Introduction

The availability of energy is a crucial pre- requisite of development in any society. According to Jarret [1], the industrial revolution was largely a revolution in power availability, while [2] formulates the concept in a mathematical terms as follows:

$$L = \frac{R \times E \times I}{P} \quad (1)$$

Where L represents the standard of living of a society (measured in terms of consumption of goods and services)

R = consumption of raw materials

E = consumption of energy

I = (consumption of ingenuity (embracing technology, political, socio economic and management components).

P = Population of the society.

In Nigeria for instance, about 80% of the population live in rural areas and depend mostly on fuel wood for their energy need. This has a negative effect on the ecosystem by causing deforestation leading to soil erosion, desert encroachment, atmospheric pollution due to carbon dioxide build-up and the loss of agricultural land. The rural dwellers and even the urban dwellers cannot depend on the use of electricity (due to its erratic supply) and cooking gas (due to its high cost). These urban and rural dwellers are left with no choice than using fuel wood as their cheapest source of energy. This fuel wood popularly known as fire wood has a low calorific value in addition to the ecological problems they cause [3]. Massive tree exploitation recorded in most Nigerian forests in the past was as a result of the fact that fire wood which serves as the major source of energy were gotten from the massive volume of timber in the forest [4].

The demand on wood is rapidly increasing due to a drastic increase in population which has driven many forest trees species into extinction thus, causing a lot of environmental havoc. As a result of inefficient conversion and low biomass recovery from these trees in the Nigerian forestry industries, it has led to prevalence of sawdust around sawmills and it constitutes a disposal problem [5]. Obviously most of the world's demand for energy is yet to be met by fossil fuels which provides about 80% of man's energy source but has failed to meet the huge demand of the teeming population which has kept on increasing on daily basis, while the volume of the fossil fuels has kept on depreciating too. There is now a world-wide growing concern on the rate of depletion, and final exhaustion of these fossils. The life span of this resource in the world which at present is the main source of energy and petrochemical feedstock is now measured in few decades [6]. In an event of depletion of the crude reserves, the ugly scenario that could be predicted by the energy crises will be better imagined than experienced.

The fact that oil has a "turbulence factor" in contemporary international affairs has led to a boast in research for alternative sources of energy especially in the technologically advanced countries in the West geared towards reducing the dependence on the OPEC nations [7, 8].

For most developing countries, biomass particularly agricultural wastes, has become one of the most promising energy sources. Biomass are organic matter in the original natural form, growing on the basis of photosynthesis, collecting and transforming solar energy into plants [9]. Biomass are excellent renewable energy sources intensively used as substitute for fossil fuels such as coal, petroleum products in the modern world [10]. Huge volumes of agricultural residues and residues from wood processing mills are not fully utilized. One of the major world crop, rice, has about 25% of the crop in the form of husk which amounts to about 100 million tonnes of husks while groundnut has about 45% of it in the form of shells, with a production of about 10 million tonnes worldwide [10]. In the light of this, it is reasonable to assume that about 25% of any agricultural feed stock is residue [11].

Briquette is described as a substance made when small particles of solid materials are pressed together to form a coherent shape of large size with or without a binder [12].

In Malaysia, briquetting has been used to upgrade the properties of oil palm biomass [13, 14] reported increased energy content and reduced moisture content of 5% and 38% of palm biomass briquettes. Where a binder is used in briquettes making, the binder to waste ratio is important so as not to confer unnecessary material strength to the briquettes and affects the mechanical characteristics, such as compressive strength [15].

2. Materials and Methods

2.1. Sample Collection

Samples of sheanut shells was collected from Aliero, Latitude $12^0$17'24.14"N and Longitude $4^0$28'1.57"E town of Kebbi State, Nigeria, while cassava starch was purchased at the Sokoto Central Market, Sokoto, Nigeria.

2.2. Sample Preparation

The collected sample was sun-dried for three days to drive off moisture and then pulverized and sieved with 80 mesh sieve to obtain a fine particle size. The pulverized sample was kept in a polyethene bag until required for briquettes preparation.

2.3. Preparation of Briquettes

A cylindrical mould 16 cm in length and 2.5 cm internal diameter was constructed. A metal bar of 2.3 cm diameter was used in pushing the formed briquette out of the moulding cylinder.

The pulverized sample was thoroughly mixed with the slurry of starch (the binder) in the mass ratio of 6:1 [16]. The mixture was then loaded into the cylindrical mould and compressed with a screw presser and kept for 30 mins. The densified briquette was pushed out of the mould with the aid of the metal bar. The same procedure was repeated several times to obtain a good quantity of briquettes. The briquettes so produced were then air dried for three weeks [17].

2.4. Determination of Moisture Content

A sample of the briquette was weighed (W_i) and placed into an oven whose temperature has been adjusted to 110°C and left for 24 hours after which it was removed and re-weighed (W_f) after cooling [18]. The moisture content was computed from equation 2:

$$\text{Percentage (\%) moisture} = \frac{W_i - W_f}{W_l} X\ 100\% \tag{2}$$

2.5. Determination of Ash Content

A sample of the briquette was placed in a pre-weighed crucible (W_c) and weighed (W_{sc}). The crucible was heated at 600°C for 2 hours in a furnace. It was allowed to cool to room temperature before it was re-weighed (W_{ac}). The ash content was computed from equation 3:

$$\text{Percentage \% ash content} = \frac{W_{ac} - W_c}{W_{sc} - W_c} X\ 100\% \tag{3}$$

2.6. Determination of Volatile Matter

Volatile matter is defined as those products, exclusive of moisture, given off by a material as gas or vapour. The volatile matter of the sample was determined using the Meynell's method. The dry sample from the moisture content determination was heated at 300°C in a furnace for 2hrs to drive off the volatiles. The temperature was then raised to 470°C for 2hrs (just before the material turns black i.e. before it ashes). The volatile organic matter was calculated from equation (4).

Volatile matter = wt of residual dry sample – wt of dry sample after heating

$$Volatile\ Matter\ \% = \frac{W_1 - W_2}{W_1} \times 100 \tag{4}$$

2.7. Determination of Fixed Carbon

Fixed carbon represents the quantity of carbon that can be burnt by a primary current of air drawn through hot bed of a fuel. The fixed carbon content of the samples was calculated using equation (5) [19].

$$Fixed\ Carbon\ Content\ (\%) = 100 - (MC(\%) + VM\ (\%) + AC(\%) \quad (5)$$

Where
MC - Moisture Content
VM - Volatile Matter
AC - Ash Content

2.8. Determination of Flame Propagation

This was determined as described by [20]. A piece of the briquette was graduated in centimeters, ignited at one end and allowed to burn until it extinguished itself. The flame propagation rate was estimated by dividing the distance burnt by the time taken in seconds.

2.9. Determination of Afterglow Time

The afterglow time was determined in order to estimate how long the individual briquette will burn before restocking when used in cooking and heating. The procedure of [20] 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.

3. Results

***Table 1.** Proximate Analysis of Raw and Briquetted Samples.*

Sample	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
SN (R)	3.50±0.50	2.50±0.40	10.50±0.33	83.50±0.40
SN (B)	2.50±0.50	4.50±0.10	16.00±0.50	77.00±1.40

*Values are mean standard deviation of triplicate result.

***Table 2.** Viability properties of sheanut shell briquettes.*

Sample	Density (g/cm^3)	Compressive strength (Mpa)	Ignition time (mm/s)	Afterglow time (s)
SN (B)	0.46±0.10	2120.00±1.00	1.70±0.03	38.0±0.85

*Values are mean standard deviation of triplicate result.

***Table 3.** Combustion characteristics of sheanut shell briquettes.*

Sample	Combustibility test (mins)	Calorific value (Mj/Kg)	Specific Power Output (W/Kg)	Efficiency, based on kerosene (%)
SN (B)	22	6.75±0.18	439.95	73.58
Kerosene	16	-	597.96	100.00

Key:
*SN(R) – Sheanut shell raw sample
SN (B) – Sheanut shell briquette.

4. Discussion

Strong and well-formed briquettes were obtained as shown in figure 1.

***Figure 1.** Sample of Briquettes prepared from Sheanut-Shell.*

The total energy that is needed to bring a briquette up to its pyrolytic temperature is dependent on its moisture content which affects the internal temperature within the briquette due to endothermic evaporation [21]. From Table 1, the moisture content varied from 2.50% (Briquetted sample) to 3.50% (Raw Sample). It is observed that densification has reduced the moisture content of the waste residue and it falls within the range of 10 – 15% as recommended by [22] which helps in storage and combustibility. It is also noted that moisture content in excess of 20% would result in considerable loss in energy during combustion [23]. This indicates that the briquetted sample would be a good source of fuel as a result of the low moisture content.

Ash is the noncombustible component of biomass and it has a significant influence on the heat transfer to the surface of a fuel as well as the diffusion of oxygen to the fuel surface during the char combustion [24]. The ash content of the material varied from 2.50% (Raw Sample) to 4.5% (Briquetted sample). It was observed that briquetting has increased the ash content of the material to almost two-fold which is in agreement with the work of [25]. The lower the ash content of a briquette, the better the quality of the fuel, hence the sheanut shell briquette is a good fuel as supported by its combustibility results in Table 3.

The result of the volatile matter varied from 10.50% (Raw sample) to 16.0% (briquetted sample). It is noted that briquetting has improved the volatile matter of the waste material and the higher the volatile matter of a fuel briquette, the higher the combustibility of the fuel briquette when the ash content is low [26]. High volatile matter is an indication of easy ignition of the briquette and proportionate increase in flame length [27].

The fixed carbon of the briquette, which is the percentage of carbon (Solid fuel) available for char combustion after the volatile matter is distilled off, gives a rough estimate on the heating value of a fuel and acts as the main heat generator during burning [24]. The result of the fixed carbon varied from 77.0% (briquetted sample) to 83.50% (raw sample). It is noted that the raw sample has a higher fixed carbon content than the briquetted sample and the low fixed carbon of the briquetted sample indicates prolong cooking time but with low heat released [28].

The result of the viability test (density, compressive strength, ignition time and afterglow time) are shown in Table 2.

It has been stated that density of biomass briquettes depends on the density of the original biomass material [29]. The density of the briquette was 0.46(g/cm^3). However, this value is higher than the densities of elephant grass and spear grass briquettes with 0.319(g/cm^3) and 0.367(g/cm^3) respectively as reported by [30]. Although the briquetting process increased the density of the bulk material; improved its handling characteristics, but it was still relatively low. Low density biomass briquettes usually have low energy and cooking with such briquettes in a briquette stove requires frequent re-feeding the stove with the briquette especially for a cooking that requires a long simmering phase due to its low mass to volume ratio [31]. The compressive strength of the briquette materials was 2120MPa which is reasonable when compared to elephant grass and spear grass briquettes [30]. The high compressive strength and maximum force of the sheanut shell briquettes, indicates more volume displacement which is good for packaging, storage and transportation and above all, it is an indication of good quality briquette because of the strong inter-particle bonds that exist [32].

The end-point of ignition in subjective and depends on one's judgement according to what stage has ignition been achieved [33]. In this study, ignition time was taken as the average time taken to achieve a steady glowing flame. The result of the ignition time was 1.70(mm/s) and is higher than those of rice husk (1.0mm/s) and corncob (1.2mm/s) as reported by [20] while the afterglow time of 38.0sec was recorded and is lower than those of rice husk and corncob as reported by [20]. This could be attributed to the high density of the briquette which results in delayed ignition time and reduced porosity [34]. Reduction in air content within the matrix of the briquette has inhibited flame propagation due to low thermal conductivity [33].

The results of the combustibility characteristics of the fuel briquette is shown in Table 3. The combustibility test was carried out to compare the cooking efficiency of the briquette and it measures the time taken for the briquette to boil an equal volume of water under similar conditions. From the result on Table 3, it took the sheanut shell briquette 22 minutes to boil 2 litres of water while it took the kerosene stove 16 minutes to boil same quantity of water. The calorific value of a fuel is the amount of energy liberated by burning a unit mass of the fuel. The computed calorific value of the briquette was 6.75(MJ/kg) and is observed to be far lower than some wood species such as Iroko (18.60MJ/kg), Mahogany (18.24MJ/kg) and silk cotton (16.93MJ/kg) as reported by [30].

The specific power output was 439.95(W/kg) while that of kerosene was 597.96(W/kg) and this low value could be attributed to the high density and low propagation time of the briquette [33]. Also the efficiency based on kerosene was computed to be 73.58% which indicates that the sheanut shell briquette is good for cooking in households and can be used for heating in cottage industries.

5. Conclusion

The findings of this study have shown that briquettes produced from sheanut shell would make a good biomass fuel which could be used for cooking and ironing. It can also be said that this biomass briquette will not crumble during transportation and storage due to the high values obtained for its density and compressive strength. Hence, an efficient and affordable alternative source of energy can be obtained from this waste residue which could be a source of nuisance to the environment.

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