Estimation of Combustion Properties of Briquettes Produced from Palm Fruit Shell

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Abstract- Agricultural residue briquettes can be used as a fuel for heating, cooking and other domestic and industrial applications. This article explored the potential of using palm fruit shells to make briquettes as an alternative fuel for both domestic and industrial use. This will significantly reduce the problem of deforestation and excessive dependence on fossil fuels and reduce the impact of greenhouse gas emissions generated by trees as a fuel for wood. Cassava starch was used in an amount of 100:15 by weight and the burning properties of the produced palm fruit briquettes were determined. The combustion characteristics of the palm fruit briquettes produced are 7.56% average moisture, 17.45% average volatiles, 6.68% average ash, 68.28% average bound carbon and 9717.74 kcal /kg of average calorific value. These results, compared with the literature, showed that briquettes made from palm husks have good combustion properties, which makes them suitable for domestic applications and small industries.

Keywords: Briquettes, palm fruit shell, calorific value, domestics use, agro residues

1. Introduction

Biomass briquetting is the compaction of loose agricultural residues with or without binder into compact solid composites of various sizes by the application of pressure [1]. Briquettes are the products formed by the physical-mechanical conversion of dry, loose material, of small particle size, with or without the addition of an additive, into a solid state of regular shape [1]. Briquettes are mainly used where heat applications are required (steam generation, metal smelting, space heating, brick kilns, tea treatment, etc.) and for energy generation through the gasification of biomass briquettes and for domestic use [1].

Reference [2] referred to the huge agricultural residue waste management problem facing developing countries. They said these agricultural and sawmill residues are usually burned on roadsides or in landfills, causing pollution problems. However, they identified the need to convert these residues into usable fuels. These residues are very difficult to handle and store and, if burned directly, result in very low thermal efficiency and high levels of air pollution. However, they concluded that these problems could be avoided by briquetting the residual biomass into a usable fuel that produces energy. This will make biomass briquettes an alternative to fossil fuels, improve waste management and reduce air pollution.

Reference [3] in his work observed that the caloric values of briquettes of mixed sawdust from three tropical hardwoods, bound with starch, cow dung and wood ash as binding agents, were high. He mixed the sawdust of each species with the binder in a ratio of 70:30 for cow dung and wood ash and 70:15 for starch. He used a 1: 1 ratio to mix the sawdust for each combination of briquettes he produced. His results showed that the best combination of briquettes was sawdust mixed with starch.

Reference [4] conducted an experimental test on the effect(s) of starch and gum arabic as binders on the combustion properties of sawdust briquettes in different ratios. The briquettes were produced by mixing with the binders. The blends were compressed to 110 kN using a manually operated hydraulic briquetting machine and the products were dried in the sun. They estimated the calorific values, the volatiles and the flame temperature of the briquettes produced. In their results, briquettes formed using starch as a binder had better combustion properties than briquettes formed using gum arabic as a binder.

Reference [1] compared the calorific values of briquettes produced by the binary and tertiary combination of biomass briquettes made from sawdust from Afzelia africana, Daniella oliveri and rice hulls with binder contents of 20%, 30% and 40% starch. They carried out an immediate analysis of the briquette samples and observed significant differences (p>0.05) between the densities, the percentage of ashes, the percentage of volatiles and the percentage of bound carbon. They observed a gradual increase in the calorific value of biomass briquettes produced with increasing intensity. They found that briquettes made from the tertiary combination of Afzeliaafricana + Daniella oliveri + rice husk biomass had the highest and lowest calorific values of 4827.20 kcal/kg and 4586.72 kcal/kg at 40% and 20% starch, respectively. They also found that the tertiary combination had the highest and lowest ash content of 9.29% and 4.30% at 20% and 40% starch content, respectively. They therefore recommended using a starch content of 40% for the production of biomass briquettes.

Reference [5] had produced biobriquettes using Napier grass, Spear grass and Biochar at moderate pressure and temperature. They performed extensive analyzes and compared their results with wood samples. Their goal was to replace firewood with briquettes in rural Nigerian households.

Briquetting biomass is a way to generate energy from agricultural waste. Biomass briquettes were developed using different types of agricultural waste. The production of biomass briquettes from agricultural and municipal waste streams could lead to viable fuel production. In this research, we estimated the combustion properties of briquettes made from palm fruits shells.

2. Materials and Methods

Palm fruits shell were homogeneously mixed with cassava starch in a weight ratio of 100:15 as described by Sotannde et al. [6], Martin et al. [7]. This mixture was fed into a briquetting machine designed and manufactured by Inegbedion and Francis-Akilaki [8] to produce the briquettes required. This machine, a single extrusion screw press, mainly consisted of a drive motor, speed reducer, feed auger, die and housing containing a hopper. The drive motor directly transfers the power to the auger through the speed reducer. While the machine is working, the raw materials are fed into the compression chamber through the hopper, the raw materials are compressed into the barrel by the screw and extruded through the nozzle. The screw continuously pushes the materials into the die. In an extrusion die screw press, pressure builds up along the screw rather than in a single area as in piston machines. Figure 1 shows briquettes made from palm bark bound with cassava starch.

Fig. 1. Briquettes produced using from Palm Fruits Shell

2.1 Determination of Moisture Content of the Palm Fruit Shell Briquettes Produced

To estimate the percentage moisture content (PMC), 1.5g samples of the palm fruit peel briquettes produced were weighed using a crucible of known mass and placed in an oven set at 105 °C±5°C. The crucible and its contents were removed from the furnace after one (1) hour and allowed to cool to room temperature, after which the crucible and its contents were reweighed. This procedure was repeated until a constant weight was recorded. Equation (1) was used to estimate the percentage moisture content of the sample briquettes produced.

$$PMC = \frac{W_1 - W_2}{W_2} \times 100\% \tag{1}$$

W_1 is the initial weight, while W_2 is the final weight of briquette sample respectively.

2.2 Determination of Volatile Matter of the Palm Fruit Shell Briquettes Produced

The percentage volatile matter (PVM) of the palm fruit shell briquettes produced was estimated by placing 1.5 g of the briquette sample in a crucible and keeping it in a furnace at a temperature of 550°C. ± 5°C for 8 minutes, then weighed after allowing it to cool to room temperature. The percentage volatile matter of the briquette samples produced was estimated using equation (2).

$$PVM = \frac{W_2 - W_3}{W_3} \times 100\% \tag{2}$$

W_2 is the weight of the oven-dried sample (g) while W_3 the weight of the sample after 8 min in the furnace at 550 °C (g)

2.3 Determination of Ash Content of the Palm Fruit Shell Briquettes Produced

1.5 g samples of the produced palm fruit briquettes were stored in a controlled oven and completely burned. An electronic scale was used to record the weight of the residue. Equation (3) was used to estimate the percentage by weight of the residue, which is the ash present in the sample.

$$PAC = \frac{W_4}{W_2} \times 100\% \qquad (3)$$

2.4 Determination of Fixed Carbon of the Palm Fruit Shell Briquettes Produced

The percentage fixed carbon (PFC) of the palm fruit shell briquettes produced were determined using equation (4) [9].

$$PFC = 100\% - (PMC + PVM + PAC) \qquad (4)$$

2.5 Determination of Calorific Value of the Palm Fruit Shell Briquettes Produced

The calorific values of the briquettes produced were determined using a bomb calorimeter. We completely burned 1.5 g of the briquette sample in oxygen oxides. The heat released during combustion was absorbed by the water and the calorimeter. The heat lost due to the combustion of the briquettes was the heat gained by the water and the calorimeter. We used equation (5) to estimate the calorific value (CV) of the briquettes produced from the measured data [10].

$$CV = \frac{BFx\ \Delta t - 2.3\ length\ of\ wire}{W} \qquad (5)$$

Where: BF = Burn Factor; Δt = Change of temperature ($t_2 - t_1$)°C; t2 = final temperature; t_1 = initial temperature; W = mass of the sample used and BF = constant = 13,257.32.

3. Results and Discussion

The estimated combustion properties of the palm fruit shell briquettes produced were: percentage moisture content, percentage volatile matter, percentage ash content, percentage fixed carbon, and calorific value.

Table 1. Percentage Moisture Content (PMC) of Palm Fruit Shell Briquettes

Sample	PMC (%)
1	7.65
2	7.52
3	7.60

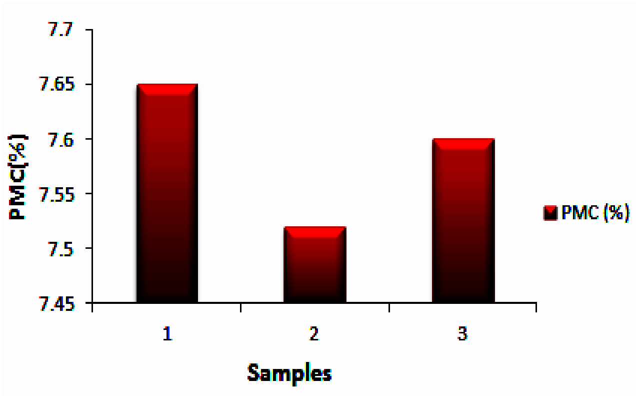

Fig. 2. Percentage Moisture Content (PMC) for Palm Fruit Shell Briquettes

In Table 1 and Figure 2, we present the results of the average percent moisture content (APC) of the produced palm fruit shell briquette being 7.56%. These results compared to the work of Pallavi et al. [11] agreed with their recommendation of 5-10% moisture content for quality briquettes. Reference [9] indicates that briquettes are easy to ignite when the moisture content is low and have a high calorific value.

Table 2. Percentage Volatile Matter (PVM) for Palm Fruit Shell Briquettes

Sample	PVM (%)
1	17.45
2	17.48
3	17.42

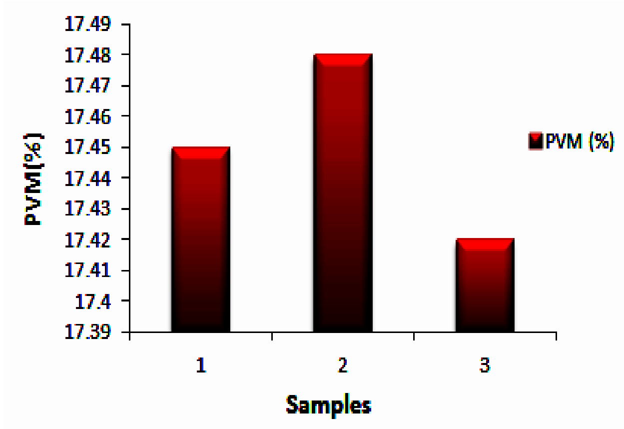

Fig. 3. Percentage Volatile Matter (PVM) for Palm Fruit Shell Briquettes

Table 2 and Figure 3 showed the results of the average percentage volatile matter (PVM) for the palm shell briquette produced being 17.45%. High volatile matter indicates easy ignition, rapid burning, and proportional elongation of flame length, but low calorific values [12]. The briquette produced from palm fruit shell has a percentage volatile matter between 10% and 25% for good quality briquettes, as reported by [12].

Table 3. Percentage Ash Content (PAC) for Palm Fruit Shell Briquettes

Sample	PAC (%)
1	6.58
2	6.98
3	6.47

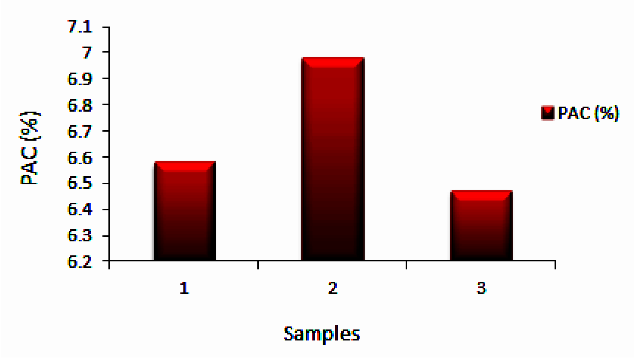

Fig. 4. Percentage Ash Content (PAC) for Palm Fruit Shell Briquettes

In Table 3 and Figure 4, we have presented the results of the average percentage ash content of the palm fruit shell briquettes produced as 6.68%. Reference [10] reported that low ash content indicates higher calorific values for briquettes, but high ash content leads to high dust emissions affecting combustion volume and briquette efficiency. Reference [13] noted that high ash content resulted in a lower calorific value and vice versa, as it minimizes the heat transfer to the internal parts of the fuel and the diffusion of oxygen on the brick surface during coal burning, which affects the burning rate.

Table 4. Percentage Fixed Carbon (PFC) for Palm Fruit Shell Briquettes

Sample	PFC (%)
1	68.32
2	68.02
3	68.51

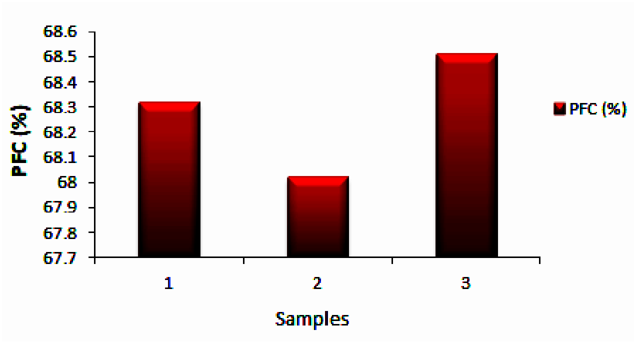

Fig. 5. Percentage Fixed Carbon (PFC) for Palm Fruit Shell Briquettes

Table 4 and Figure 5 showed that the average percentage of fixed carbon for the palm fruit shell briquettes produced was 68.28%. These results compared to the result of Pallavi et al. [11] reporting the suitability of solid carbon briquettes at 80.5% for domestic applications shows a good agreement. Reference [14] reported that the higher the fixed carbon content of a fuel, the higher the calorific value, the lower the volatile matter, the lower the ash and moisture content and the better the fuel quality.

Table 5. Calorific Values (CV) for Palm Fruit Shell Briquettes

Sample	CV (kcal/kg)
1	9,710.53
2	9,721.12
3	9,721.56

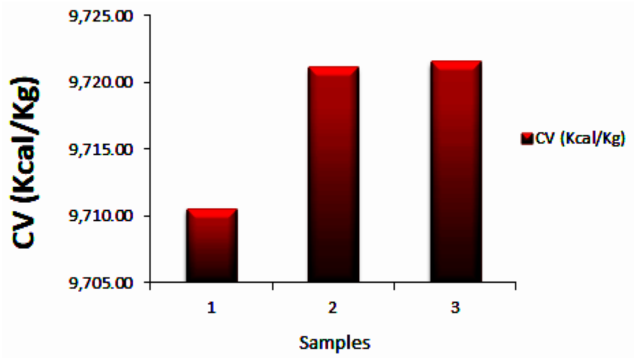

Fig. 6. Calorific Values (CV) for Palm Fruit Shell Briquettes

Calorific value is the amount of thermal energy present in a material. In Table 5 and Figure 6 we presented the average calorific value for the palm fruit briquette produced as 9717.74kcal/kg. Reference [1] in their work obtained caloric values ranging from 4586.72kcal/kg to 4827.20kcal/kg and reference [3] in their work obtained caloric values ranging from 33116kcal/kg to 23991kcal/kg when compared to the results obtained from this work showed that the briquettes samples produced have good combustion properties that are good enough for domestic use and small-scale industrial applications.

4. Conclusions

Fossil fuels, gases and wood fuels are the main source of energy for such household activities. Excessive use of these fuels can lead to problems such as global warming, air pollution and deforestation. It is high time to transform agricultural, sawmill and municipal waste into useful briquettes which will be good substitutes for these fuels. This work focused on estimating the calorific values of palm husk briquettes to determine their suitability for domestic and small-industrial application. The results obtained indicate that the briquettes obtained from the shell of palm fruits have high combustion properties sufficient for domestic use and for small-scale industrial applications.

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