



DETERMINATION OF PHYSIO-THERMAL PROPERTIES OF BRIQUETTES MADE FROM SAW DUST, SUGARCANE BAGASSE AND RICE HUSK

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ABSTRACT

This study was specifically conducted to determine the physical and thermal properties of briquettes made from saw dust, sugarcane bagasse and rice husk and binding materials (cassava starch and cow dung). The idea of the study emanates from the urge to solve the environmental challenges of two neighbouring rural communities where saw dust, rice husk and sugarcane bagasse have become a menace. The briquettes used in the study of physio-thermal properties were made of sawdust as biomass with cow dung as binding material, rice husk and sugarcane bagasse as biomass materials both with cassava starch as binding material in varying ratios with the aid of a screw-press briquetting machine. Properties of the briquettes studied include moisture content, density, shatter resistance, burning rate, water boiling time test and fuel consumption rate. The results obtained showed that sugarcane bagasse briquettes contain more moisture than the other produced briquettes with values ranged between 13.63 and 14.94%. This implies that briquettes produced from sugarcane bagasse with cassava starch binders would take longer time to dry and combust than the other briquettes. It was also observed that briquettes from sugarcane bagasse have greater shatter resistance of 100% while briquettes from rice husk have less shatter resistance of 55.56 - 83.33%. Similarly, sugarcane bagasse briquettes have highest density value of 0.0004236 kg/cm³; while rice husk has the lowest density value of 0.000190 kg/cm³. The study was able to produce briquettes that provided cheap and safe energy for the two communities, thus resolving the environmental and health challenges posed by the not easily disposed abundant of waste biomass in the locality.

Keywords: Biomass, Briquettes, Burning Rate, Physical Properties, Thermal Properties

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INTRODUCTION

Most of the world's energy demand is met by fossil fuel, a non-renewable energy source that is mainly derived from coal, crude oil and natural gas, providing about 80% of man's energy requirements. Thus, the current energy needs is thus largely dependent on fossil fuels, which negatively affects air quality and contribute significantly to greenhouse gas emission [1]. Fossil energy in both urban and rural areas has also become a huge challenge due to its non-availability, high cost and environmental problems [2]. However, this source of energy depreciates as such alternative energy source might be inevitable in meeting man's energy needs in the near future that has been the major concern of the world today [3, 4]. Clean, efficient, affordable and reliable energy system is indispensable for global prosperity. Use of agricultural residues as source of energy that could be the promising energy resource for domestic and industrial development is being underutilized most especially in Nigeria and other developing countries. Converting such residues into briquettes for cooking and other domestic needs as well as for industrial purposes has not been widely accessible and successful especially in Nigeria and most developing countries. Previous studies on biomass briquetting has shown that Sugarcane Bagasse and Rice Husk has been proved to be good materials for briquette

production. [5, 6]. Market for briquette have not also been fully explored in these areas, as the rural people depend on upon direct combustion of biomass available in the locality. Most of the biomass energy source are, thus consumed using traditional household technologies (direct combustion) thereby contributing to increased forest degradation and release harmful gases and particulate matters that often cause indoor air pollution which is health hazardous to the user and the environment [2].

However, exposure to waste biomass smoke through direct combustion contains a large number of pollutants at varying concentration posing substantial risk to human health on children and adult Acute Lower Respiratory Infection (ALRI) especially pneumonia among children [7, 8]. A large number of agricultural residues such as corn stalks, groundnut shell and husks generated in rural areas are mainly deposited on farms or burnt directly on the field thereby causing severe ecological problems [2, 8]. A more efficient method of using and/or disposing these residues could be developed to improve the energy situation and provide sustainable and safe environment [9].

Conversion of these residues through briquetting process will go a long way in solving their disposal problems. In addition, deforestation which promotes pollution will be drastically reduced [10, 11]. It is, therefore necessary to characterize such converted

biomass residues. The objective of this study is to determine the physical and thermal characteristics of briquettes made from sugarcane bagasse and rice husk with cassava starch as binder and saw dust with cow dung as binder used in order to analyze the quality of fuels used in order to reduce the hazardous effects of direct combustion emanating from the urge to solve the environmental challenges of two neighbouring rural communities of the university for healthier and safer environment.

MATERIALS AND METHODS

Materials selection and instrumentation

The materials used in conducting the study includes briquettes form the selected waste biomass materials, an improved cookstove, 50 kg capacity weighing balance (WT1000KF, 0.001 accuracy), heat resistant pad used to protect the scale, 1000 ml capacity measurement cylinder, digital thermometer (100 °C capacity, accuracy: 1/10 of a degree with thermos-couple probe suitable for immersion in liquids), digital stop watch with sensitivity of 0.01sec accuracy, small shovel/spatula to remove briquette from stove, tongs for handling briquettes, dust pan for transferring briquettes, small standard pot(s) of 3.5 liters and metal tray to hold briquettes for weighing, heat resistant gloves and bundles of briquettes fuelwood (saw dust, rice husk and sugarcane bagasse) each weighing between 1 and 2 kg for each test while a screw press biomass briquetting machine was used in producing the briquettes.

The briquettes used in the study of physio-thermal properties were made of sawdust as biomass with cow dung as binding material, rice husk and sugarcane bagasse as biomass materials both with cassava starch as binding material. The choice of these biomass materials and the binders specifically emanates from the urge to solve the environmental challenges of a rural community.

Methods of physio-thermal tests

The following tests were conducted to determine the physical and thermal properties of the briquettes used for the study:

Determination of moisture content

The moisture contents of the briquettes were determined using the standard oven-dried method in accordance with the ASAE (1998). Each sample of briquette was weighed and then oven-dried at 105°C to constant masses for 3 hours [12, 13]. The loss in mass, expressed as a percentage of final oven-dried mass was taken as the moisture content of the briquettes [14]. The expression in Eqn. (1) was used for the determination of the moisture content as given by Mohsenin [15]:

$$MC = \frac{(W_1 - W_2)}{W_2} \times 100 \quad (1)$$

Where, MC = moisture content (%), W_1 = wet weight (kg), W_2 = weight after drying (kg).

Density test of the briquettes

The densities of the briquettes (ρ) used for the study were calculated as suggested by Maira *et al.* [16] in Eqn. (2):

$$\rho = \frac{M}{V} \quad (2)$$

$$V = \frac{\pi D^2}{4} L$$

Where: M = mass (g), V = volume (cm³), D = diameter (cm) and L = length of individual pellet (cm).

Determination of shatter resistance

The shatter resistance is applied in simulating the forces encountered when emptying the briquettes or moving them from one place to another [17]. The method adopted in determining the shatter resistance in this study was as suggested by Birwatkar *et al.* [14] and Sengar *et al.* [18]. The sample was dropped onto the concrete floor from 2 m high 3 times continuously. Shatter resistance of the briquettes was computed when the weight of the sample briquettes was recorded before and after shattering, and thus the percentage of shatter resistance calculated from Eqn. (3):

$$W_l = \frac{(W_1 - W_2)}{W_2} \times 100 \quad (3)$$

Where: W_1 = initial weight (g), W_2 = final weight (g)
Shatter Resistance (%) = 100% - weight loss (%)

Water boiling time test

Water boiling test was conducted using all the produced briquettes on the cookstove. Time spent in boiling and the total weight of boiled water were used to compute the results of water boiling test. A stainless-steel pot with 3.6 kg weight, stop watch, weighing balance and blocks of briquette samples were used to heat and boil 1litre of water as detailed by Parmar *et al.* [19] in Eqn. (4):

$$BT_w = \frac{T}{W_{bw}} \quad (4)$$

Where; BT_w = Water boiling time (min/kg),
T = total time spent in boiling water,
 W_{bw} = total weight of boiled water

Burning rate test

The burning rate test was conducted from Eqn. (5) as suggested by Okwu *et al.* [20]; Akinwande and Olatunde [21]:

$$\text{Burning Rate} = \frac{(\text{Mass of fuel consumed})}{\text{Total time taken}} \quad (5)$$

Determination of Fuel Consumption Rate

The rate at which the briquettes samples were burnt was determined from Eqn. (6) as suggested by Madhava *et al.* [22]; Okwu *et al.* [20]:

$$R_{fc} = \frac{W_i - W_f}{T} \quad (6)$$

Where:

R_{fc} = Fuel consumption Rate (L/s), W_i = Initial mass of fuel (g), W_f = Final mass of fuel after consumption (g), and T = Total boiling time (s)

RESULTS AND DISCUSSIONS

Briquettes from sugarcane bagasse, saw dust and rice husk materials with different binders (cassava starch and cow dung) have produced (Figure 1) while their physical and thermal characteristics have been determined. Results obtained during the course of the study were also subjected to descriptive statistical analysis as discussed under the following sub-headings:

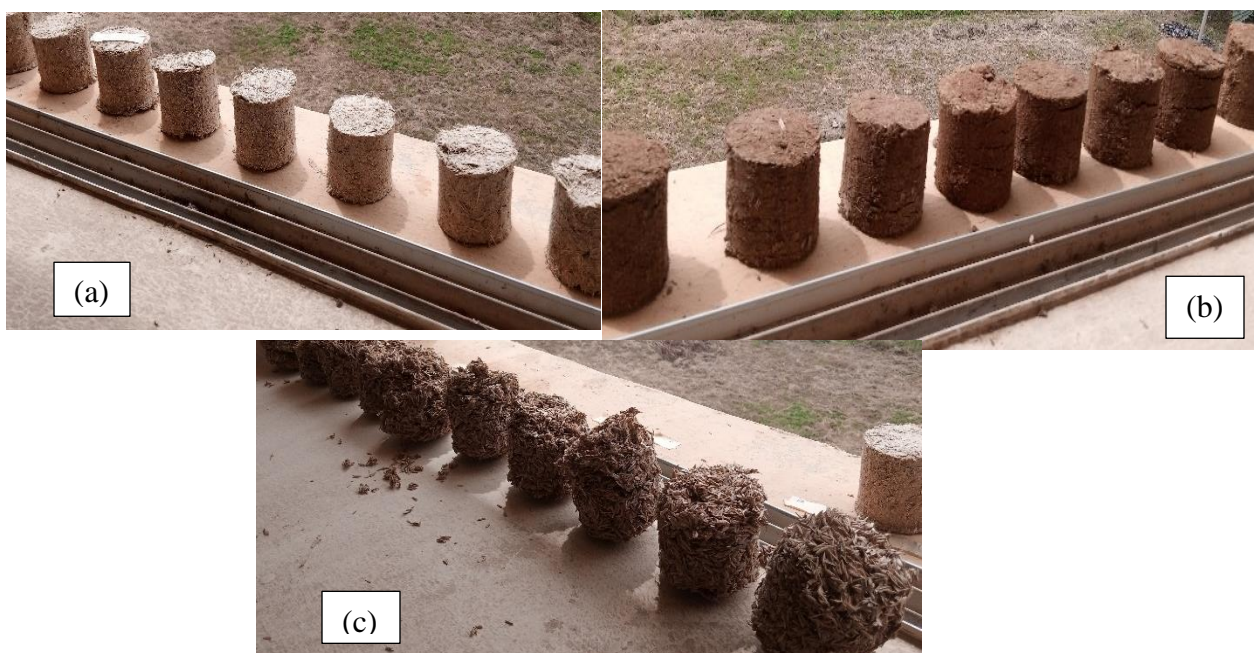


Figure 1: Pictorial views of the Produced Briquettes (a) Sugarcane Bagasse, (b) Saw Dust and (c) Rice Husk Materials

Moisture contents of the briquettes

The moisture content of the briquettes produces were presented in Table 1. Sugarcane bagasse was observed to contain more moisture than the other briquettes whose values ranged between 13.63 and 14.94%. The implication of this is that briquettes produced from sugarcane bagasse with cassava starch binders would take longer time to dry. It would also take longer time to combust than the other briquettes produced. This was in perfect agreement with the findings of Tembe *et al.* [10] and Sengar *et al.* [18] in separate studied conducted. Bikash *et al.* [23] also observed similar challenges of combustion on wet briquettes.

Briquettes produced with rice husk and cassava starch as binder, on the other hand have the lowest moisture contents of 11.11% for all the trials conducted; thus: indicating that these briquettes would be easily combusted and do not take much time to dry when compared the other briquettes. Lower moisture contents of this briquettes could be attributed to the porous textural structure of the briquettes that allows easy circulation of air and heat within it, a discovery that conform with some past studies [11, 24, 25, 26]. Similarly, the range of moisture level (11 – 12.35 %) obtained from saw dust is similar to what was obtained

by Adegoke and Mohammed [4] and Grover and Mishra [27].

Table 1: Moisture content of the briquettes

Briquette	Sample	Initial Mass (g)	Final Mass (g)	Moisture Content (%)
Sugarcane Bagasse and Cassava Starch	SS 1	10	8.8	13.64
	SS 2	10	8.7	14.94
Rice Husk and Cassava Starch	RS 1	10	9.0	11.11
	RS 2	10	9.0	11.11
Saw dust and Cow Dung	SC 1	10	8.9	12.35
	SC 2	10	9.0	11.11

Density of the Briquettes

Table 2 presents the density of the briquettes produced. Briquettes from sugarcane bagasse briquette displayed the highest density values ranging from of 0.0004187 to 0.0004236 kg/cm³. It could also be observed that the density values of saw dust briquette samples were next to sugarcane bagasse with values ranging between 0.0003003 and 0.0003050 kg/cm³; while briquettes from rice husk were less dense with values ranging from 0.0001899 to 0.0001940 kg/cm³. The briquettes

produced from sugarcane bagasse and saw dust were denser than those of rice husk, a characteristic that allow them to burn with very high combustion efficiency and has more positive attributes of biomass fuel than its rice husk counterpart as reported by Nwaokocha and Giwa [28]. All these observations could be affirmed with the related study by Onuegbu *et al* [28] in their comparative analyses of densities and calorific value of wood and briquettes samples.

Table: 2: Density of the briquettes

Briquette Material	Sample	Mass of dried sample(kg)	Volume (cm ³)	Density (kg/m3)
Sugarcane Bagasse & Cassava Starch	SS 1	0.181	432.26	0.0004187
	SS 2	0.183	432.26	0.0004236
Rice Husk & Cassava Starch	RS 1	0.089	458.04	0.0001940
	RS 2	0.087	458.04	0.0001899
Saw dust & Cow dung	SC 1	0.135	442.61	0.0003050
	SC 2	0.133	442.61	0.0003005

Results obtained (Table 2) is also in agreement with the study of Antwi-Boasiako and Acheampong [25], who found briquette density is affected significantly by the raw material particle size, wherein finely ground materials produce denser briquettes. This was also confirmed by Mitchual *et al.* [30] suggesting that raw material with finer particles results in the production of briquette with a higher density. It was also observed that

the denser a briquette is, the more it resists water absorption, thereby making it safer during storage and transportation processes as earlier noted by Okot *et al.* [31]. Similarly, briquettes with higher densities generally have higher calorific values as rightly observed by Emerhi [11] and Tumuluru *et al.* [32].

Shatter resistance of the briquettes

Results presented in Figure 2 shows shatter resistance tests of the briquette where the briquettes were dropped from a certain height. Shatter resistance is a direct means of gauging the strength of briquettes for the purposes of handling, transportation and storage. Results in Table 2 show that briquettes from sugarcane bagasse recorded the greatest shatter resistance of 100%, this was closely followed by the briquette samples from saw dust with shatter resistance values ranging from 95.16 to 97.64%. However, the shatter resistance of briquette samples from rice husk shows a wide range of shatter resistance values of 55.56 to 83.33%.



Figure 2: Shatter resistance test

Table 3: Shatter Resistance Tests of the Briquettes

Briquette Material	Sample	Mass of sample Before Drop (kg)	Mass of sample After Drop (kg)	Mass Loss (%)	Shattering Resistance (%)
Sugarcane Bagasse & Cassava Starch	SS 1	194	194	0	100
	SS 2	187	187	0	100
Rice Husk & Cassava Starch	RS 1	72	40	44.44	55.56
	RS 2	84	70	16.67	83.33
Saw dust & Cow dung	SC 1	127	124	2.36	97.64
	SC 2	124	118	4.84	95.16

The results of the best shatter resistance obtained for the sugarcane bagasse and saw dust were similar to what was obtained by Ajiboye *et al.* [24] (98.21% and 98.17%) in a study conducted. These results were in agreement with Borowski *et al.* [34] who determined the acceptable shatter resistance of briquettes to be a minimum of 90%. The shatter resistances of these briquettes (The shatter resistance of a briquette shows its ability to produce fewer fines during handling) reveals that they can be good for transportation and storage [24].

Burning rates of the briquettes

Results presented in Figure 3 shows burning rate of the briquettes produced. The flame time test results for all

briquette samples (Table 4), indicates that the burning rate of saw dust briquette had the highest burning rate of 0.02020 kg/min. This was closely followed by the rice husk briquette with 0.01333 kg/min. this could be attributed to the fact that these briquettes had similar moisture content even as their densities differs. The results further show that briquettes produced from sugarcane bagasse has the least burning rate of 0.00956 kg/min when compared with other briquettes studied. This agrees with the discoveries of Nwaokocha and Giwa [28] and Onuegbu *et al.* [29] that denser briquettes have the best calorific values.



Figure 3: Burning rate test

Table 4: Burning rate of briquettes with their binders

Briquette Material	Sample	Mass of Fuel Consumed (kg)	Total Time Taken (min)	Burning Rate (kg/min)
Sugarcane Bagasse & Cassava Starch	SS 1	0.093	8	0.011625
	SS 2	0.086	9	0.00956
Rice Husk & Cassava Starch	RS 1	0.080	6	0.01333
	RS 2	0.075	9	0.00833
Saw dust & Cow dung	SC 1	0.101	5	0.02020
	SC 2	0.102	8	0.01275

Boiling time test

Results obtained from the study as presented in Figure 4 show boiling time of produced briquettes while Table 5 highlight the results observed from the study. The total mass of boiled water was within the range of 0.813 to 0.832 kg within a range of 5 to 9 minutes spent in boiling the water. The lowest time spent to boil 1 litre (0.956 kg) of water by using sawdust briquette has resulted to the lowest boiling time of 6.15 kg with 0.813 kg of water

remained after boiled. However, boiling water with some sugarcane bagasse and rice husk briquettes were observed to consume highest time of 9 min which led to the boiling time of 10.63 and 10.82 min/kg respectively with 0.831 and 0.832 kg of water remained after boiling. While the longer time taken by the sugarcane bagasse briquettes could be attributed to its density values, that of rice husk could be attributed to the volume of the briquette.



Figure 4: Boiling time test

Table 5: Boiling time test of the briquettes

Briquette Material	Sample	Total Time Spent in boiling Water (min)	Total Mass of Boiled Water (kg)	Boiling Time (min/kg)
Sugarcane Bagasse & Cassava Starch	SS 1	8	0.817	9.79
	SS 2	9	0.831	10.63
Rice Husk & Cassava Starch	RS 1	6	0.815	7.36
	RS 2	9	0.832	10.82
Saw dust & Cow dung	SC 1	5	0.813	6.15
	SC 2	8	0.818	9.78

Fuel consumption rate test of the briquettes

Results presented in Figure 4 show state of the produced briquettes before and after combustion, while Table 6 highlight the results observed from the study. From the results obtained, it is observed that fuel consumed with lower values are rice husk (RS 2) and sugarcane bagasse (SS 2) with 0.00833 kg/min and 0.009556 kg/min

respectively. While on the other hand the higher values of fuel consumed are sawdust (SC 2) and rice husk (RS 1) with values of 0.02020 kg/min and 0.01333 kg/min, respectively. The fuel consumption test that ranges with values from 0.009556 to 0.02020kg/min which also indicates the relation between the briquettes burnt and total time for boiling the water.



Figure 4: Briquettes used for fuel for consumption rate test (a) before and (b) after combustion

Table 6: Consumption rate of the briquettes

Materials	Sample	Initial mass of Fuel (kg)	Final Mass of Fuel (kg)	Fuel Consumption Rate (kg/min)
Sugarcane Bagasse & Cassava Starch	SS 1	0.181	0.088	0.011625
	SS 2	0.183	0.097	0.009556
Rice Husk & Cassava Starch	RS 1	0.089	0.009	0.01333
	RS 2	0.087	0.012	0.00833
Saw dust & Cow dung	SC 1	0.133	0.031	0.01275
	SC 2	0.135	0.034	0.02020

CONCLUSION

The briquettes made of sawdust as biomass with cow dung as binding material, rice husk and sugarcane bagasse were produces while their physio-thermal properties were determined. The flame test results for all briquette samples indicates that the burning rate of saw dust briquette had the highest burning rate of 0.02020 kg/min. The fuel consumption test that ranges with values from 0.009556 to 0.02020 kg/min which also indicates the relation between the briquettes burnt and total time for boiling the water. The study was able to resolve the environmental and health challenges posed by the abundant biomass in the university neighbouring community.

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