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Physiochemical and Combustion Properties of Briquettes Produced From Rice Husk and Corncob Admixture

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Abstract- In an effort to reduce the emission of gasses and provide an affordable firewood alternative to the rural household in Nigeria, this research was carried out to analyze some properties of bio-briquettes made from carbonize rice husk and corn cob. Briquettes were prepared at moderate pressure and ambient temperature using a simple extruder briquetting machine. Different briquette samples were produced by blending varying percentage of the biomass materials in the ratio of 100:0, 80:20, 70:30, 60:40, and 50:50. The results of the proximate analysis shows that the corn cob has a higher moisture content, fixed carbon than the rice husk briquette but lower ash content and volatile matter. As the proportion of the corn cob increases, the moisture content, ash content and volatile matter also increases while there is slight decrease in fixed carbon. The viability properties results shows that corncob briquette has a higher density and compressive strength than the rice husk briquette and as the proportions of the corn cob increases, the density and the compressive strength also increases except at ratio 50:50 were a slight drop was observed. Combustion results show that the rice husk briquette has significantly higher ignition time and lower afterglow time. As the proportion of corncob increases, there is a slight decrease in the ignition time, afterglow time and calorific value of the admixture briquettes. The combustibility test results ranges from 18mins to 22mins to boil 2litres of water while it took kerosene stove 16mins to boil the same quantity of water. These properties show a slight decrease as the blend ratio increases.

Indexed Terms- briquettes, density, relaxation, durability, binder Ratio

I. INTRODUCTION

Deforestation which promotes pollution will be drastically reduced if the use of rice husk and corn cob waste is enhanced. Before promoting the use of any new type of fuel, it is expedient to have good understanding of its performance. The performance of any solid biomass fuel such as rice husk briquette mixed with corncob can be evaluated effectively through its burning rate, taking into consideration the effect of compaction pressure, binder level and particle sizes. Recent research and future predictions has shed light to the fact that crude oil might run out within 40 to 70 years from now and natural gases have the possibility of finishing in 50 years (Courtney and Dorman, 2003). Thus, global average temperature was predicted to increase from 1.4℃ to about 5.8℃ by the year 2100 and may continue to increase with time (Dow and Downing, 2006). Several investigation pointed out that natural disasters like drought, increase in hurricane and tornadoes, flooding and wide spread crop failure are likely to be inevitable (Sen, 2009; Mills, 2009).

Thus, the increase in the concentration of greenhouses gases (CO_2 and others) in the atmosphere are emitted mainly by the combustion of fossil fuels, containing carbon like natural gases, crude oil and so on (Jaynes, 2010). And the rising of greenhouse gases emission, decreasing fossil fuel supplies and energy security have led to the introduction of renewable energy as main target at national level (Smyth *et al*., 2011). The objective of this research is to determine the physicochemical and combustion properties of the fuel briquettes produced from rice husk and corn cob admixture.

II. MATERIAL AND METHODS

- Sample Collection: Samples of rice husk and corn cob were collected from Aliero, while cassava starch was purchased at the Sokoto central Market, Sokoto State.

- Preparation of the Sample: The collected samples were sun-dried for three days and then pulverized and sieved with 80 mm mesh sieve to obtain a fine particle size. The samples were kept in a polyethylene bag until required for preparation of briquettes.

- Preparation of Briquettes: A cylindrical mould of 16cm in length and 2.5 cm internal diameter was constructed. A metal bar of 2.5 cm diameter was used in pushing the formed briquettes out of the moulding cylinder.

Blend of a pair of rice husk and corncob were prepared in the ratio of 80:20;70:30; 60:40;50:50. Each blend was thoroughly mixed with the slurry of the starch (the binder) in the mass ratio of 6:1. Each blend was then loaded into the cylinder 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 a metal bar. The same procedure was repeated for the other ratio. The produced briquettes were air dried for three weeks (Kyari, 2000).

- Moisture Content: Moisture content of the briquette samples was determine based on weight measurement before and after oven drying 2g of the sample was measured out (initial weight of the sample before drying) the sample and the crucible was put in a drying oven set at 105°C for 24hrs. The crucible and its content was removed and put in desiccators to cool at room temperature and re-weighed. The process was repeated until the weight after cooling is constant, and was recorded as the final weight (final weight of the sample after oven drying) (Adekunle *et al.*, 2015).

$$Moisture\ Content(\%) = \frac{Initial\ Weight\ of\ Sample - Final\ weight\ of Sample}{Initial\ Weight\ of\ Sample} \times 100$$

- Volatile Matter: The briquettes percentage volatile matter content was determine using Lenton furnace. The residue of the dry sample from moisture content determination was preheated at 300^{0}C for 2hrs to drive off the volatiles, the resulting sample was further heated at 470^{0}C 2hrs,to remove volatile matter, just the before materials was turn to ashes, and then cooled in desiccators (Adekunle *et al.*, 2015). The crucible with known weight and it content was weigh and as the percentage of weight loss, the percentage volatile matter was calculated using the equation below.

$$Volatile\ matter(\%) = \frac{Final\ \ Weight}{Original\ \ Weight} \times 100$$

- Ash Content: The ash contents of the briquettes were determined. A portion of 2g were placed in a pre-weighed porcelain crucible and transferred into a preheated muffle furnace set at a temperature of 600^{0}C for 1 hour after which the crucible and its contents were allowed to cool. The crucible and its content were weighed and the new weight noted. Same process was repeated three time at 1hr interval until the weight is constant. The weight was recorded as the final weight of the ash (Adenkunle *et al.*, 2015). The percentage ash content was calculated using equation below.

$$Ash\ Content(\%) = \frac{Weight\ \ of\ Ash}{Initial\ Weight\ \ of\ dry\ \ Sample} \times 100$$

- Fixed Carbon: The fixed carbon represents the amount of carbon that can be burnt by a primary current of air drawn through the hot bed of fuel (Moore and Johnson, 1999). The fixed carbon of the sample was determined using the following relation.

$$Fixed\ Carbon\ Content = 100 - [(MC\ \%) + (VM\ \%) + (\text{AC}\%)]$$

Where: MC = Moisture Content, VM = Volatile Matter, AC = Ash Content

- Compressive Strength: The compressive strength of the briquette was determined using a compressive testing machine. The length and the width of the briquette was measured and recorded.

The machine was on and allowed to warm up for 4 minutes. The sample was place on the movable bed, and the control lever was apply upward to bring contact between the upper fixed bed and the movable lower bed on which the samples was sit. The reading was taking the moment the crack is notice in the briquette samples showing that the sample is compress. The value of the reading was recorded.

$$Compressive\ strength = \frac{compressive\ force\ \ (Ft)}{cross\ \ sectional\ area\ of the\ sample(\ Ac)}$$

Where: cross sectional area = Length × Width

- Density: The density of the briquettes was determined using a weighing balance by taking the weight of all the briquettes samples and dimension measurement using a vernier caliper. The volume was calculated using $\pi r^2 h$

$$Density\ = \frac{Mass(g)}{Volume(cm^3)}$$

Where: π = Pie, r = radius, h = height

- Calorific Value: The calorific value measures the energy content of the briquettes. The procedure of the ASTM standard D5373-02 (2003) was used to determine the calorific values of produce briquettes by using the equation.

$$Qv = \frac{\mathrm{C(Q1 - Q2)}}{\mathrm{Wb}}$$

Where:
Q_v = Heating/ Calorific value (kJ/kg),
C = Calibration of constant for biomass acid (0.6188),
Q_1 = Galvanometer deflection without sample,
Q_2= Galvanometer deflection due to test sample,
W_b = Weight of sample.

- Ignition Time: Ignition time was determined as reported by Oladeji (2010). The samples was graduated in centimeters, ignited at the base and allowed to burn until it extinguished itself. The rate at which flame propagated was calculated by dividing the distance burnt by the time taken in seconds.

$$Ignition\ time = \frac{distance\ burnt\ (mm)}{total\ time\ taken(sec)}$$

- Burning Rate: Briquettes burning rate were determined by recording the briquettes weight before combustion and after the briquettes were completely burnt, the rate at which fire consume the briquette samples were calculated using equation (Onuegbu *et al.*, 2011).

$$Burning\ Rate = \frac{mass\ of\ total\ fuel\ comsume\ (g)}{total\ time\ taken(\mathrm{min})}$$

Combustibility Test: Water Boiling Tests was conducted by combusting 100g of briquettes of different percentage of binders (gum arabic and starch) samples respectively using charcoal stove to compare the fuel combustibility and the fuel that cooked food faster. 2 litres of water was used for the test. The temperature reading was taken after every 2 minutes with mercury in glass thermometer (Kim *et al.,* 2001) until the water boil. The time taken by each sample to boil water was monitored using stop watch.

Results Table: 1. Physico-chemical properties of rice husk and corn cob briquettes and their blends

Briquettes	Moisture Content (%)	Ash Content (%)	Volatile Matters (%)	FixedCarbon(%)
Rice husk(Rh)	5.14±0.20	5.02±0.60	17.63±0.40	72.86±0.30
Corn Cob(Cc)	6.43±0.30	4.50±0.20	12.00±0.30	77.07±0.20
Rh/Cc(80:20)	3.00±0.10	4.00±0.20	10.00±0.60	83.00±0.33
Rh/Cc(70:30)	3.50±0.10	4.00±0.40	9.00±0.50	83.50±2.60
Rh/Cc(60:40)	4.00±0.20	4.50±0.40	8.00±0.10	83.53±0.40
Rh/Cc(50:50)	5.00±0.50	4.60±0.30	14.00±0.40	80.40±0.30

Values above are mean value of standard deviation of triplicate results.

Table: 2. Viability and Combustibility Properties of rice and corncob briquettes and their blends

Briquettes	Density(g/cm^3)	Compressive strength(MPa)	Combustibility test (mins)
(Rh)	0.36±0.01	370.00±0.02	22
(Cc)	0.53±0.20	680.00±0.10	20
(80:20)	0.34±0.01	560.00±0.20	20
(70:30)	0.29±0.02	730.00±0.20	18
(60:40)	0.35±0.10	930.00±0.30	18
(50:50)	0.60±012	600.00±0.03	22

Table: 3. Combustibility Properties of rice and corn cob briquettes and their blends

Fuel briquettes	Ignition time (mm/s)	Afterglow time(s)	Calorific Value(MJ/Kg)
(Rh)	1.70±0.01	20±0.12	7.20±0.10
(Cc)	0.50±0.01	82±1.0	6.80±0.20
(80:20)	1.60±0.03	61±0.02	7.60±0.20
(70:30)	1.40±0.02	45±1.0	8.20±0.10
(60:40)	1.10± 0.01	35± 0.7	8.15±0.03
(50:50)	1.00±0.03	30±1.0	6.70±0.20

III. DISCUSSION

The result of the moisture determination is shown in Table 1.1. The moisture content of the briquettes samples varied from 5.14% (rice husk) to 6.43% (corncob). As observed in Table1.1 above, densification has reduced the moisture content of the raw materials. Also on the blends the moisture content varied from 3% (Rh/Cc 80:20) to 5% (Rh/Cc 50:50). The moisture content of the blend briquettes decreased and falls within the range of 10-15% which helps in storage and combustibility (Maciajewska *et al*, 2006). It is noted that moisture content in excess of 20% would result in the loss in energy during combustion (Idah and Mopah, 2013). High ash contents usually lead to higher dust emission and affect the combustion volume and efficiency (Akowuah *et al*, 2012). The result of the ash content determination is shown in Table 1.1. The ash content varied from 5.2% (rice husk) to 4.5% (corncob). While the value of blend briquettes varied from 4.0% (Rh/Cc 80:20) to 4.6% (Rh/Cc 50:50). It was observed that briquetting has increased the ash content of the material. There was no significant difference ($P \leq 0.04$) between the ash contents of all the briquettes since the materials have particles within their bonded structures which easily turn into ash after combustion. The results of the volatile matter varied from 17.63% (rice husk) to 12% (corncob). In the case of the blend, the volatile matter varied from 10% (Rh/Cc 80:20) to 14% (Rh/Cc 50:50). There was a significant difference ($P \leq 0.001$) between the briquettes and their blends in terms of their volatile matter content. The high proportion of volatile matter exhibited by 14% (Rh/Cc 50:50) could be attributed to the high organic matter in the material (Olorunnisola, 2007). It was observed that, the higher the organic matter of fuel briquette, the higher its combustibility when the ash content is low. Higher volatile matter is an indication of easy ignition of the briquette and the proportionate increase in the flame length and during combustion most of the briquette sample will volatise and burn as gas in the cook stove (Loo and Koppejain, 2004). The fixed carbon content of the briquette, which is the percentage of carbon (solid fuel) available for char combustion after the volatile matter is distilled off. It 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 results of the fixed carbon varied from 72.8% (rice husk) to 77.0% (corn cob) and the values for the blends varied from 83% (Rh/Cc 80:20) to 80% (Rh/Cc 50:50). There was a significant difference ($P \leq 0.0001$) between the fixed carbon of the non-blended and the blended materials. The low fixed carbon of the 80% (Rh/Cc 50:50) briquettes indicates prolonged cooking time but with low heat release (Olorunnisola, 2007). The density of the briquette varied from $0.36 g/cm^3$ (rice husk) to $0.53 g/cm^3$ (corn cob) while the blends briquettes varied from $0.34 g/cm^3$ (Rh/Cc 80:20) to $0.29 g/cm^3$ (Rh/Cc 50:50). The higher the density of the of the corncob could be attributed to the coarse nature of the material while the lower in rice could be attributed to the fine texture (praveena *et al,* 2014). Though, the briquetting process increased the density of the bulk materials, improved the handling characteristics, but it was observed relatively low from the result in Table 2.1. This could be becaused of the fibrous and the natural springiness of the biomass materials. After compression, the material tend to expand as the pressure is released which negatively affect the density of the briquettes (Sotanndes *et al,* 2010). The results of the compressive strength of the various briquettes were found to be reasonable from 680 MPa (Corncob) having the highest value while rice husk briquettes had the lowest value of 370MPa. The compressive strength of the blends varied from 560MPa (Rh/Cc 80:20) to 600MPa (Rh/Cc 50:50). This properties increases as the blends ratio is increased except at ratio of 50:50 where slight decrease was observed. There is no difference ($P \leq 0.0001$). These results compared favourably with that of Elinge *et al*., *(*2011) that, briquettes strength increases with the increase in pressure up to the limit of the compacting material and binder, as this contributes greatly on the durability of the briquettes. This is because increase in compressive strength of the briquettes reduces absorption of atmospheric humidity while briquettes with low compressive strength might suffer damage during transportation and storage. The ignition propagation depends on one's judgement according to what stage ignition has been achieved (David *et al*, 2013). In this process, ignition time was taken as the average time taken to achieve a steady glowing flame. The results of the flame propagation are shown in Table 3.1. The flame propagation values ranged from 1.70mm/s (rice husk) to 0.50mm/s (corn cob). The biomass briquettes have short ignition time and will catch fire easily. The blend briquettes have the ignition time of 1.60 mm/s (Rh/Cc80:20) to 1.0mm/s (Rh/Cc 50:50). As the proportion of biomass reduces, the ignition time also reduces as shown in Table 3.1. A direct relationship was established between compaction pressure and ignition time at ($P \leq 0.0001$). This observation is in agreement with Davies and Abolude (2013) who recorded that increased density of briquettes, results in delayed ignition time of the briquettes.

The results of the afterglow time is shown in Table 3.1. Of the blend briquettes ranged from 61sec (Rh/Cc 80:20) to 30sec (Rh/Cc 50:50). The low value of afterglow time at Rh/Cc 50:50 blends could be attributed to its high density which resulted in reduced porosity. Reduction in air content within the matrix of the briquettes has inhibited flame propagation due to low thermal conductivity (Davieds *et al*., 2013). The higher value of the corncob briquette is attributed to the coarse nature of the particle size which allows for free infiltration of oxygen into the briquettes leading to increase in burning time. Oladeji (2010) reported that corncob briquettes will ignite more easily and burn with intensity for long than rice husk briquettes. The calorific value results are shown in Table 3.1. The computed calorific value of the briquettes varied from 7.20MJ/Kg (rice husk) to 6.80MJ/Kg (corncob). It was observed that blending these residues actually enhanced the calorific value of the sample except at the ratio 50:50 which shows a slight decrease. These values are significantly differently at ($P \leq 0.0001$).

Calorific value is the most important fuel property (Ayahan and Ayse 1998). Since the primary aim of briquetting biomass is to produce a good and efficient high energy fuel source that enhances combustion. The combustibility test result of the briquettes is shown in Table 2.1. It measured the time taken for each set of briquettes to boil an equal volume of water under similar conditions. Rice husk took 22 minutes to boil 2 litres of water while it took 20 minutes for corncob to boil the same quantity of water, it was observed that blending the agro-wastes with each other actually reduced the time taken to boil, the same quantity of water while improving the residence time for the briquettes to undergo complete combustion.

CONCLUSION

The findings of this study have shown that the briquette produced from these agricultural wastes residues would make a good biomass fuel and utilizing the agricultural wastes would reduce over dependence on fire- wood and other source of energy. Also blending the residues with each other has enhanced the combustion properties of the wastes, the residence time of combustion and the calorific value since the moisture content has decreased and the volatile matter increased.

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