Combustion Profile of Fuel Briquettes Produced From Millet Stalk with Charcoal as Blend

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Abstract- Energy availability is a crucial pre-requisite of development to any society. In an effort to provide an affordable firewood alternative to the rural households in Nigeria, this study was carried out to analyze some properties of bio-briquettes (millet stalk, coconut shell) prepared at moderate pressure and ambient temperature using a simple extruder briquetting machine. Also different briquette samples were produced by blending fuel briquettes of the biomass materials such as millet stalk with charcoal and coconut shell with charcoal respectively. The proximate analysis of the raw materials was also determined. The moisture content of the briquettes varied from 0.44±0.04% (millet stalk) to 0.30±0.09% (coconut shell). The ash content varied from 3.91±0.30% (millet stalk) to 1.94±032% (coconut shell). The ash content of the blended briquettes made from (millet stalk, coconut shell and charcoal) ranged from 8.08±2.30% for (millet stalk with charcoal) to 4.19±0.02% for (coconut shell with charcoal). The viability test results showed that coconut shell blended with charcoal briquettes has shorter ignition time 0f (00.013cm/s) this shows that it would easily ignite, while millet stalk briquettes has the longer afterglow time of (96sec) and slow propagation time of (0.00073cm/s). The mechanical properties showed that, compressive strength and density of the briquettes produced showed that millet stalk briquettes has the highest value of 1.05N/mm2 while millet stalk and coconut shell briquette gave the highest density values of 0.33g/cm^3(millet stalk) to 0.34g/cm^3 (coconut shell), it took the coconut shell briquettes 30 minutes to boil 2litres of water, the same was obtained for charcoal as control while the millet stalk briquettes took 28 minutes to boil the same quantity of water. Conclusively, efficient and affordable alternative sources of energy have been obtained from these agro-wastes.

Indexed Terms- Biomass, Binder, Density, Briquetting,

I. INTRODUCTION

The importance of energy differs for different social-economic setting. For developed nations, energy abundance may mean difference between economic development and a period of economic drop in a country and possibly, a change in lifestyles from energy extravagance to moderation. High-energy consumption has been associated with higher quality of life, which in turn is related to Gross National Product (GNP). Economic growth amongst nations has drawn interest to global energy resource inventories as well as regional or country wise energy source endowments. Energy can be renewable and non-renewable. Renewable energy is infinite energy source obtained from the continuing or repetitive current of energy occurring in natural environment (Twidell and Weir, 2006). The energy sources are biomass, solar energy and wind energy. While non-renewable energy is finite, exhaustible and cannot be re- placed. These are type of energy obtained from static stores of energy that remain bound unless released by human interventions. Non-renewable energies such as fossil fuel, petroleum, coal, natural gases and nuclear fuels. Nearly all the western world's energy still comes from fossil fuel that will become increasingly hard to secure. Affordable oil and gas are unlikely to last more than another century. As supplies reduces, prices will rise and use will increasingly be restricted to premium applications like in transport and plastics manufacture shortage will create a renewed risk of instability in international markets. Nigeria as a member of OPEC, which she joined in 1971, has been firstly a beneficiary and secondly, a victim of the price increases (Ayodele,and Nweke,1987). Wood was the first the major source of energy and readily available, because extensive forest grew in many parts of the world and the amount of wood needed for heating and cooking was relatively modest. However, the situation changed when wood began to be used during the middle ages to make charcoal. The climate in many developing nations like Nigeria favours renewable energy, if only there is commitment on the part of government and stakeholders in energy matters in Nigeria to indicate or initiate major policies that would be sup- ported by a variety of other measure including targets, energy studies and strategies. One of such alternative source of energy is biomass energy, which is highly favoured because of its result in cleaning environment. Briquetting this biomass for energy source utilization could also be the solution to the ever increasing energy crises and shortage of energy in the country.

II. MATERIALS AND METHODS

- Sample Collection: Samples of millet stalk and coconut shell were collected from Aliero, while cassava starch was purchased at the Sokoto central Market, Sokoto State.

- Preparation of the Sample: The collected samples were crushed to fine powder using grinding machine. The powder 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 polythene 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. 25g of starch and 150g of coconut shell and millet stalk were weighed out using a triple beam balance into a 100ml plastic basin, they were thoroughly mixed with the slurry of the starch (the binder) , the 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 (Elinge *et al*, 2018).

- 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 samples before drying) the sample and the crucible was put in a drying oven set at 105^{o}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.

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

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.

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

- Burning Rate: Briquettes burning rate were determined by recording the briquettes weight before scombustion 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.

- Porosity of the Briquettes: Moore and Johnson (1999) was adopted in determining the parameter. The porosity determines the cell opening of the briquettes. It was carried out by weighing an equal dimension of the various briquettes samples. Then the briquettes were immersed in 100ml of water for 3 minutes. The excess water was allowed to drain out. The volume of water drained out, the volume retained in the briquette samples and the weight of the briquettes after immersing in water was noted and recorded.

- Porisity Index of the Briquettes: The method of Moore and Johnson (1999) was used and it was calculated using the following relationship:

$$Porosity\ Index = \frac{\text{Mass of water absorbed}}{\text{Mass of the sample}}$$

III. RESULTS AND DISCUSSION

Table 1.1 Results of the proximate analysis and Mechanical Properties of Briquettes

Briquettes	Moisture Content%	Volatile Matter%	Ash Content %	Fixed Carbon%	Porosity Index	Density (g/cm^3)	Compressive Strength (N/mm^2)
MS	0.44±0.04	2.90±0.69	3.91±0.30	91.43±0.88	0.50	0.33	1.05
MS/CH	0.17±0.02	3.38±0.74	8.08±2.30	91.32±1.36	0.11	0.27	0.58
CS	0.30±0.09	3.40±0.70	1.94±0.32	93.30±1.36	0.40	0.34	0.45
CS/CH	0.19±0.02	2.23±0.08	4.19±0.02	94.21±0.80	0.25	0.32	0.61
CH	0.33±0.05	3.59±0.24	10.66±0.28	85.56±0.26	0.10	0.30	2.21

Values above are mean value standard deviation of triplicate result

Key: MS - millet stalk, MS/CH- Millet Stalk with Charcoal, CS- Coconut Shell, CS/CH- Coconut Shell with Charcoal, CH- Charcoal.

Table.2. Results of the Combustion Properties of Briquettes

Briquettes	Afterglow (sec)	Flame propagation (s/cm^3)	Combustibility Test (sec)
MS	96	0.0007328	28
MS/CH	87	0.0007224	24
CS	83	0.00092	30
CS/CH	67	0.0013	26
CH	23	0.0028	30

Values above are mean value standard deviation of triplicate result

Key: MS - millet stalk, MS/CH- Millet Stalk with Charcoal, CS- Coconut Shell, CS/CH- Coconut Shell with Charcoal, CH- Charcoal.

IV. DISCUSSION

The moisture content of the briquettes sample varied from 0.44±0.04 (millet stalk) to 0.33±0.05 (charcoal) while the moisture content of the blend varied from 0.17±0.02 (millet stalk and charcoal) to 0.19±0.02 (coconut shell with charcoal) the moisture content decreases and falls the accepted range of 10-15% which help in storage and combustibility (Maciajewska *et al*., 2006). Moisture content is an important property that can greatly affect burning characteristic of the briquettes. Hence, low moisture content is required to avoid decomposition and disintegration of briquettes during storage and handling. Generally, when the moisture content is low, the briquettes will easily be ignited, no slagness during burning will occur. A further disadvantage of high moisture content is the facilitation of a breeding ground for fungi and microorganisms (Ollet *et al.*, 1993).

The ash content varied from 3.91±0.30 (millet stalk) to 10.66± 0.28 (charcoal) also the blend briquettes varied from 8.08±2.30 (millet stalk with charcoal) to 4.19±0.02 (coconut shell with charcoal). The recommended level of ash content is 4% (Grover and Mishra, 1995). The amount of ash content correlated with the amount of fixed carbon and combustion substance such as volatile matter, low ash content offers higher heating value for briquettes but high ash content results into dust emission which lead to air pollution and affect combustion volume and efficiency (Akowuah *et al.,* 2012). The higher the ash content, the lower its calorific value and vice versa, this is because ash content influence the burning rate. Therefore, high ash content in briquette minimized the heat transfer to fuels interior parts and diffusion of oxygen to the briquette surface during char combustion (Chaney, 2010). That is why ash content is one of the criteria that decides the quality of briquettes. The lower the ash content, the better the quality of the fuel briquettes (Chaney, 2010).

Millet stalk briquettes are good fuel briquettes. The volatile matter results varied from 2.91±0.69 (millet stalk) to 3.40± 0.74 (coconut shell) while the blended briquettes varied from 3.38±074 (millet stalk with charcoal) to 2.23±0.08 (coconut shell with charcoal). High volatile matter of a briquette is an indication of easy ignition, fast burning and proportionate increase in flame length. Generally, the higher the volatile matter, the better the briquette (Oladeji *et al.,* 2009). It was observed that, high volatile matter briquettes ignites easily, but burn with smoky flame while low volatile charcoal briquettes is difficult to ignite but burn with less smoke. Therefore, 3.40± 0.74 (coconut shell) is recommended, since it burns with less smoke which helps in reducing the emission of gases to the atmosphere. The results of the viability test (compressive strength, density, after glow, flame propagation) the compressive strength of the various briquettes are found to be reasonable with briquettes from charcoal having the highest value of 2.21N/mm^2 while coconut shell briquettes has the lowest value of 0.45N/mm^2 this could be attributed due to the nature of the particle size. The compressive strength of fuel briquettes is one of the qualities used to assess its ability to be handled, packed and transported without breaking (Onuegbu *et al.,* 2010). Since, the low compressive strength can cause the briquettes to crumble faster during transportation, burning at very short time and generates less heat in the process. The highest compressive strength of charcoal 2.21N/mm^2 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 (Kaliyan and Morey, 2009).

The density results showed that briquettes produced from coconut shell has the highest value of 0.34g/cm3 while millet stalk blended with charcoal has the lowest value of 0.27g/cm3 respectively. It could be as the result of the coarse nature of the coconut shell while the low value in millet stalk could be attributed to the fine fine texture of the charcoal and millet stalk samples (praveena *et al*., 2014). The higher the density of the briquette, the higher the energy value as reported by (Ayahan and Ayse, 1998). High quality briquettes should have high density and strength in order to burn for a longer time and have higher energy content. The higher the density, the higher the compressive strength (Ingwold and Gerold, 2004).

The flame propagation(ignition time) results ranged from 000092cm/s (coconut shell) to 0.0028 cm/s (charcoal) and the blend ranged from 0.00072cm/s (millet stalk with charcoal) to 0.0013 cm/s (coconut shell with charcoal) biomass have shorter ignition time and would catch fire easily as the value blend increase, the value of the ignition time also reduces. Densification leads to decrease in ignition time (delay the ignition time) of the briquettes consequently (Davies and Abolude, 2013). The ignition time was therefore a comparison of how fast the briquettes achieve steady burning. It is apparent that particle sizes of the briquettes have a negative impact on the ignition time of the briquettes. This observation might be adduced to the fact that bigger particle size could have more spaces in between the particle than fine particles thus, increase in porosity index of the briquettes to be ignited (Davies and Abolude, 2013). The result of afterglow ranged from 23sec (charcoal) to 96 sec (millet stalk) while the blend ranged from 67sec (coconut shell with charcoal) to 87 sec (millet stalk with charcoal) the low value of afterglow time in coconut shell with charcoal is due the mineral contents which hindered it from maintaining flame (Oladeji, 2010). The longer the afterglow time and slow propagation foe the coconut shell briquettes indicated it would ignite more easily and burn with intensity for a long time compared to other briquettes (Oladeji, 2010) and this could be as the result of its high porosity and nature of its particle size.

The combustibility result shows that the blended briquettes (millet stalk and charcoal) and coconut shell and charcoal) took 24 minutes to boil 2 litres of water while millet stalk took 28 minutes to boil the same volume of water. This shows that blending of bio-wastes with charcoal reduced the time taken to boil water and also improved the residence time for the briquettes to undergo complete combustion.

CONCLUSION

The results of the study shows that briquettes produced from these agricultural wastes residues would make a good biomass fuel. Since the quality of biomass fuel depends on providing sufficient heat, igniting easily, generating less smoke and gases that may be harmful to the environment, generating less ash as may constitute nuisance during combustion. Conclusively, the use of millet stalk and coconut shell to produced briquettes fuel can be economical, sustainable and environmental eco-friendly and reduced deforestation and climate change challenge.

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