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Evaluation of Briquettes Produced from Charred Sawdust, Corncob and Ricehusk

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Abstract:
The use of firewood, twigs and charcoal as fuel sources has resulted increase in the rate of deforestation. This study evaluated the physical and chemical properties of briquettes produced from charred farm wastes to supplement the use of charcoal and firewood. Charred farm wastes namely; corncob, rice husk and sawdust were used to produce the briquette with starch as the binding material. A ratio of 100 %, 50-50 % and 33.33 % mixture of the raw material were used in preparation of the briquettes. Laboratory tests including shatter index, boiling test, proximate and ultimate analysis were carried out to determine the physical and chemical qualities of the developed briquettes. From results obtained, sawdust briquette with the least density (325.6kg/m^3) recorded the least boiling time of 30mins compared to the other samples. The proximate analysis showed that, the mixture of corncob and sawdust briquette had the highest values of volatile matter (71.48%) and fixed carbon content (19.99%), least amounts of ash content (2.29%) and moisture content (6.24). Mixture of corncob and sawdust also had the highest heating value of 30804.72kJ/kg. The production of briquettes from these waste materials as shown in this study provides alternate fuel to charcoal or firewood as well as helps manage waste disposal.

Keywords: *Charred briquette, farm waste, thermal properties, proximate & ultimate analysis*

1. Introduction

In developing countries, people rely on the use of charcoal or firewood for basic activities like cooking, for instance in Ghana where fuel for domestic use is not easy to access. According to Allotey et al., (2006), the use of firewood and charcoal mainly for household activities accounts for 60 % and 2 % of the total national energy consumption and Gross Domestic Product of Ghana. It has been reported that an estimated population of about three billion people around the world cook daily using wood as fuel (Yank et al., 2016).

The majority of households especially in rural communities depend on traditional stoves with woodfuel as source of energy for their primary activities. These activities in addition to institutional and industrial use for commercial purposes have over the past years increased the demand for woodfuel. The reliance on woodfuel in Ghana is significant that a report by the Energy Commission (2008) projects that by the year 2020; woodfuel demand would have risen by 25 million metric tonnes. This expected rise in demand for woodfuel has become of great concern especially as the bulk source of these woodfuels amounting to 90 % is obtained directly from the natural forest whiles the remaining 10% is from wood waste, which is logging and sawmills residues and planted forest (Energy Commission, 2012). The implication of obtaining the bulk woodfuels from the natural forest is high rate of deforestation. A report by the UN Food and Agriculture Organization (2010) reveals that, the rate of deforestation is highest in Africa and South America. According to the Ghana Energy commission (2012), forest growth is far less current level of woodfuel consumption, and as a result, Ghana is amongst countries in Africa with the highest rate of deforestation.

Increase in population growth resulting in an escalating demand for fuel and the fight against destruction of the forest is shifting the world's attention towards renewable energy. This shift must focus on energy sources that are renewable and easily accessible to the poor (Olorunnisola, 2007). Aina et al. (2009) draw the attention to the need to have alternative energy forms that are renewable in Africa as result of continuous increase in price of cooking gas and decreasing woodfuel availability.

Smoke from the use of firewood is one of the leading causes of death and disease in the world's poorest countries. People are suffering from indoor air pollution because of excessive use of firewood in traditional stoves.The world today is tilting towards the use of energy sources that will be environmentally friendly, thus, the tilt towards the use of renewable energy and energy derivable from biofuels. With large dumping of agricultural waste daily, which have (in themselves) constituted environmental nuisance, converting them into forms for generating energy will not only save the environment, but it will also boost the economic status of the nation (UNDP, 1982). The economy of any nation is dependent on the quantity of energy that is available for use.

This study is most needful as it seeks to provide a clean less expensive energy and also to help in waste management. In Ghana and other developing countries where over 60% of the population is into farming, both the produce and its waste, e.g., rice husk can produce a residual income The income incentives will further go a long way to curb the standard practice of farmers burning their farm residues which pollutes the environment. Pollutants like carbon dioxide (CO_2) are released into the atmosphere when farmers openly burn their farm wastes (UNDP, 1982).In this study, the farm waste was charred, mixed with a suitable binder and then pressed into small blocks that can be used as coal. This is with the intent of making good use of the waste generated.

2. Materials and Methods

2.1. Raw Materials

The farm waste products namely; rice husk and corn cob are the materials obtained from the Crop Research Institute at Fumesua-Kumasi. Next, behind the Department of Housing and Planning of Kwame Nkrumah Science and Technology (KNUST) carpentry shop, raw sawdust was also collected. Then from the Ayeduase Market, cassava flour which served as a binding material for the briquette production was obtained. Except for the binding material and cost of transportation, the majority of the raw materials were free. The samples of the raw materials for the briquette production were sundried for two weeks.

2.2. Charring of Raw Materials

In charring the dried raw materials, the Top-Lit Updraft (TLUD) kiln with a chimney was used. A top-lit updraft kiln is a drum used to produce charcoal, especially in biochar. At the bottom of the drum, many 2inches holes were cut at an evenly spaced distance to serve as intake vents. With this kiln, fire is set on top of the raw material to be charred – in that way forcing combustion to the bottom.

20kg of each of the raw material was tightly packed in a drum of height 85cm and 50cm diameter. The drum stood upright with the open-end up with 2/3 of its inner space filled with the prepared raw material. Fire was then started on top of the raw material and the open end of the drum is covered. The cover used in this study had a chimney. The fire burned from the top which eventually spread to the bottom gradually. The setup is as shown in Figure 1.

Figure 1: Set Up Drum for Charring of Raw Material

2.3. Briquette Production

Using a digital balance, the char and the binding material (cassava flour) were weighed at ratio of 90: 10. The weighed char and binder were then mixed till a uniform mixture was obtained. The prepared mixture was fed into a hydraulic screw press and pressure of 25MPa applied until the char was compressed to form briquette. This briquette dried under the sun for two weeks. The briquettes produced were in the following ratio and as shown in Table 1.

- Pure briquettes: These were produced from 100% of corn cob, rice husk and sawdust.

- Mixed briquettes: These were produced by firstly mixing two of the agricultural waste in a 50-50% composition with a fixed amount of binder.
- The last fraction was the addition of one third (33.33%) of all the three samples.

Briquette Type	Composition
A	Corncob
B	Sawdust
C	Rice husk
D	Corncob + rice husk
E	Rice husk +sawdust
F	Corncob + sawdust
G	Sawdust + Corncob + Rice husk

Table 1: Briquette Composition

2.4. Boiling Test of Developed Briquette

A comparison was carried out to determine boiling time of the briquettes. It measured the time taken for each set of briquettes to boil an equal volume of water to 100 ^{O}C. The cold start boiling test was carried out under the following conditions: Wind speed- 7 mph, relative humidity- 80 % and room temperature of 29 °C. 0.5kg of each of the briquette was used to boil 3kg of water using Gyapa cook stove. The temperatures build up and time at every 5min was recorded up to boiling point. The remaining briquette was then dry quenched with aluminium silicate and allowed to cool. The cooled briquette was re-weighed and the burning rates of the briquettes determined using Equation 1;

$$\text{Burning rate} = \frac{\text{mass of fuel consumed (g)}}{\text{total time taken (min)}} \quad (1)$$

2.5. Determination of the physical and chemical characteristics of the briquette

The Department of Chemistry laboratory-KNUST assisted with the proximate, ultimate, heating values and density analysis of the briquette. The physical properties of briquettes determined were overall length, the diameter of briquettes, shatter index and density of the briquettes. The external surface and the structure of the cross-section were also examined. Using standard methods for proximate analysis as shown in Akowua et al., (2012), the following parameters were determined; ash content, volatile matter, fixed carbon, moisture content, and carbon content.

The ultimate analysis test followed ASTM analytical methods as prescribed by Jenkins et al., (1998) to determine the chemical elements of the briquettes. The chemical properties determined were Sulphur, carbon, nitrogen, hydrogen and oxygen contents of the briquette.

2.5.1. Heating Value (H_v)

The heating values of the briquettes were determined using Equation 2;

H_v = 2.36(147.6c + 144v) (2)

Where c and v are percentage fixed carbon and volatile matter respectively (Bailey et al., 1982)

2.5.2. Shatter Index Test

In this study, to determine the durability of the briquette, the shatter index method as described by Rajaseenivasan et al. (2016) was used. From a known height of 2m, the briquette was released to hit a hard floor. Both the weight of briquette before being dropped and weight of the disintegrated briquette are then noted. The percentage loss of briquette is then calculated using Equation 3

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (3)$$

Where W_1 and W_2 is the initial weight before shatter and final weight after shattering of briquette respectively. The shatter resistance is then computed using Equation 4 (Tembe et al., 2014)

$$\text{Shatter resistance (\%)} = 100 - \text{Percentage weight loss} \quad (4)$$

3. Results and Discussion

3.1. Physical properties of the charred briquettes

The produced briquette evaluated on its physical condition was well compacted with a smooth outer surface. The hydraulic press used for the compaction created an opening in the middle (hole) of the briquette for an adequate air circulation to help in ignition. The hole also provides sufficient toughness to withstand exposure and shocks of transportation and storage. The average length and diameter are 32 mm and 62 mm respectively. The average density of briquette was lowest for sawdust (B). The average densities of the charred briquettes are presented in Table 2.

Briquette	Average Mass(Kg)	Average Length(Mm)	Average Diameter	Average Density(Kg/M³)
Corncob	0.035	33	62	352.6
Sawdust	0.031	32	62	322.2
Rice husk	0.047	32	62	489.9
Corncob + rice husk	0.054	32	62	556.2
Rice husk +sawdust	0.050	32	62	520.9
Corncob + sawdust	0.041	33	62	412.8
Sawdust + Corncob + Rice husk	0.048	33	62	478.5

Table 2: Physical Properties Of The Briquettes

The results for weight loss and shatter resistance for the briquettes are as presented in Table 3.From the results obtained, sawdust briquette recorded the lowest percentage loss of 7 % with high shatter resistance. Briquettes with low percentage weight loss and high shatter resistance are generally durable. High shatter resistance briquettes as result of their high stability can withstand handling stresses like packaging and conveyance without disintegrating (Tembe et al., 2014) especially that of sawdust and the 50-50 mixture of sawdust and rice husk briquette as shown in Table 3. The weight loss for Sawdust + Corncob + Rice husk was quite significant compared to the others. Maximum care must be taken when handling and transporting the briquette samples with high percentage weight loss to reduce the possibility of disintegration (Tembeet al., 2017).

Briquette Sample	Weight loss %	Shatter Resistance %
Corncob	21	79
Sawdust	7	93
Rice husk	12	88
Corncob + rice husk	15	75
Rice husk +sawdust	9	91
Corncob + sawdust	20	80
Sawdust + Corncob + Rice husk	27	73

Table 3: Shatter Index of Briquettes

3.2. Proximate Analysis and Heating Value of Briquettes

The results of proximate analysis of the charred briquettes are as shown in Figure 2. The range of values for moisture content observed in this study for the briquettes as shown in Figure 2 varied from 6.24 to 6.93 %. These results are within the limits of 15% recommended by Grover and Mishra (1996), for a briquette of agro-residues. The volatile matter observed ranges from 71.32 to 71.48 %. The values of volatile matter and ash content are reasonable and acceptable; however, a mixture of corn cob and sawdust is the best because it has the highest value of volatile matter and heating value. The level of volatile matter in the briquettes directly affects their burning efficiency. The higher the volatile matter, the more the burning efficiency of the briquette (Gbabo et al., 2105). The heating value for each of the briquettes determined from the proximate analysis and the results shown in Figure 3. These results indicate that briquettes tend to have higher calorific values thereby releasing more heat energy when burnt. The mixture of sawdust and corn cob also recorded the least amount of ash and moisture content. The lower the ash and moisture content, the better the briquette.

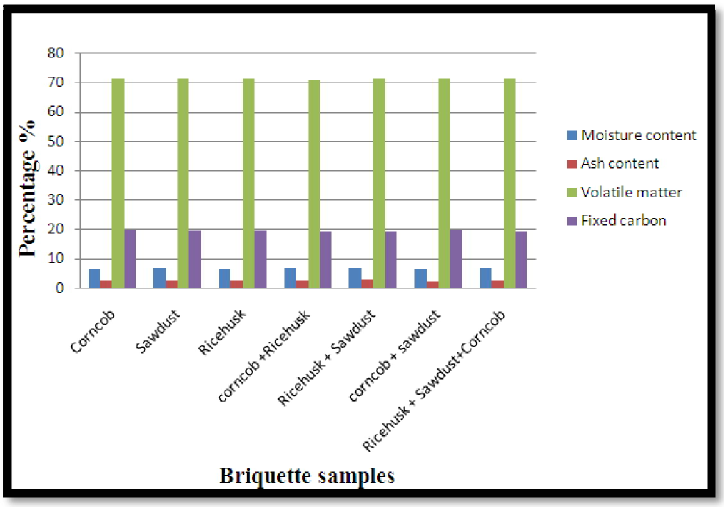

Figure 2: Proximate Analysis of Charred Briquette

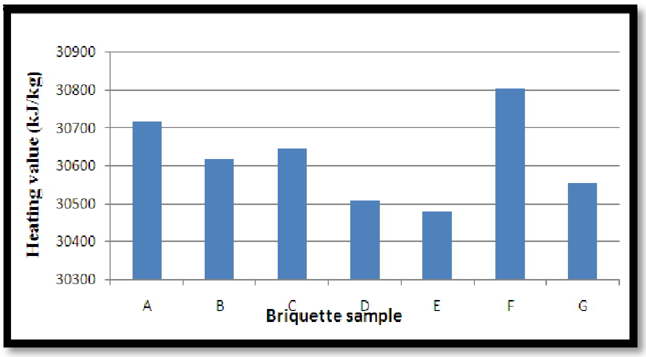

Figure 3: Heating Values of the Briquettes

3.3. Ultimate Analysis of the Briquettes

The results of the ultimate analysis of the briquettes are shown in Table 3. The amount of carbon and hydrogen are good and acceptable as they contribute immensely to the combustibility of the briquettes (Musa, 2007). All the briquettes are environmentally friendly as a result of their low Sulphur content which ranges from 0.321 to 0.341 %, however sample Sawdust+ Corncob+ Ricehusk released the highest amount of Sulphur (0.341%) compared to the other samples.

Briquette	**Carbon (%)**	**Hydrogen (%)**	**Oxygen (%)**	**Sulphur (%)**
Corncob	52.86	4.26	39.36	0.321
Sawdust	53.26	4.22	39.21	0.331
Rice husk	52.89	4.16	39.29	0.326
Corncob + rice husk	52.98	4.19	39.46	0.322
Rice husk +sawdust	52.92	4.31	39.51	0.339
Corncob + sawdust	52.94	4.24	39.32	0.336
Sawdust + Corncob + Rice husk	53.19	4.29	39.42	0.341

Table 4: Results of Ultimate Analysis of Briquette

3.4. Boiling Test

The boiling test and burning rate results of the briquettes to compare their cooking efficiency are as shown in Figure 4 and Table 5 respectively. Sawdust briquette, with the least density (322.2 kg/m³) and highest burning rate of 10.33 g/min recorded the least time of 30 mins compared to the other samples to boil water. The excellent performance also of rice husk briquette (35 min) and corncob briquette (40 mins)is attributed to their high heating values shown in Figure 3. Burning rate (how fast fuel burns) and heating value are the two combined factors controlling the cooking time.

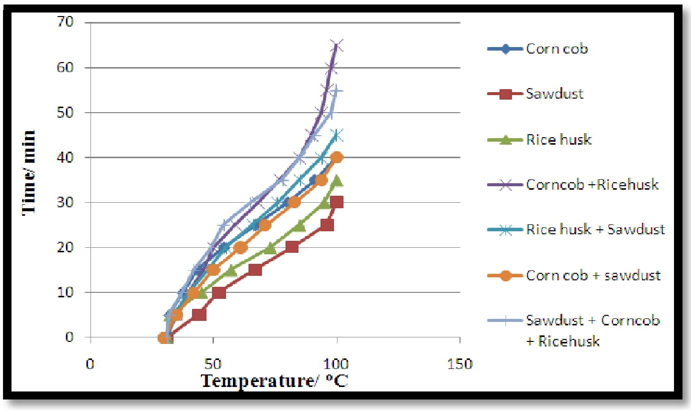

Figure 4: Water Boiling Test

Briquette Sample	**Mass Of Briquette Left After Boiling Test Kg**	**Burning Rate G/Min**
Corncob	0.20	7.50
Sawdust	0.19	10.33
Rice husk	0.28	6.29
Corncob + rice husk	0.09	6.31
Rice husk +sawdust	0.18	7.11
Corncob + sawdust	0.11	9.75
Sawdust + Corncob + Rice husk	0.12	6.91

Table 5: Burning Rate of Briquette

4. Conclusion

From the study, Sawdust briquette boiled the water at the fastest time of 30 minutes. Sawdust briquette recorded the highest burning rate, therefore, may be appropriate for regular domestic cooking. The mixture of corn cob and sawdust briquette (50-50 ratio combination) had the highest heating value and fixed carbon content. For the most part, both industrial and domestic heating activities that require simmering for an extended period can benefit from the 50-50 ratio combination of corncob and sawdust. The study recommends the use of corncob, rice husk and sawdust be used for the production of briquettes to supplement the use of charcoal and wood fuel.

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