THE EFFECT OF BINDER RATIO ON THE PHYSICAL AND COMBUSTION CHARACTERISTICS OF CARBONIZED RICE STALK BRIQUETTES

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ABSTRACT

The selection or choice of agro-waste briquettes for domestic and industrial cottage applications depends on the fuel properties. In this study, the briquette was produced by carbonizing the rice stalk followed by crushing and sieving, the binder was prepared by dissolving the starch in hot water, then mixed with the sieved carbonized rice stalk and then the briquette was produced using the briquetting machine. Proximate analyses, viability, characteristics and combustion were determined to know the average composition of their constituents. From the results obtained it was observed that ash content, moisture content, after glow and ignition propagation decrease as the binder ratio increase while fixed carbon content, volatile matter, calorific value, density and compressive strength increase. The results of this work indicate that briquettes produced using high concentration of the binder would make good biomass fuels. However, it has a high moisture content of 25.00%, high ash content of 23.00%, moderate volatile matter of 44.80%, low fixed carbon content of 32.20%, moderate calorific value of 13.86 MJ/Kg and high density of 0.643g/cm³. The results obtained for all the parameters showed that rice stalks briquettes produced with high concentration of the binder (starch) had a better performance based on their combustion profile.

Keywords: Rice stalk, Binder, Charcoal, Fuel, Briquette, Starch

1. INTRODUCTION

The availability of energy for domestic use in Nigeria continues to pose a formidable challenge, especially with the high cost of cooking gas and kerosene and the environmental problems associated with firewood. Alternative forms of energy need to be sourced. This has necessitated the need to improve on the use of agro wastes such as rice-husk and many more as alternatives.

Numerous agricultural residues and wastes are generated in the country, but they are poorly utilized and badly managed, since most of these wastes are left to decompose or they are burned in the field resulting in environmental pollution and degradation (Jekayinfa and Omisakin, 2005). However, scientific studies have concluded that a lot of potential energy abounds in these residues (Fapetu, 2000). The Nigerian government recently came up with a policy decision in 2019 to ban rice importation completely. It is very obvious that the foreign rice in Nigerian markets now depreciating due to border closure against smuggling and there is an increase in rice production in Nigeria (Ige *et al.*, 2020).

Among several kinds of biomass, agricultural residues have become one of the most promising choices. Some agricultural wastes such as wood can be directly utilized as fuels. Nevertheless, a majority of them are not suitable apparently because they are bulky, uneven, and have low energy density. All these characteristics make them difficult to handle, store, transport, and utilize in their raw form. Hence, there is the need to subject them to conversion processes in order to mitigate these problems. One of the promising solutions to these problems is the application of briquetting technology (Wilaipon, 2007). The technology may be defined as a densification process for improving the handling characteristics of raw materials and enhancing volumetric calorific value of the biomass. In Africa, the search for fire wood is left to children and women who walk long distances hence reducing the time they put in agricultural production and other household activities. It results into low production, low incomes and household food insecurity (Kagere, 2012). Though some urban population that are above poverty line have access to fuels like kerosene, LPD gas, electricity, still these fuels are relatively expensive to be used as the only energy sources for cooking. Incidentally, fuels like kerosene, LPD gas when burnt, emit greenhouse gases which have contributed to global warming (Sugumaran and Seshadri, 2009).

The aim of this research is to study the effect of binder ratio on the combustion profile of charcoal briquette produced from carbonized rice stalks.

2. MATERIALS AND METHODS

2.1 SAMPLE COLLECTION

Samples of rice stalks were collected from Aliero in the month of February, 2018. In Kebbi state, Nigeria of latitude 12°17'24.14°N and longitude 4°28'1,57°E (Ige *et al.*, 2018). The samples collected were sun dried for one week to reduce the moisture content of the materials.

2.2 SAMPLE PREPARATION

The rice stalks biomass was carbonized using the clay pot method (Ugwu, 2011). The materials were carbonized and grounded the char. The grinded particles were sieved with a 2mm mesh (Ige *et al.*, 2018).

2.3 BRIQUETTES PRODUCTION

Different binder concentrations were produced by dissolving 10, 15, 20, 25, and 30g of cassava starch in 0.5 litre of water (Yael, 2006). At first, the cassava starch was dissolved in 100 ml of hot water to form a paste, and 400ml of water was put to boil. The paste was gradually mixed with the boiling water and stirred gently while hot until smooth homogeneous gelatinized starch solution was obtained. The samples were produced at moderate pressure and ambient temperature. The briquettes produced were then air dried for three weeks (Kyari, 2000).

3. RESULT AND DISCUSSION

TABLE 1. PROXIMATE ANALYSES OF THE BRIQUETTES PRODUCED FROM RICE STALK USING STARCH AS BINDER

SUBSTRATE RATIO (%)	ASH CONTENT (%)	MOISTURE CONTENT (%)	FIXED CARBON (%)	VOLATILE MATTER (%)
10	27.00±0.25	31.20±0.17	30.00±0.05	43.00±0.02
15	25.50±0.01	28.30±0.21	31.00±0.01	43.50±0.20
20	24.74±0.15	26.10±0.45	31.46±0.22	43.80±0.50
25	23.50±0.08	25.50±0.27	32.00±0.42	44.50±0.10
30	23.00±0.12	25.00±0.12	32.20±0.18	44.80±0.30

Values are mean standard deviation of triplicate results

TABLE 2. VIABILITY CHARACTERISTICS OF THE BRIQUETTES PRODUCED FROM RICE STALK USING STARCH AS BINDER

SUBSTRATE RATIO GLOW (%)	DENSITY (g/cm ³)	COMPRESSIVE STRENGTH (N/mm ²)	IGNITION PROPAGATION (cm/s)	AFTER (sec)
10	0.547±0.20	0.642±0.14	0.14±0.01	341±0.13
15	0.565±0.10	0.689±0.02	0.13±0.20	323±0.60
20	0.572±0.01	0.721±0.10	0.13±0.12	244±0.20
25	0.580±0.22	0.750±0.60	0.11±0.50	200±0.01
30	0.642±0.12	0.820±0.20	0.10±0.22	144±0.11

Values are mean standard deviation of triplicate results

TABLE 3. COMBUSTION CHARACTERISTICS OF THE BRIQUETTES FROM RICE STALK USING STARCH AS BINDER

SUBSTRATE RATIO (%)	CALORIFIC VALUE (MJ/Kg)	COMBUSTIBILITY TIME (min)
10	12.90±0.02	28
15	12.96±0.12	24
20	13.10±0.30	18
25	13.50±0.14	14
30	13.86±0.10	12

Values are mean standard deviation of triplicate results

4. DISCUSSION

4.1 ASH CONTENT

Ash content is inorganic oxides that remain after complete combustion of materials (Speight, 2008). This parameter is an important characteristic influencing the burning rate technology, emission of solid particle (Voicea *et al.*, 2013). Briquette produced with high percentage of starch has a very low ash content compared to the one of low percentage. It was observed that as the percentage of the starch increase there is decrease in the ash content of the briquettes shown in the Table 1 above, the value of the ash content obtained for each ratio were higher than 18% dry basis (Zagreb, 2008) which implies that they burn with minimum slagging effect. The cause of difference between the ash content of all briquette produced was a result of added proportion of the starch.

4.2 MOISTURE CONTENT

It was observed that briquettes produced with high percentage of starch have low moisture compared to those produced with low percent of starch binder as shown in the Table 1 above, the moisture content decreases as the percentage of starch increases. The moisture content values obtained is higher than 20% of the recommended standard by Olawale *et al.*, (2014), therefore, there will be considerable loss in energy required for water evaporation during combustion at the expenses of the calorific value of the fuel as reported by Olawale *et al.*, (2014). At 20% moisture content it means that the material does not contain free water but water is chemically bonded within the material (bound water). Therefore, since the moisture content of all the briquettes produced is above 20%, their physico-chemical properties would be influenced by the moisture content.

4.3 VOLATILE MATTER

There was difference in the volatile matter of the briquette produced as observed in the Table 1 above. The value of the volatile matter was higher than those obtained by other researchers like Akowuah *et al.* (2012); this indicates that the material and the binders which were selected are better for briquetting. Briquettes which had high relatively volatile matter are an indication of easy ignition, fast burning and proportionate increase in flame length as suggested by Loo and Koppejan (2008).

It is observed that, the briquettes produced with high concentration of the binder (starch) are the better briquettes because, the higher volatile matter of a fuel briquette, the higher the combustibility of the fuel when the ash is low (Maninder *et al.*, 2012).

4.4 FIXED CARBON CONTENT

It was observed that the percentage of fixed carbon of the briquette produced varies as the percent of binder (starch) varies. It was observed that the higher the percentage of the binder, the higher the fixed carbon. As shown in the Table 1 above, the fixed carbon of the briquette is the percentage of carbon (solid fuel) available for char combustion after volatile matter is distilled off or lost to the atmosphere. Therefore, fixed carbon gives a rough estimate of the heating value of fuel and acts as the main heat generator during burning (Akowuah *et al.*, 2012).

4.5 DENSITY

From the Table 2 above, the density at 10% concentration of the binder was 0.547g/cm³, 15% was 0.565g/cm³, at 20% was 0.72g/cm³, at 25% was 0.580g/cm³, at 30% was 0.642g/cm³. Therefore, as the binder ratio increases, the density of the briquette also increases. This implies that briquettes produced with high concentration of starch (binder) are denser and have a longer burning time when used for drying and heating or cooking while those produced with low concentration of starch (binder) are less dense and therefore they are likely to ignite much easier when compared with high concentration of binder (Ugwa and Agbo, 2011)

4.6 COMPRESSIVE STRENGTH

The compressive strength of the briquettes produced with high concentration / ratio of the binder (starch) were higher than those produced from low concentration of the binder (starch), as observed from the Table 2 above. There was difference between the compressive strength on briquettes produced with high concentration of the binder compared to those briquettes produced with low concentration of the binder because of the variations in the strength of bonds between the material and binder and within the particles.

Briquettes produced with low concentration of the binder which have low compressive strength are tends to crumble faster during burning and easily break during their transportation (Voicea *et al.*, 2013).

4.7 AFTER GLOW

The afterglow time of 341 s, 323 s, 244 s, 200 s and 144 s were recorded for the briquettes produced with 10%, 15%, 20%, 25% and 30% concentration/ ratio of the binder respectively. Therefore, as the concentration of the binder increases, the afterglow time decreases. Those briquettes with long after glow time will ignite more easily and burn with intensity for a long time.

4.8 IGNITION PROPAGATION

It was observed that as the binder composition increased, the ignition propagation of the briquettes sample decreased and this may be due to increase in density and this is supported by the findings of Oladeji (2010) who observed that the flame propagation in the briquette was influenced by density, low porosity in briquette hinders drying, devolatilization and char burning processes due to fewer free spaces for mass diffusion. It is noted that the variation in burning rate could have contributed by incombustible matter which tends to inhibit flame propagation because it slows down the diffusion of oxygen and combustion products into and out of the briquettes. Similarly, low volatile matter in briquettes is associated with difficulty to ignite and burn slowly (Sotannde *et al.*, 2010).

4.9 CALORIFIC VALUE

The calorific value also called the heating value or energy value of the charcoal briquette is the amount of heat librated for unit mass of the briquette (Aina *et al.*, 2009). The binder concentration has effect on the calorific value of the briquettes produced. It was observed from the Table 3 above that the calorific value increases as the binder concentration also increases.

The calorific value increases as the concentration of the binder increases because starch has the ability to release heat as much as possible. The calorific value at 10% concentration of the binder was 12.90MJ/kg and increased to 12.96MJ/kg at 15% concentration. The results of calorific values compared well with the result of charcoal briquettes with 25.92 MJ/Kg reported by Pinate and Dangphonhong (2018) and also in compliance with the result of carbonized rice husk briquettes with 25.78MJ/Kg reported by Elinge *et al.* (2019).

4.10 COMBUSTIBILITY TEST

The results of the combustibility test are shown in Table 3 above; it was observed that the time reduced as the concentration of the binder increased. It took 28mins, 24mins, 18mins, 14mins and 12mins for 10%, 15%, 20%, 25%, and 30% concentration of the binder respectively to burn one litre of water. It was observed that the increase in the binder proportion actually reduced the time while improving residence time for the briquettes to undergo complete combustion (Olawale *et al.*, 2014).

5. CONCLUSION

The proximate composite, viability characteristics and combustion characteristics of rice stalks briquettes have been investigated. The results obtained for all the parameters showed that rice stalks briquettes produced with high concentration of the binder (starch) had a better performance based on their combustion profile. The properties were improved progressively with increase in binder ratio (starch).

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