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Direct Research Journal of Agriculture and Food Science

Vol.6 (9), pp. 231 -237, September 2018
ISSN 2354-4147
DOI: https://doi.org/10.26765/DRJAFS.2018.1603
Article Number: DRJA8749151603

Direct Research Journal of Agriculture and Food Science
http://directresearchpublisher.org/journal/drjafs

Research Paper

Evaluation of some Combustion properties of Rice Husk Briquettes Produced at Varying Binder Concentrations from a Modified Block Briquetting Machine

Gbabo[1], A., Gana[2*], I. M., Efomah[3], N. A. and Aturu[1], B. O.

[1]Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Niger State,Nigeria.
[2]Department of Agricultural and Bio-Environmental Engineering, Federal Polytechnic Bida, Niger State, Nigeria.
[3]Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria.
*Corresponding Author E-mail: ganaibro74@yahoo.com

Received 24 July 2018; Accepted 21 August, 2018

Some combustion properties of rice husk briquettes produced at varying binder concentrations from a modified block briquetting machine that was designed and fabricated in the Federal University of Technology Minna, Niger State, Nigeria, were assessed with a view to ascertaining the best binder concentration that produced the best briquettes in terms of their combustibility. 10 kg of rice husk was collected from Onyx rice mill, Bida, Niger State Nigeria. They were manually cleaned to remove minor rice bran particles and other impurities using sieve of hole size 3 mm diameter. The rice husk were dried in the sun to 5% and mixed with five different concentrations: 10 g, 20 g, 30 g, 40 g and 50 g and mixed uniformly. The resultant aggregates were used to produce briquettes and sun dried for 3 days at an average daily temperature of 32°C to a moisture content of 5%. The process was replicated three times and their combustion properties: percentage volatile matter, ash contents, fixed carbon and heating values were evaluated. The briquettes with lower starch concentration, 10% and 20 % had higher and similar volatile matter value of 72.00±0.01^{d} and 73.20±0.00^{e} respectively while the volatile matter percentage reduce with increase in starch concentration value from 68.49±0.04^{c} to 57.14±0.01^{a} at 30% and 50%. Ash content values of the briquettes produced increased from 9.73±0.00^{a} at 10% binder concentration to 22.15±0.00^{e} at 50%.Fixed carbon percent reduced from 18.27±0.01^{b} to 16.59±0.01^{a} at 10% and 20% binder concentration levels and increased from 16.59±0.01^{a} at 20% to 20.71±0.02^{e} at 50% binder concentration, while heating value of briquettes reduced with increase in binder concentration from 30.39±0.01^{e} MJ/kg to 26.25±0.00^{a} MJ/kg at 10% and 50% binder concentrations respectively.

Keywords: Combustion properties, rice husk, briquettes and binder concentrations

INTRODUCTION

Due to energy crisis and constant increase in the price of fossil fuels and the environmental problems associated with firewood, the world's trend is gradually changing to renewable sources of energy like solar, wind and biomass briquetting of agricultural residues and wastes (Meihu, *et al.*, 2017). 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 burnt 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, 2000a). In Nigeria, a large quantity of rice husks are produced annually and these residues are left to rot away or they are burned like other agricultural wastes. These residues could however, be used to generate heat for domestic and industrial cottage applications (Fapetu, 2000b). Mahar, (2011) assessed different technologies for converting agricultural biomass such as rice husk into energy and found biomass pellets and briquetting technologies as most feasible, environmentally sound and economically viable.

Rice husk is a by-product of milling paddy. It is produced after the paddy passed through the husker and conveyed outside the mill through an aspirator. The amount of rice husks produced in a rice mill depends on the capacity of the milling plant. Large capacity mill usually produces a lot of rice husks per unit hour. Rice husks may either be whole or ground, depending on the type of husker used. For rice husk briquetting, ground rice husk is better to use in attaining proper densification. In addition, ground rice husk may require a higher-pressure blower. A kilogram of paddy can produce about 200 grams of rice husks. This is about 20% of the weight of paddy and this may vary in few percent, depending on the variety of rice. Therefore, a 1-ton paddy per hour rice mill is capable of producing 200 kg of rice husks per hour.

Maih *et al*. (1999) conducted a study on rice husk briquettes at Sylhet, Khulna and DinajPur districts of Bangladesh in order to identify the problems and prospects of using the briquettes as an alternative fuel for cooking. Rice is the staple food for the people of Bangladesh. The total annual production of paddy is about 28 million tonne (FAO, 1992) and about 20% of this (5.6 million tonnes) is rice husk. The study also concluded that to prevent environmental hazards caused by rapid deforestation activities, rice husk briquettes may be introduced as an alternative fuel which is smoke free, less hazardous, high calorific value and comparatively cheap. Shakya *et al*. (2005) stated that agricultural residues like ground nut shells, straws, tree leaves, grass, rice and maize husks, banana leaves and sawdust can be used for briquette making. Although some materials burn better than others, the selection of raw material is usually dependent on what is easily available in the surrounding area of where the briquettes are made. These properties, more specifically influences the formation of briquette on the average and the variation in elemental compositions, are also of essential for modeling and analyzing the energy conversion processes.

Rajvir *et al*. (1980) reported that rice husk is quantitatively the largest by-product of rice milling industry and constitutes one fifth of paddy on a dry weight basis. However, rice husk in its present form, just like any other agricultural residues, cannot be effectively used for energy conversion. This is because utilization of agricultural residues is often difficult due to their uneven characteristics. It is widely accepted that the majority of the residues in their natural forms have lower density, higher moisture content and lower energy density. Besides, the low bulk density and dusty characteristics of the biomass also cause problems in transportation, handling and storage (Husan *et al*., 2002). The application of biomass briquetting which is the densification of loose biomass residues, such as sawdust, straw, rice husk etc, into high density solid blocks called briquettes that can be used as a fuel is an effective way to solve these problems and contribute towards alleviation of energy shortage and environmental degradation (El-Saeidy, 2004). A briquette is therefore a block of flamable matter used as fuel to start and maintain a fire. Common types of briquettes are charcoal and biomass briquettes. Biomass briquettes (including pellets, which are very small briquettes) replace fossil fuels or wood for cooking and industrial processes. They are cleaner and easier to handle, and cut greenhouse gas emissions.

Biomass briquettes produced under different binder concentrations have been reported to have different handling characteristics. These characteristics are also found to be strongly affected by the raw material properties and binder concentration. If biomass or agro-waste briquettes are to be used efficiently and rationally as fuel, they must be characterized to determine parameters such as the moisture content, ash content, density, volatile matter, and heating value among others. The result of these determinations indicates the positive and negative attributes of the agro waste briquettes.

The broad objective of this work is to convert rice husk which is a popular agricultural residue in Nigeria into biomass briquettes using a vibratory block mould briquetting machine fabricated by Desfabeng Co. LTD. Bida, Niger State, Nigeria. This would be followed by determination of the combustion properties of the briquettes produced at varying binder concentrations with a view of obtaining the best binder concentration ratio that will produce briquettes with the best combustion properties that would produce sufficient heat energy needed for domestic and industrial utilization.

DESCRIPTION OF THE MODIFIED BLOCK BRIQUETTING MACHINE

This motorized vibratory briquette making machine (Plate 1) has four major assembling units which comprises of the housing frame, the mould unit, the ram and the head casing.

Machine housing frame

This component of the machine is designed with a rouged and compact housing frame in which other assembling parts are attached (Plate 2). It is made up of

Plate 1. Motorized vibratory briquette making machine.

Plate 2. Machine housing unit.

Plate 3. Machine mould unit.

10 mm thick mild steel plate, cut, shaped and welded together to form a rectangular frame of (330 × 500) mm × 508 mm (*w: l: h*) with a flat base on which there are four clits provision to fastened the machine to a spot. Attached to the housing is an electric motor seat, the two vertical shaft of 50 mm diameter that carries the other attaching parts of the machine, the hand control lever mechanism to actuate the vertical movement of the mould and also four grooves housing the springs.

Machine mould unit

The mould (Plate 3) which is framed into a rectangular compartment of size 220×470×230 mm (*w: l: h*) is made up of a 4 mm thick mild steel plate welded to form a rectangular shaped box, in which two cylindrical moulding compartments are housed. Inside the cylindrical moulding compartments are also two tapered cylindrical pipe to allow for the design of hollow briquette. Among the purpose of the middle hole in briquette is to encourage rapid drying, high efficient burning e.t.c. The mould unit itself is attached to the housing by four 10 mm studs on the mould compartment at the four corners by a corresponding landing groove on the housing frame vertical shaft.

The ram

In other to achieve proper briquette compaction, a ram is introduced as a press. The ram itself holds the piston press and it comprises of the ram guide shaft with a sliding groove slot on both sides for easy attachment to the head casing. A plate of 10 mm thick mild steel holding the two cylindrical shaped piston studs of six pieces of Y12 rod for each mould is fastened to the rammer guide by four 10 mm bolts (Plate 4).

Plate 4. Ram plate.

Plate 5. Head casing.

The head casing

The machine head casing unit comprise of two adjourning grooves to connect the housing vertical shaft (Plate 5). Attached to the head casing is the rail slide slot for the ram guide. The head casing has a mechanism through which the ram unit is being locked or unlocked to achieve a steady ramming operation at compaction.

Wooden pallet

A wooden pallet of size 520 × 360 mm was made to support discharged mould and to transport each briquette.

MATERIALS AND METHODS

The following materials were used for the study:

Materials

(i) Rice husk
(ii) Cassava starch gel
(iii) Water

Equipment

(i) Sieve
(ii) Oven (E.L.E limited-serial number S80F185-Hemal Hempstead Hertfordshire S80F185 – Hemel Hempstead Hertfordshire, England)
(iii) Furnace (Isotemp Muffle Furnace Model 186A – Fisher Scientific)
(iv) Metal cans
(v) Electronic weighing machine
(vi) Fuel samples (briquettes produced and, fuel wood).

METHODOLOGY

10 kg of rice husk was collected from Onyx rice mill, Bida, Niger state Nigeria. They were manually cleaned using sieve of size 3 mm diameter which allowed passage of unwanted materials such as bran and other minute particles and retained the husk.

The rice husk were dried in the sun to reduce the moisture content to 5% and mixed with measured quantities of cassava starch gel (water/starch solution) of five different concentrations: 10 g, 20 g, 30 g, 40 g and 50 g and mixed uniformly with a shovel (Plate 6). The resultant aggregate was fed into the briquette machine, compacted and discharged on the mould pallet (Plate 7) and the briquette produced was sun dried for between 3 days to a moisture content of 5%. The briquettes were then analyzed for the following combustion properties and results presented in (Table 1 and Figure 1).

Percentage volatile matter

An estimation based on ASTM standard for the percentage volatile matter of the briquette produced was computed using the following experimental process. A unit of each briquette samples of rice husk was placed in a crucible of known weight and oven dried using oven model ELE international limited serial number S80F185-Hemal Hempstead Hertfordshire S80F185, England to a constant weight after which it was heated in the furnace (Isotemp Muffle Furnace Model 186A – Fisher Scientific) at a temperature of 550°C for 15 min. The percentage volatile matter was then expressed as the percentage of loss in weight to the oven dried weight of the original sample as shown:

$$V_m = \frac{m_3 - m_4}{m_2 - m_1} \times 100 \qquad (1)$$

Where, V_m = Percentage of volatile matter,
m_1 = weight of empty cup,
m_2 = weight of empty cup + sample,
m_3 = weight of empty cup + sample after taken from the stage (I),
m_4= weight of empty cup + sample after cooling.

Ash content

5 g of the briquette samples was weighed into a porcelain crucible. This was transferred into the muffle furnace set at 550°C and left for about 4 h. About this time it had turned to white ash. The crucible and the content were cooled to about 100°C in air, then to room temperature in a desiccator and weighed. The ash content was compute as:

$$\text{Ash content} = \frac{\text{Weight of ash} \times 100}{\text{Original weight of sample}} \qquad (2)$$

$$\text{Ash content} = \frac{W_a - W_c}{W_o - W_c} \times 100 \qquad (3)$$

Where
W_a=weight of ash+can (4)
W_c =weight of empty can
W_o =original weight of sample + can

Percentage fixed carbon

The formula for fixed carbon is obtained following the procedure by Suryaningsih *et al.* (2017) as:

$$FC\,(\%) = 100 - MC(\%) - VM\,(\%) - AC(\%) \qquad (5)$$

Where, FC = Fixed carbon (%)
MC = Moisture content (%)
VM = Volatile matter (%)
AC = Ash content (%)

Heating value (Hv)

The heat value is also obtained using the expression given by Tamilvanan (2013) as:

$$H_v = 2.326\ (147.6C + 144V) \qquad (6)$$

Where
C = % fixed Carbon
V = % Volatile matter

Plate 6. Material preparation.

Plate 7. Ejection of briquettes from machine.

Table 1 Combustion properties of rice husk briquette

% Binder	Volatile matter %	Ash content %	Fixed carbon %	Heating value MJ/kg
10% Starch	72.00±0.01^{d}	9.73±0.00^{a}	18.27±0.01^{b}	30.39±0.01^{e}
20% Starch	73.20±0.00^{e}	10.21±0.00^{b}	16.59±0.01^{a}	30.21±0.00^{d}
30% Starch	68.49±0.04^{c}	11.56±0.00^{c}	19.92±0.01^{d}	29.79±0.01^{c}
40% Starch	62.72±0.00^{b}	18.75±0.00^{d}	18.50±0.01^{c}	27.37±0.00^{b}
50% Starch	57.14±0.01^{a}	22.15±0.00^{e}	20.71±0.02^{e}	26.25±0.00^{a}

Mean value with different superscript in each column are significantly different ($P < 0.05$) using Duncan Multiple Range Test (DMRT).

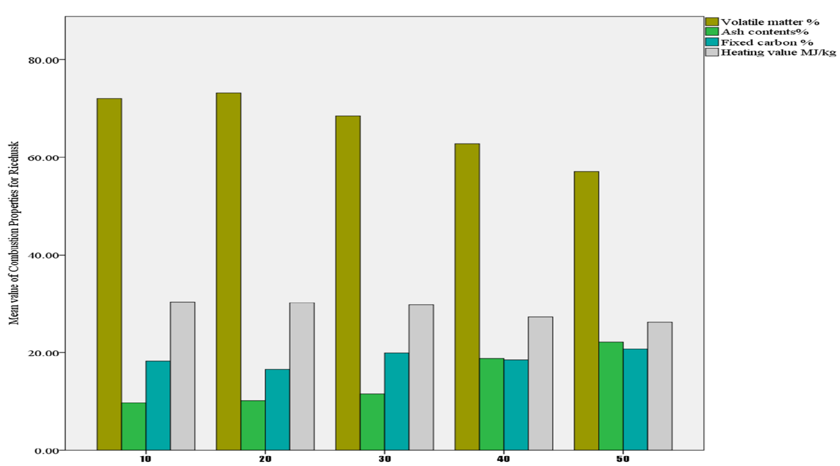

Figure 1, Combustion properties of rice husk.

RESULTS AND DISCUSSION

Volatile matter

The briquettes with lower starch concentration, 10% and 20% had higher and similar volatile matter value of 72.00±0.01[d] and 73.20±0.00[e] respectively while the volatile matter percentage reduce with increase in starch concentration value from 68.49±0.04[c] to 57.14±0.01[a] at 30% and 50%. The initial increased in volatile matter value with increase in starch concentration from 10 % to 20% is in lined with the results of an earlier study by Ogwu *et al.* (2014), where the volatile matter value of briquette produced from combination of biomass materials (sawdust) of *Afzelia africana, Daniella oliveri* and Rice husk increased with increase in starch binder. Since the briquette is to be used for the generation of heat energy and lower starch concentration levels in binder results in the production of higher volatile matter.

Ash content

The ash content values of the briquettes increased from 9.73±0.00[a] at 10% binder concentration to 22.15±0.00[e] at 50%. However, the ash content values at binder concentration values of 10% and 20% were almost the same, 9.73±0.00[a] and 10.21±0.00[b] respectively. Increase in ash content level is an indication of low combustibility of the product. As such binder with lower concentration of 10% and 20% has preferable quality in terms of ash content production level after combustion process. The higher percentage of the starch binder serves as an impurity that reduced the burning capacity of the briquette. This agreed with result reported by Suryaningsih *et al.* (2017), where the percentage of the ash content of rice husks was found to increase with decrease calorific value and volatile matter.

Fixed carbon

Fixed carbon percent reduced from 18.27±0.01[b] at 10% to 16.59±0.01[a] at 20% binder concentration levels and increased from 16.59±0.01[a] at 20% to 20.71±0.02[e] at 50% binder concentration. Since fixed carbon is the solid combustible residue left after combustion of biomass material, lower values of fixed carbon is an indication of better combustibility of that material. Therefore, the binder concentration level of 20% with 15.59% carbon fixed carbon combusted better compared to the highest binder concentration 50% with 20.7% fixed carbon. This also indicated that the more the volatile matter the lesser the fixed carbon content of the briquette. The results agreed with the findings reported by Erzam *et al.* (2017), where increase of the starch content of briquette increased the volatile matter but reduced the fixed carbon content of the briquette.

Heating value

Heating value of the rice husk briquettes also reduced with increase in binder concentration. Accordingly the heating value of the lowest binder concentration of 10% had the highest heating value of 30.39±0.01[e] MJ/kg while the heating value of the briquettes of 50% binder concentration is 26.25±0.00[a] MJ/kg**.** It is also noteworthy that the heating value, 30.21±0.00[d] MJ/kg of the briquettes produced by 20% binder concentration is the same with those of 10% binder concentration. This shows that the optimum binder concentration level for the production of rice husk briquette with desirable heating value range from 10-20%. Therefore, the decreased in heating value of the briquette with increase in binder concentration could as result of initial movement of the liquid starch binder to pores spaces between the rice husks.

During the heating process the moisture (water content) contained in these pores spaces become difficult to evaporate. Consequently, the water content in the briquette became higher and reduced the heating value. This agreed with results of an earlier study by Erzam *et al.* (2017), where high moisture content of binding material was found to reduce the heating value of rice husk briquette.

Conclusion

The volatile matter, ash content, fixed content and heating value of rice husk briquettes produced at varying levels of starch binder using a modified block mould machine were investigated in other to ascertain their combustibility. Results indicate that:

(i) Briquettes produced at lower starch concentration of 10% and 20% had higher volatile matters of 72.00±0.01[d] and 73.20±0.00[e] respectively while those produced with higher starch concentration of 50% had lower value of 57.14±0.01[a].
(ii) Ash contents of briquettes produced at higher, starch concentration of 50% were higher with 22.15±0.00[e] compared to those produced at lower concentration of 10% which had 9.73±0.00[a] .
(iii) Fixed carbon percent is lowest, 18.27±0.01[b] at 10% binder concentration and highest with value of 20.71±0.02[e] at the highest 50% binder concentration.
(iv) Briquettes produced at the lowest binder concentration of 10% had the highest heating value of 30.39±0.01[e] MJ/kg while those produced with the highest binder concentration of 50% were lower, 26.25±0.00[a] MJ/kg.

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