CHARACTERIZATION OF PELLETS PRODUCED FROM RICE BRAN AND CORNCOB

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ABSTRACT

Production of pellets from biomass has gained the interest of researchers in recent times due to their carbon-neutral characteristics. Problems such as low density and bulkiness inhibit their use as solid biofuels. This study produced and characterized pellets from Rice Bran (RB) and corncob using a pelleting machine. RB was collected from a rice milling factory in Ilorin, Nigeria and corncob was collected from a farm in Ogbomoso, Nigeria. The corncobs were hammer milled. Then both the hammer-milled corncob and RB were sieved with BS 14 sieve. 500 g samples were mixed with starch binder at 5% by weight. Pellets were then produced from the starched RB and corncob. The pellets produced from both materials were evaluated for pellet length, bulk density, proximate composition (moisture, ash, volatile matter and fixed carbon contents) and higher heating value. The mean values of pellet length, bulk density and moisture, ash, volatile matter and fixed carbon contents and higher heating values were 39.90 mm, 0.367 g/cm^3, 14.30%db, 32.60%, 18.20% 34.90% and 17.69 MJ/kg; and 14.90 mm, 0.166g/cm^3, 11.60%db, 72.10%, 14.30%, 2.00% and 16.92 MJ/kg for RB and corncob pellets, respectively. The results revealed that both materials can be used as raw materials for solid biofuels.

Keywords: *Pellets, Characterization, Starch Binder, Rice Husk Pellet, Corncob Pellets.*

INTRODUCTION

Biomass is a source of energy that can replace coal in certain applications like small-scale power plants, heating and many industrial applications. Domestically, it can be used in small stoves, which could decrease the effective cost of cooking (Tondare *et al.*, 2018). It is generally known that the use of fossil fuels is a major contributor to climate change and the use of biomass as an alternative energy source provides substantial socioeconomic and environmental benefits, compensating for its localized nature for its high availability and carbon-neutral properties (Japhet *et al.*, 2019). Many of the developing countries producing huge quantities of agro-residues use it inefficiently, thereby causing extensive pollution to the environment (Pandey and Dhakal, 2013).

The process of producing solid biofuel from biomass helps in the management of agro-residues in a productive way, which has been promoted to be used in various heating systems during the past decades (Markson *et al.*, 2013). Densification of biomass is a process that is used to compress raw materials to obtain denser fuels, with homogenous properties and size and also improves their handling characteristics and volumetric values and reduces transportation, collection and storage costs (Markson *et al.*, 2013). Biomass pelleting is achieved using rollers to press ground material through a die that is shaped either as a ring or a flat plate, with holes to allow for passage and densification of the ground biomass (Ciolkosz, 2009). Studies have investigated the pelletization of various types of biomass materials including woods, composts, grasses, straws, crop residues and torrefied materials (Puig-Arnavat *et al.*, 2016; Stelte *et al.*, 2012; Stelte, *et al.*, 2011; Wang *et al.*, 2018) and the lists are however not yet exhausted. Characterization accesses the potential of bioenergy resources for their natural properties such as calorific value (Pua *et al.*, 2020), thus creating new market opportunities in the agricultural sector and reducing dependency on fossil fuels. Hence, this study characterized pellets produced from rice bran and corncob for use as solid biofuel.

MATERIALS AND METHOD

Sample Preparation

Rice bran was procured from a rice milling factory in Ilorin on Latitude 8.4784237 and Longitude 4.6657027, while Corncob was collected from a farm in Ogbomoso on Latitude 8.16676 and Longitude 4.26804, Nigeria. The corncobs were hammer milled. Then, both the milled corncob and rice bran were sieved using BS 14 sieve size according to the procedure described in ASTM D442 (2014) standard. The particles of both materials that passed through the sieve size were collected and used for the experiment. 500 g of the sieved samples were then mixed with cassava starch additive at 5% by weight separately prior to the pelletization process.

Experimental Procedure

Pellets were produced from the starched samples of rice bran and maize cob using a motorized pelleting machine in the Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The pelleting machine has a die plate thickness of 6 mm and die hole diameters of 5 mm (compression ratio 6/5). Figure 1 shows the pictorial view of the experimental pelletizer.

For the production of pellets, starched feedstock materials (rice husk and corncob) were introduced into the hopper and the machine was allowed to operate by switching on the control switch. Pellets produced were collected from the pellet's outlet in a plastic bowl and allowed to air-dry and packed for characterization. Figures 2a and 2b show the sample of ground rice husk and corncob, respectively and Figures 3a and 3b show the produced rice husk and corncob pellets, respectively.

Fig. 1: The experimental pelletizer

(a) (b)

Fig. 2: Ground (a) rice bran and (b) corncob

(a) (b)

Fig. 3: pictorial view of (a) rice bran and (b) corncob pellets

Determination of physicochemical properties of pellets

The analyses of the pellets physicochemical properties were performed in triplicate and the average results were recorded. The length of pellets was measured using the method adopted by Prvulovic *et al.* (2014). Twenty (20) sample pellets were randomly selected. The length (L) of each pellet was measured using a digital Vernier caliper and the average length was calculated as the mean of the lengths of the selected pellets.

The bulk density of pellets was determined according to ASTM E873-82 (2014) standard method. Sample pellets were packed in a container of known volume, v and weight, w_0. The weight of the container with the pellets was measured as w_1. The bulk density was calculated by dividing the weight of the sample (g) by the volume (cm^3) according to the relationship in Equation 1 (Japhet *et al.*, 2015).

$$B_D = \frac{W_1 - W_0}{V} \quad (1)$$

The moisture content of pellets was determined using ASTM E871 (2013) oven-dry method. A known mass of sample (W_i) was dried in an oven at 103 ± 1 °C until three consecutive weights (W_f) of the samples are equal. The percent moisture (*MC*) in the sample is calculated using Equation 2 (Frodeson *et al.*, 2019).

$$MC = \left[\frac{(W_i - W_f)}{W_i}\right] \times 100 \quad (2)$$

Ash content was determined using ASTM D1102-84 (2013). Sample of mass, W_1 was dried in an oven at 100 °C for 30 mins to remove the available moisture in the sample. The sample was then poured into a crucible and dried in an electric furnace at 600°C until a constant weight of burnt ash was achieved. The ash was weighed and recorded as W_2. The ash content, *AC* (%), based on the weight of the moisture-free material was calculated from Equation 3 (Pazalja *et al.*, 2021).

$$AC = \frac{W1}{W2} \times 100 \quad (3)$$

Volatile matter was determined using ASTM E872 (2013) method. One gram (1 g) of sample was placed in the covered crucible of weight w*i*. The covered crucible with the sample was placed on nickel-chromium wire supports and heated at a temperature of 950 ± 20 °C for 7 min in a muffle furnace. The crucible was removed from the furnace and cooled in a desiccator. The final weight of the covered crucible with the sample was measured and recorded as W_f. Weight loss, *A* (%) was calculated using Equation 4 (Lu *et al.*, 2019) and the volatile matter, *VM* (%) in the sample was calculated using Equation 5 (Lu *et al.*, 2019).

$$A = 100 \times \frac{(W_i - W_f)}{W_i} \quad (4)$$

$$VM = A - MC \quad (5)$$

According to ASTM E870-82 (2019) standard, fixed carbon content was calculated by the difference of the summation of moisture, ash and volatile matter contents from 100 and was determined using Equation 6 as reported by Imran *et al.* (2020).

$$FC = 100\% - (MC + AC + VM) \quad (6)$$

The Higher Heating Value, *HHV* (MJ/kg) of the pellets was determined using Equation 7 (Acar *et al.*, 2016) for calculating the HHVs of biomass fuels from the proximate composition.

$$HHV = 0.196FC + 14.119 \quad (7)$$

RESULTS AND DISCUSSIONS

Tables 1, 2 and 3 show the result of pellet length, physical and proximate properties of pellets, respectively.

Length of Pellets

The maximum and minimum pellet lengths of 16.85 and 50.60 mm were obtained for rice bran pellets, while 10.00 – 20.50 mm were obtained for corncob pellets.

Table 1: result of pellet length

Pellet material	Minimum length (mm)	Maximum length (mm)	Average length (mm)
Rice bran	16.85	50.60	39.90
Corncob	10.00	20.50	14.90

Table 2: bulk density and HHV of pellets

Pellet property	Pellet material	1st trial	2nd trial	3rd trial	Average
Bulk density (g/cm^3)	Rice bran	0.343	0.36	0.397	0.367
	Corncob	0.166	0.166	0.165	0.166
Higher heating value (MJ/kg)	Rice bran	18.10	17.39	17.58	17.69
	Corncob	16.85	16.95	16.96	16.92

Table 3: pellets proximate composition

Proximate composition	Pellet material	1st trial	2nd trial	3rd trial	Average
Moisture content (%)	Rice bran	14.35	14.10	14.40	14.30
	corncob	11.30	11.60	11.90	11.60
Volatile matter (%)	Rice bran	32.45	32.80	32.55	32.60
	corncob	71.90	72.20	72.20	72.10
Fixed carbon (%)	Rice bran	18.10	17.90	18.60	18.20
	corncob	14.25	13.95	14.70	14.30
Ash content (%)	Rice bran	34.80	35.10	34.80	34.90
	corncob	2.30	1.80	1.90	2.00

The values obtained were in the range of $3 < L \leq 40$ mm (where *L* is the length of the pellet in mm) stipulated by the ISO 17829 (2015) testing standard for solid biofuels. The values obtained in this study are higher than the range of 13.25 - 14.00 mm obtained by Liu *et al.* (2013) for a mixture of bamboo and rice straw pellets. Carone *et al.* (2011) obtained the range of 16.63 - 27.83 mm for pruning residues of *Olea europaea* L. pellets using a single pelletizer unit which has control over both compression force and temperature which were also lower than the values obtained in this study. The difference in lengths may be due to the effect of the binder used in this study which is found to increase the binding ability of pellets (Rajput *et al.*, 2020). Pellets with longer length will aid packaging during transportation and efficient loading in gasification systems (Pradhan *et al.*, 2018).

Density of Pellets

The average bulk density of 0.367 and 0.166 g/cm^3 were obtained for rice bran and corncob pellets, respectively. These results were lower than the range of value of 0.6 – 0.75 g/cm^3 stipulated by ISO

17225-3 (2015) standard for solid biofuels and were also lower than the range of 0.524 – 0.793 g/cm^3 obtained by Japhet *et al.* (2015) in their study of rice husk pellets using a mould and a small hydraulic press. The difference in values may be due to the mode of pressure application during pellet production. Similar results of bulk density range of 0.30 - 0.9 g/cm^3 were obtained by Ighodalo *et al.* (2020) in their study to optimize some operational parameters in the production of high-grade fish feed pellets using a screw-type pelletizer.

Proximate Composition of Pellets

The average values of 14.30, 32.60, 18.20 and 34.90% were recorded for moisture, volatile matter, fixed carbon and ash contents, respectively for rice bran pellets while 11.60, 72.10, 14.30 and 2.00% were the corresponding values obtained for corncob pellets. The results obtained in this study deviated quantitatively from 10% (db) moisture content, 83.41% volatile matter, 15.29% fixed carbon and 1.3% ash contents obtained by Sáchez *et al.* (2014) for waste wood (sawdust) and closely related to 2.87% (db) moisture content, 30.42% volatile matter, 45.01% fixed carbon and 21.70% ash contents obtained by Ikelle and Anyigor (2014) for briquettes produced from mixture of 80% coal and 20% corncob using starch as binder. The values obtained for moisture and ash contents were higher than the ≤10% and ≤2% stipulated in the ISO 18125 (2017) standard. The reason for the difference in values may be due to the state of the pellets after production which may require additional drying processes

Higher Heating Value (HHV) of Pellets

The average values of 17.69 and 16.92 MJ/kg were the HHV values obtained for rice bran and corncob pellets, respectively. The values of HHV obtained are higher than 16.5 MJ/kg stated in ISO 18125 (2017) standard for the calorific value of biofuel, thereby confirming the usability of the pellets in energetic applications. Similar results were obtained by Tokan *et al.* (2016) who obtained values ranging from 15.129 – 17.589 MJ/kg for pellets of rice husk and charcoal. They concluded that rice bran pellets had good physical and combustion characteristics. The difference in the values of HHV for rice bran and corncob can be related to the properties of the materials. This proves the statement of Dietenberger and Hasburgh (2016) that heat of combustion depends on relative lignin, hemicellulose and extractive contents of biomass materials.

CONCLUSION

Solid biofuel in the form of pellets was made from rice bran and corncob. The pellets can serve as a source of energy generation and also aid the utilization of residues of rice and maize corn production as renewable energy sources. The length of rice bran and maize cob pellets meets the requirements of the ISO standard for solid biofuel. Their bulk density however may be improved by additives of mixture with other biomass materials. The proximate analysis of the pellets from rice husk and corncob affirms their suitability as solid biofuel. The HHV of rice bran and maize cob pellets meets the requirement for their use as solid biofuel. The pellets of rice bran and maize cob are recommended for use as solid biofuel. The performance of rice bran and corncob pellets in forced and open-air combustion mechanisms should be investigated.

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