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Effect of Binder on the Physico-Chemical Properties of Fuel Briquettes Produced from Sugarcane Peels at Ambient Temperature and Die Pressure

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Abstract: Briquetting of agricultural wastes is suitable to combat the environmental problem such as deforestation, flooding, soil erosion etc. and also serve as an alternative fuel for household cooking and supplement in small scale industries. This study investigated the physico-chemical analysis of the sugarcane briquettes at die pressure and ambient temperature. The sugarcane briquettes were prepared with cassava starch and gum Arabic as binders using a fabricated hydraulic press. The moisture content of the both briquette samples were 2.91±0.10% and 6.12±0.12%respectively are less than 15% of recommended standard. The briquette sample using cassava starch as a binder has a fixed carbon content and ash content values of 15.50±0.20% and 9.00±0.10% respectively, while that of gum Arabic are 14.00±0.12%and 8.50±0.10% respectively. The calorific values of the sample briquettes with cassava starch binder and also that of gum Arabic binder are 13.18±0.25MJ/Kg and 12.75±0.06MJ/Kg, respectively. Comparatively sugarcane briquette with cassava starch binder performs better.

Keywords: Briquettes, Sugarcane Peel, Biomass Fuel, Starch, Gum Arabic

1. Introduction

In Nigeria, biomass has become one of the most promising renewable energy sources which is striking most faster since they are accessible and environmentally friendly [1]. Some of the biomass can be use directly as fuel while majority of them are not useable directly because they have low energy density. Low density contributed to difficult to handle, transport, store and utilize in their uneven form [2].

Briquetting of biomass is a densification process which improves its handling characteristics, enhances its volumetric calorific value, reduces transportation cost and produces an even, clean and environmentally friendly and stable fuel [3]. Briquetting technology can be in two ways which are dry and wet process, the dry process requires high pressure for the production of the briquettes and does not need binder while wet pressure requires low pressure for the production of the briquettes, and also it is necessary to use binder to enhance the densification process and handling quality [4].

The previous findings show that physico-chemical and combustion characteristics of briquettes are influenced by the process used and also the raw materials parameters such as die pressure and moisture content. Many studies have been done on the use of agricultural wastes for briquettes such as groundnut shell [1], corn cob [5] and sawdust [6]. Most of research done in using agricultural waste for the briquette production focused on briquetting rice husk, corn cob, groundnut shell etc. but had little information on characteristics of the sugarcane peel with different binder types. The aim of this research is to study the effect of the binders on the physico-chemical characteristics of the sugarcane peel briquettes.

2. Methodology

2.1. Sample Preparation

Sample of sugarcane peels was obtained from Aliero, in Kebbi state, Nigeria. It was dried and the coarse particles were crushed by domestic electric grinder after drying. The grinded particles were sieved with a 2mm mesh. Cassava starch and gum Arabic were used as binders in this study.

2.2. Briquetting of Wastes

The sugarcane and binders were thoroughly mixed in order to obtain a uniformly blended mixture with 30% of binders with 200g weight of sugarcane peels. The briquettes were produced in a fabricated hydraulic press and were air dried for three weeks [7].

2.3. Physico-chemical Analysis

2.3.1. Moisture Content

Various methods could be used to determine the moisture content, the moisture content as loss in weight in a drying oven, in this research the percentage moisture content of the briquette samples were determined based on sample weight measurement before and after oven drying. The initial weight of the samples were determined (W_1), and placed in an oven set at 105±3°C for 24hours. The samples were removed and cooled in a desiccator, reweighed (W_2). Percentage moisture content was calculated according to [8] procedure, using equation 1.

$$\text{Percentage moisture} \frac{W_1 - W_2}{W_1} \text{ x } 100 \tag{1}$$

Note: W_1 = weight of sample before oven drying, (gram)
W_2 = weight of oven dried sample, (gram)

2.3.2. Volatile Matter

The briquettes percentage volatile matter content was determined using Lenton furnace. The residue of dry sample from moisture content determination preheated at 300°C for 2hrs to drive off the volatiles, the resulting sample was further heated at 470°C 2hrs, to ensure complete elimination of volatiles, just before the materials turns to ashes, and then cooled in desiccator, based on the [8] procedure. The crucible with known weight and its content was weighed and expressed as the percentage weight loss, the Percentage volatile matter was computed using equation 2.

$$volatile\ matter \frac{\text{final weight}}{\text{original weight}} \text{ x } 100 \tag{2}$$

2.3.3. Fixed Carbon Content

Fixed carbon was determined by using the data previously obtained in the proximate analysis and according to [9] using the formula was computed using equation 3

$$\%FC = 100 - (\%ash + \text{volatile matter}) \tag{3}$$

2.3.4. Ash Content

Ash content of the samples briquettes were determined using a furnace residue from fixed carbon determination were heated in a furnace at 590°C, for two hours and transferred into a desiccators to cool down the materials turned into white ash and weighed. Same procedure was repeated three time at 1hr interval until the weight was constant. The weight was recorded as the final weight of the ash, according on [8]. The percentage ash content was then calculated using equation 4.

$$\text{Ash content} = \frac{\text{weight of ash}}{\text{original weight of sample}} \text{ x } 100 \tag{4}$$

2.3.5. Density

Density as physical property of the briquette is defined as structural packing of the molecules of the substance in a given volume. The density was determined using a weighing balanced in the laboratory by taking the weight of briquette sample and the dimension measurement using vernier caliper based on [10], the volume was evaluated using the relation nr^2h and the density was computed using equation 5

$$\text{Density}\left(\frac{g}{cm^3}\right) = \frac{\text{mass}}{\text{volume}} \tag{5}$$

2.3.6. Compressive Strength

Each sample of the rectangular briquettes with dimension 3.0cm x 2.5cm and thickness of 2.0cm were loaded into the ELE tritest 50 compression machine, and the shear load was determined at 20% at 0.38mm/minute. The load dial per division (R) was noted for every change in strain (AL). The stress (in kN/m^2) and % strain was calculated using the formular [10] in equation 6 and 7.

$$\text{Stress} = \frac{\text{force (F)}}{\text{Unit Area}} = \frac{\text{load dial x calibration(CR)}}{\text{lenght x breadth of sample}} \tag{6}$$

$$= \frac{\text{R x 2.11x10KN}}{7.5\text{m}^2} = \frac{2.81\text{RKN}}{\text{m}^2} \tag{7}$$

$$\%\ \text{strain} \frac{AL}{L_0} \text{ x } 100 \tag{8}$$

(L_0 = original thickness of sample)

2.3.7. Calorific Value

Leco AC-350 oxygen bomb calorimeter interfaced with a microcomputer was used to assess the heat values of the briquettes produced. The calorific value was determined following procedure of [11] (2013).

2.3.8. Combustibility Test

About 200g of each set of briquettes was stacked into an improved stove. It was lightened with a match after application of little absolute ethanol to initiate combustion. The fire was allowed to assume a steady combustion. One litres of water in an aluminum pot whose initial temperature was recorded will be placed on the stove and a stop watch was initiated. A digital thermometer was inserted into the water inside the pot and readings taken after every two minutes interval and the corresponding temperatures recorded until water boiled [12].

3. Results and Discussions

Table 1. *Shows the average moisture, volatile matter, and fixed carbon and ash contents for the samples.*

Samples	Moisture content (%)	Volatile matter (%)	Ash (%)	Fixed carbon (%)
A	2.91±0.10	75.50±0.20	9.00±0.10	15.50±0.20
B	6.12±0.10	77.50±0.10	8.50±0.40	14.00±0.12

Values are mean standard deviation of triplicate results
Key: A = Sugarcane and Starch
B = Sugarcane and gum Arabic

As it was shown on the table above, the moisture content of the both samples were 2.91% and 6.12% respectively. The values obtained were required values for the storability, proper handling and enhance heating value as recommended by [13].

Ash is meant to be an impurity in the combustibility of the briquettes, the values of ash content obtained were 9.00% and 8.50% for the both samples respectively. The high ash content in sample A will impede combustion and sample B with low ash content is better suited for thermal utilization [14] and according to [9] general values of ash content may appear in a range from levels below 5-20%.

As it was shown on the table above, sample B of 77.50% has higher volatile matter than sample A of 75.50%. Biomass generally contains high volatile matter content range 70%-86% and low char content [15]. The volatile matter from briquettes of both samples is comparable with 67.98% of rice husk briquette reported by [5]. It is noted that the higher the volatile matter of a fuel briquette the higher the combustibility of the fuel briquette when the ash content is low [16].

The fixed carbon of the briquette, gives a rough estimate of the heating value of a fuel and acts as the main heat generator during burning [17]. The result of the fixed carbon shows that the briquette produced from sample B has a lower fixed carbon content of 14.00±0.12% which indicates prolonged cooking time but with low heat release [18]. The briquettes are better with higher fixed carbon because the corresponding calorific value is usually higher as reported by [19].

Table 2. *Shows the results of mechanical compressive strength, density, calorific value and combustibity test.*

Samples	Compressive strength (N/mm^2)	Density	(g/cm^3)	Calorific value (MJ/Kg)	Combustibility test (Sec)
A	0.99±0.03	0.709±0.02	13.18±0.25	12	
B	0.58±0.12	0.481±0.01	12.75±0.06	24	

Values are mean standard deviation of triplicate results
Key: A = Sugarcane and Starch
B = Sugarcane and gum Arabic

The compressive strength for the two samples were found to be reasonable with the briquette from sample A having the higher value of 0.99±0.03 N/mm^2. The implication of this is that briquette from sample A will suffer less damage during packaging, storage and transportation [19] and above all; it is an indication of good quality briquettes because of the strong inter particle bonds [12].

The values of 0.481±0.01g/cm^3 and 0.709±0.02g/cm^3 were obtained for the density for both samples. It is expected that it will take a longer time for the sample A briquette to burn and may release less fly ash than the other briquette [20].

Calorific value is the most important combustion property for determining the suitability of a material as fuel. The higher heating value of 13.18±0.25MJ/Kg obtained from sample A briquette compared to 12.75±0.06MJ/kg obtained in sample B briquette could be attributed to its higher density, lower volatile matter, higher fixed carbon and low ash content. It was observed that, the starch binder in sample A briquette improved the calorific value of the sample. The values obtained are less than those obtained from previous findings, for example; groundnut shell briquette 12.6MJ/kg [2], cowpea 12.37 MJ/kg and soyabeans 12.95MJ/kg [21]. It was also observed that, the briquette of sample A has a high bulk density and energy value of the briquette is influenced by its density. The higher the density the higher the energy value [22].

The result of combustibility test in Table 2, shows that the samples A briquette took 12 minutes to boil one litre of water and also took 24minutes for sample B briquette to boil one litre of water under similar condition. These indicates that the burning rate (how fast the fuel burns) and the calorific value (how much heat released) are two combined factors that controlled the water boiling time according to the calorific values obtained for both samples [12].

4. Conclusion

This study has confirmed that the briquette produced with cassava starch binder has lower moisture content, higher calorific and density than the briquette produced with gum Arabic binder. The cassava starch binder improved the qualities of the sugarcane briquette compared to gum Arabic. The briquettes produced from the two binders used in this study have proven to be suitable for bringing pulverized biomass materials together which will enhance easy transportation of briquette products.

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