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COMBUSTION QUALITY EVALUATION OF BRIQUETTES PRODUCED FROM SESAME HULL AS SOURCE OF SUSTAINABLE ENERGY

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ABSTRACT

Briquetting is an efficient way of converting agricultural and forestry residues to clean alternative energy form for rural and sub-urban communities. Therefore, this study was carried out to determine the combustion properties of briquettes produced from sesame hull as an alternative fuel source to firewood and charcoal which are drivers of deforestation. Two different briquette samples were produced; Sample (A) is a briquette produced from sesame hull with 100% binder level of starch while sample (B) is a briquette produced from sesame hull with 50% binder level of starch as binding agent. The combustion properties examined include moisture content, ash content, volatile matter, fixed carbon, density, calorific value, water boiling time and time taking by the samples to burn to ashes were also determined. The physico-chemical characteristics of the briquettes studied showed that briquettes produced of 100% binder had higher fixed carbon of 13.78 %, notable high calorific value of 26.75 MJ/Kg, water boiling time at 4.02 min and with burning time of 13.22 min. The utilization of sesame hull for the production of briquette has provided an alternative economical energy source to firewood and charcoal. The briquettes produced showed that they are suitable as an alternative source of fuel energy which can be utilize for both domestic and industrial applications.

Contribution/Originality: This study has provided additional information in the utilization of agricultural residue (sesame hull) as a potential energy raw material via briquetting densification process. The utilization of sesame hull for the production of briquette has provided an alternative economical energy source to firewood and charcoal thereby ensuring environmental cleanliness with zero tolerance for waste management.

1. INTRODUCTION

Biomass is a competently energy raw materials that could be used as a sustainable energy raw material in solid, liquid and gaseous form of energy sources (Olatunde, Bolaji, Waheed, & Adekunle, 2015).Biomass is an organic matter that is procured from plants, cereals, algae, animal wastes. It is plentifully obtainable due to its accessibility and also that carbon generated is harmless. It is made up of three main parts which are cellulose, hemicelluloses and lignin (Ige, Elinge, Aliyu, Gwani, & Hassan, 2020). Biomass remains can be divided into three main groups: primary biomass residues, found at the farm; secondary biomass residues, discharged in the agro-food industry; and tertiary biomass, which is remaining after use of products.

The fast increase in industrialization both in developed and developing countries has led in a rise in the urgent needs and consumption of energy globally (Goswam & Kreith, 2007). Traditionally, energy sources used for household use such as cooking in most developing countries have been wood fuels which consists twigs, firewood and charcoal (Emerhi, 2011). The significant use of fossil fuels has impacted so immensely to climate change which has led in the search for not traditional sources of renewable energy which are ecologically friendly and also renewable such as biomass (Akowuah, Kemausuor, & Mitchual, 2012). One of the most encouraging sustainable energy sources for substitute fuel wood in Nigeria is other forms of biomass which exhibit great opportunity as principal input for bio-energy due to their accessibilityin significant quantities as waste (Phonphuak & Thiansem, 2012).

The world has now gone into rigorous research to determine affordable processes of re-using waste materials into beneficial products. Nigeria demand for sustainable energy is on the rise. In Nigeria, numerous tonnes of agricultural by-products; sugar cane bagasse, rice husk, maize stalk, groundnut shell, palm kernel shell, etc. are produced annually which amount to the environmental hazard and resulted in air pollution when burnt-off (Achebe, Obika, Chukwuneke, & Ani, 2019; Babajide et al., 2018; Imeh, Ibrahim, Aleivo, Stanley, & Opeoluwa, 2017). Biomass residues can be transformed into valuable products via briquetting which provide vital substitute sources of energy for domestic use and small industrial scale.

Transforming biomass into briquettes aids in eliminating wastes and also makes the environment clean from unacceptable wastes (Ige Ayodeji, Moki Elinge, Gusau Hassan, Abimbola Adegoke, & Harrison, 2018). It also diminishes greenhouse gas emissions and to attain alternative livelihood to the urban and rural communities (Banconguis, 2007).Several types of encouraging briquette fuels such as, groundnut shell, bagasse, castor seed shell, saw dust, cotton stalks, bamboo dust, coffee husk, tobacco waste tea, paddy straw, mustard straw, mustard shell, sugarcane, wood chips, sesame shells and others were investigated (Munoj, Gohil, & Nikita, 2015). Sesame (*Sesamum indicum*) can be considered as a significant oil producing plant, which is cultivated mainly for the production of sesame bread, tahini (or tehineh), halva and sesame oil but the hull of the Sesame is yet to explore for the production of briquette (Abou-Gharbia, Shehata, & Shahidi, 2000; Abu-Jdayil, Al-Malah, & Asoud, 2002; Nikolakakis, Bonos, Kasapidou, Kargopoulos, & Mitlianga, 2014). The selection of the above-mentioned biomass is owing to the fact that such materials are readily available in abundance at North-Eastregion of Nigeria.This part of the country is faced with high level of desertification and this is due to deforestation activities of the inhabitants, mostly for domestic cooking purpose. Meanwhile, much waste is generated from sesame after harvesting and processing which can be converted to briquette and use for domestic cooking. The aim of this research work is to examine the combustion quality analysis of briquettes produced from Sesame hull as source of sustainable energy. The specific objectives are to determine the proximate analysis and combustion properties of the briquettes produced

2. MATERIALS AND METHODS

2.1. Sample Collection and Preparation

Sesame hulls were collected from farm lands around Gashua, Yobe State and Cassava Starch was purchased from Gashua market Bade local government of Yobe State, Nigeria. The materials were crushed into fine particle sizes using hammer mill as shown in Figure 1.

Figure-1. Sesame hulls sample.

The starch was prepared into slurry with about 10cm^3 of water. Approximately 500ml was boiled. The hot water was poured into the already dissolved starch solution and stirred to form the cassava starch paste. This procedure was used to prepare binder at 50% and 100% starch by weight of biomass material before stocking into fabricated briquetting machine. Six replicates were prepared for each procedure. Binding agents are usually added to enhance compaction biomass material to improve the quality of the resultant briquettes. Biomasses have a limited degree of elasticity. They have the tendency to spring back or even fall apart when compression is released (Etonihu, Akpabio, & Sambo, 2008). In order to reduce its springiness and maintain bulk density, binders are introduced. Cassava starch is chosen as binders in this study because they are naturally abundant in rural communities. The briquettes produced are of 35mm diameter and 75mm height. Each experiment was replicated six times.

2.2. Fabrication of Manual Briquette Machine

The materials selection for the briquetting machine components was based on the available construction material, cost and their availability of technical know-how of the fabricator. The machine molds and pistons were produced from cylindrical galvanized steel alloy to prevent rust as shown in Figure 2.

Figure-2. Fabricated manual piston briquetting machine.

Figure-3. Sesame briquette samples and its combustion.

2.3. Determination of Proximate Analysis of the Briquette Samples

2.3.1 Moisture Content

The moisture content of the briquette samples was determined and calculated as ratio of the weight of moisture to the initial weight of sample, according to Adekunle, Ibrahim, and Kucha (2015) procedure as expressed in percentage as given in Equation1 below:

$$percentage\ moisture = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

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

W_2 = weight of oven dried sample, (gram).

2.3.2. 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 Adekunle et al. (2015) the volume was evaluated using the relation $\pi r^2 h$ and the density was computed using Equation 5.

$$Density\left(\frac{g}{cm^3}\right) = \frac{Mass}{Volume} \quad (2)$$

2.3.3. 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^{0}C for 2hrs to drive off the volatiles, the leftover sample was further heated at 470^{0}C 2hrs, to ensure complete elimination of volatiles, just before the materials turns to ashes, and then cooled in desiccator, based on the Adekunle et al. (2015) 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.

$$Volatile\ matter\% = \frac{final\ weight}{original\ weight} \times 100$$

(3) (Adekunle et al., 2015)

2.3.4. Fixed Carbon Content

Fixed carbon was determined by using the data previously obtained in the proximate analysis and according to García, Pizarro, Lavín, and Bueno (2012) using the formula in Equation 4.

$$\%Fixed\ Carbon = 100 - (\%Ash + \%Volatile\ matter) \quad (4)$$

2.3.5. Ash Content

Ash content of the briquette's samples were determined using a furnace residue from fixed carbon determination were heated in a furnace at 590⁰C, 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 ASTM (1990). The percentage ash content was then calculated using Equation 5.

$$Ashcontent = \frac{Weight\ of ash}{Original\ weight\ of\ sample} \times 100 \quad (5)$$

2.3.6. Heating 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 Obi, Akubuo, and Okonkwo (2013).

2.3.7. Determination of Water Boiling Test Set-Up

500mls of water was put into the pot; the mass of the water was measured and recorded. The briquettes were sprinkled with about 5ml of kerosene to initiate initial ignition.

The briquettes were ignited, after the kerosene had burnt out, the pot of water was placed on the mud stove. The time taken for the water to boil and the temperature of the water was taken and recorded. Boiling was allowed to continue until a briquette sample in the stove was used up.

Water boiling test is one of the very important tests necessary in assessing combustion efficiency of briquette. The burning characteristics of briquettes are important in assessing both its performance and likely acceptance in domestic fireplaces.

3. RESULTS

Table-1. Results of the physico-chemical of the briquettes.

Binder level	% Ash	%Moisture Content	% Volatile matter	% Fixed carbon	Density (g/cm^3)	Heating value MJ/kg
Sample A 100	6.40±0.08	33.01±3.35	79.81±0.11	13.79±0.11	1.30±0.05	26.75±29.85
Sample B 50	7.27±0.05	46.06±2.79	82.66±0.08	10.07±0.14	1.28±0.087	22.69±11.39

Note: Values are mean standard deviation of triplicate results

Table-2. Results of the water boiling tests of the briquettes.

Briquette sample(g)	Quantity of Water boiled (ml)	Time taken to boil water (min)	Time taken to burn briquette sample ashes (min)
Sample A 100	500	4.02±0.21	13.22±0.02
Sample B 50	500	5.10±0.40	10.51±0.56

Note: Values are mean standard deviation of triplicate results

4. DISCUSSION

The moisture content of briquette samples produced from sesame hull was at 100% binder level with moisture content of 33.01±3.35% while 50% binder level has the lower moisture content of 46.06±2.79% as shown in Table 1. The result obtained is in contrast with the report of Ige Ayodeji et al. (2018) that reported moisture content of less than 18% for watermelon briquette and Sesame stalk and 10.6% and 10.8% of rice husk and saw dust briquettes charcoal reported by Thliza, Abdulrahman, Akan, Chellube, and Mand (2020). The variation observed may be due to carbonization process of the sesame stalk prior to production of briquette which has driven off the free water content of the feedstock.

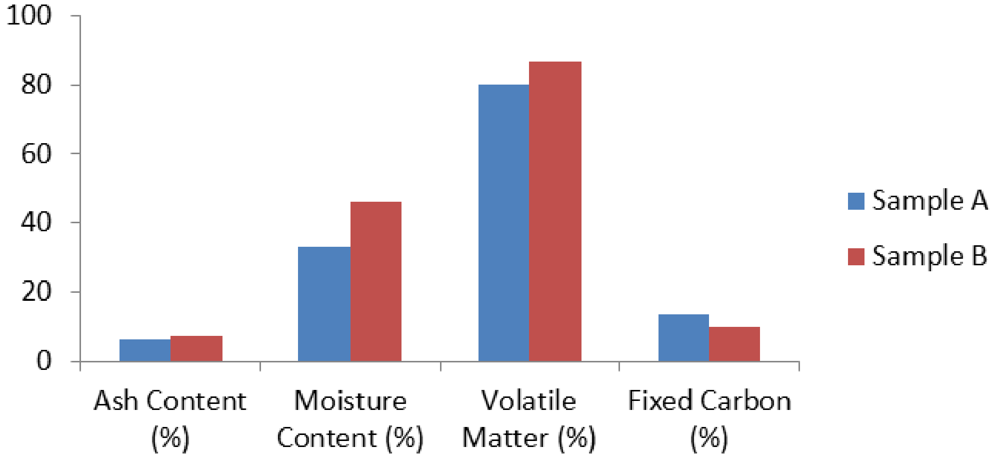

Figure-4. The proximate compositions of the sesame hull briquettes.

The amount of volatile matter in sesame hull briquette samples was higher at 50% binder level with 82.81% as shown in Figure 4, which implies that the quantity of binder used contributed to the amount of volatile matter present in the briquette samples produced. The volatile matters from sesame briquettes samples are comparable with rice husk briquette reported by Oladeji (2010). 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 (Maninder, Singh, & Grover, 2012). The sesame briquette sample with 100% binder level with lower volatile matter has an incomplete combustion which contributes to release of significant amount of smoke and gases (Akowuah et al., 2012). This was visible during the water boiling test has large amount of smoke was given off.

The fixed carbon of the briquette, predict a rough estimate of the heating value of a fuel and acts as the main heat producer during burning (Akowuah et al., 2012). The result of the fixed carbon obtained shows that the briquette produced from sesame hull generally has a lower fixed carbon content across the twobinders level used. The results of fixed carbon obtained are less than the result of the bio-coal of groundnut shell of 33.68% reported by Ikelle et al. (2020) and compare well with the results of *Prosopis juliflora*sawdust briquette of 12.28% reported by Sisay et al. (2020). Briquettes are better with higher fixed carbon because the corresponding calorific value is usually higher as reported by (Praveena, Satya, Ramya, & Sarveswara, 2014).

The lower the ash content the better the quality of fuel briquettes. Hence, the samples produced has low ash content, sample with 100% binder level has the lower which make it have the best quality compared with other sample. The results were in compliance with the reports of 7.68% of charcoal briquettes byPinate Wand Dangphonthong (2018) and 6.65% of charcoal briquettes from Acacia melifera by Chukwuneke, Umeji, Sinebe, and Fakiyesi (2020). High ash content results in high dust emissions which lead to air pollution and affects the combustion volume and efficiency (Katimbo, Kiggundu, Kizito, Kivumbi, & Tumutegyereize, 2014); Bhattacharya, Korschun, and Sen (2009) and according to García et al. (2012) general values of ash content may appear in a range of 5-20% in which result obtained fall within.

The average density value of briquette produced from Sesame hull briquette is presented in Table 1. The average values of the densities obtained fell above the values obtained in earlier studies and compared well with density of notable biomass fuels of watermelon of 0.590 and 0.397 and paper of 0.490 as reported by Ige Ayodeji et al. (2018) and Aries and Romallosa (2017). The briquette produced at 100%has the higher density when compared with the briquette produced at 50% binder content as obtained in Figure 2.The variation in density can be attributed to the increase in the binder content. Density is an important parameter in briquette production. The density of briquettes depends on the density of the original feedstock, the pressure, binder and time of densification. The higher the density, the higher is the energy ratio of the briquette (Ige Ayodeji et al., 2018).

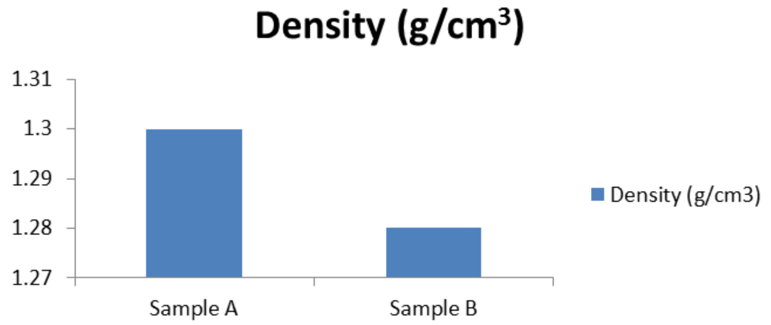

Figure-5. The density of the sesame hull briquettes.

The results of calorific values compared well with the result of charcoal briquettes with 25.92 MJ/Kg reported by Pinate Wand Dangphonthong (2018) and also in compliance with the result of carbonized rice husk briquettes with 25.78MJ/Kg reported by Elinge et al. (2019). The most important fuel property of any fuel is its calorific or heating value (Adegoke & Fuwape, 2008). The briquette produced with 100% binder level with higher heating value as shown in Figure 6 is the most suitable alternative source of fuel energy which can be utilize for both domestic and industrial application.

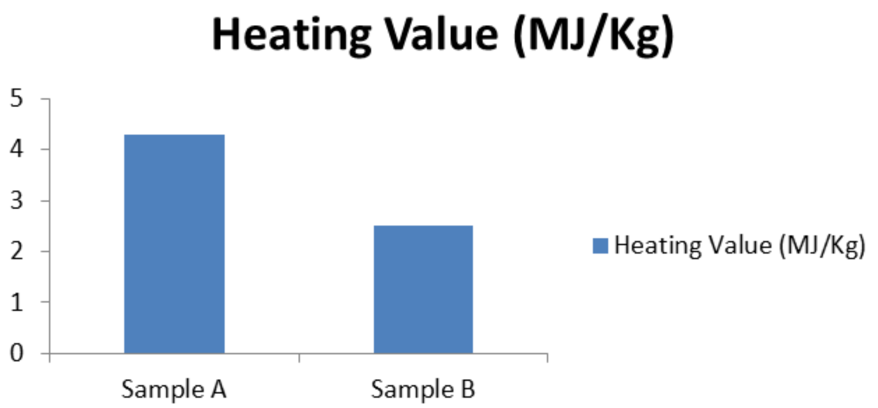

Figure-6. The heating value of the briquettes produced from sesame hull.

Water boiling test result from Table 2 showed that sample B takes longest time to boil 500ml of water (5.10min.) compared to sample A (4.02min.). Briquettes are a substitute for wood charcoal because of their similar combustion characteristics such as low volatiles content and higher fixed carbon content(Vogsaysana & Achara, 2009). It took sample A more time to burn to ashes compare to sample B as shown in Figure 7. Increasing the amount of binder increases the briquettes density, durability, time taken to burn to ashes and shear strength of the briquettes (Xianglan, Xu, Xu, & Cheng, 2001).

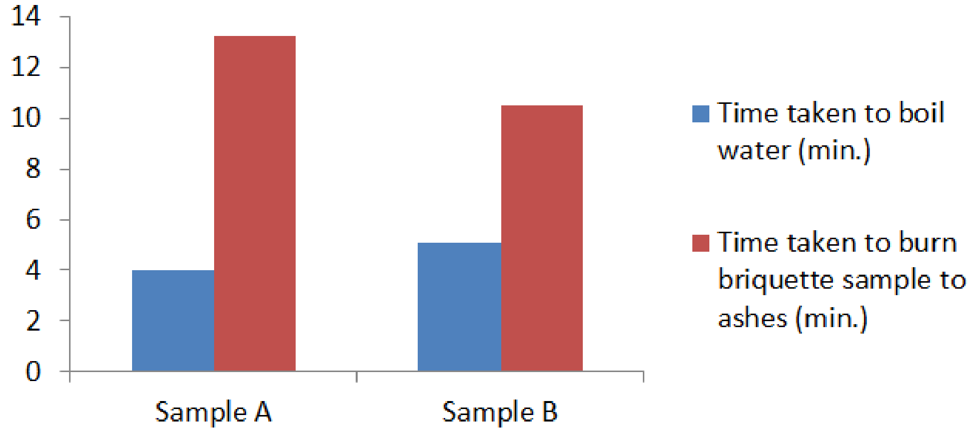

Figure-7. The water boiling tests of the briquettes.

5. CONCLUSION

Determination of briquette combustion quality, the combustion profile, such as moisture content, ash content, volatile matter, fixed carbon, density, etc., were found to be index of good biomass briquettes and therefore required properties as an alternative source of renewable energy. The physico-chemical characteristics of the briquettes studied showed that briquettes produced of 100% binder had higher fixed carbon of 13.78%, notable high calorific value of 26.75MJ/Kg, water boiling time at 4.02 min and with burning time of 13.22 min. These values showed that the briquettes with 100% binder had considerable combustion profile when compared with briquette of 50% binder level. Furthermore, the popularization and adoption of briquette production using the abundant agro-residues in the North-East region will create employment opportunities and also improve the economic power of the people.

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