INVESTIGATION OF ESSENTIAL COMBUSTION PROPERTIES OF WOOD WASTE (SAWDUST) BRIQUETTES PRODUCED BY A MODIFIED BLOCK MOULD MACHINE AT DIFFERENT BINDER CONCENTRATION

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Abstract: An investigation on essential combustion properties of sawdust briquettes of varying starch binder concentrations produced from a block mould machine was carried out. The study was carried out in order to ascertain the binder concentration that produced the best briquettes in terms of its combustibility. The sawdust was manually sieved using 3 mm hole diameter sieve and then dried to 5% moisture content. It was further divided into five samples of 1 kg each. A measured quantity of cassava starch gel of five different concentrations: 10, 20, 30, 40 and 50% were prepared and mixed uniformly with the sample. The combustible properties of the briquette were investigated. The results revealed that heating value 33.37±0.01 MJ/kg of saw dust briquettes of 30% starch concentration is the highest while the lowest value of 27.02±0.00 MJ/kg is obtained for saw dust briquettes having 50% starch concentration. This result clearly indicates that the 30% starch concentration briquettes posses better ability to release heat energy when combusted.

Keywords: Binder, briquettes, combustion properties, investigation, sawdust

Introduction

In Nigeria and other developing countries the rural and some parts of the urban areas depend solely on biomass such as wood fuel and charcoal for household cooking and space heating. The wood fuel is the main fuel used in the rural areas while charcoal is the preferred fuel used in urban centres. This may be attributed to its low cost and abundance, poverty level of the population, lack of awareness on negative effects of burning this biomass and absence of simple, low cost and appropriate technology for heat generation. The process of converting biomass to energy involves burning of the biomass. This process have many negative effects both on the environment and also on the health aspect of the people who are exposed to the air pollution generated (Ghorani-Azam *et al.*, 2016). According to Ramanathan and Feng (2009), biomass burning has significant influence on the Earth's atmosphere and climate as result of emission of greenhouse gases such carbon dioxide and other gases which contribute to global climate change. Another waste product of wood available in saw-mills, wood processing and paper industries is the saw dust. In most parts of Nigeria this waste product is gathered in a large volume in form of heaps and mostly burnt off and this resulted to environmental pollution (Rominiyi, 2017).

Many research works have focused on effects of wood fuel and saw dust burning and came up with many alternatives. One of such alternative is development of an equipment for densification of the saw dust and converting it to pellets or biomass briquettes (Shukla and Vyas, 2015).

According to Kuti and Adegoke (2008), conversion of sawdust wastes to briquette will go a long way in reducing waste disposal and burning problems in majority of the wood processing industries. Basically two types of sawdust briquetting system have developed over time these are the solid and hollow types. The former is produced using a piston press that compresses sand witched layers of sawdust together while the later are produced with a screw press (Adekunle, 2004).

A good understanding of performance characteristics of a solid biomass fuel (briquette) is an important factor to be considered in its acceptability and promotion. The performance determination can be achieve by evaluating its combustion properties such as the volatile matter, fixed carbon, moisture content, ash content, calorific value and heat value for various binder concentrations. This study is therefore aimed at converting sawdust which is a popular waste from the sawmilling industries in Nigeria into biomass briquettes using starch as binders at varying binder concentrations. The natural lignin in the wood assists in binding the particles of wood together to form a solid. Meanwhile, the briquetting process was achieved through the use of vibratory block mould briquetting machine fabricated by Desfabeng Co. LTD. Bida, Niger State, Nigeria. The produced briquettes at different binder concentrations were analysed based on their individual volatile matter, fixed carbon, moisture content, ash content, calorific value and heat value. This would help in determining the best binder concentration that would produce briquettes with the highest volatile matter and lowest ash content needed for sufficient heat generation for both 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.

Plate 1: Modified vibratory briquette making machine

Plate 2: Machine housing unit

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 10 mm thick mild steel plate, cut, shaped and welded together to form a rectangular frame of 330 x 500 x 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 and high efficient burning.

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.

Plate 3: Machine mould unit

Plate 4: Ram plate

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).

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 x 360 mm was made to support discharged mould and to transport each briquette.

Materials and Methods

Materials

The following materials were used for the study: Saw dust, cassava starch gel and water

Equipment

The following equipments were used for the study: Sieve, oven (E.L.E limited-serial number S80F 185-Hemal Hempstead Hertfordshire S80F185 – Hemel Hempstead Hertfordshire, England), furnace (Isotemp Muffle Furnace Model 186A – Fisher Scientific), metal cans and electronic weighing machine (Gbabo *et al.,* 2018).

Method

Sawdust of 50 kg was collected from saw mill, Mokwa road, Bida, Niger state Nigeria. They were manually cleaned using sieve of hole size 3 mm diameter which allowed passage of the saw dust and retain unwanted materials such as sand and lumps of mud. The saw dust 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, 20, 30, 40 and 50% and mixed uniformly with a shovel (Plate 5). The resultant aggregate was fed into the briquette machine, compacted and discharged on the mould pallet (Plate 6) and the briquette produced was sun dried to a moisture content of 5% (Gbabo *et al.,* 2018).

Plate 5: Material preparation

Plate 6: Ejection of briquettes from the machine

The briquettes were then analyzed for the following combustion properties; percentage volatile matter, ash content, percentage fixed carbon, heating value and the results are presented in Table 1:

i. **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 sample of saw dust was placed in a crucible of known weight and oven dried using oven model E.L.E 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 550ºC 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 (Gbabo *et al*., 2018), as shown:

$$P_{DM} = \frac{W_3 - W_1}{W_2} \times 100 \qquad (1)$$

Where P_{DM} is percentage of the volatile matter (%),W_2 is weight of crucible and the final sample (g),

W_1 is weight of the empty clean crucible (g), W_2 is the initial weight of the briquette sample (g)

ii. **Ash content:** The briquette sample of 5 g was weighed into a porcelain crucible. This was transferred into the muffle furnace set at 550ºC and left for about 4 h. About this time it had turned to white ash. The crucible and the content were cooled to 100ºC in air, then to room temperature in a desiccator and weighed. The ash content was computed as reported by Gbabo *et al*. (2018) and is given as:

$$Ac = \frac{W_{a-}W_c}{W_{o-}W_c} \times 100 \qquad (2)$$

Where Ac is the percentage ash content (%), W_a is the weight of ash and can (g), W_a is weight of the empty can (g), W_o is the original weight of the sample and can (g)

iii. **Percentage fixed carbon:** The formula for fixed carbon is obtained following the procedure by reported Ikwuagwu and Uzoegbu (2017) and is given as:

$$F_C = 100 - (V_m + A_C) \qquad (3)$$

Where: F_C is percentage of fixed carbon, V_m is volatile matter, A_C is percentage ash content

iv **Heating value (Hv):** The heat Value is also obtained using the expression reported by Ikwuagwu and Uzoegbu (2017) and is given as:

$$H_v = 2.326\,(147.6C + 144V) \qquad (4)$$

Where C = % fixed Carbon; V = % Volatile matter

Results and Discussions

The results of the study are shown in Table 1 and Fig. 1.

Volatile matter

The percentage volatile matter of the saw dust briquette is highest with value of 83.63±8.00 at starch binder concentration of 30% and lowest, 63.15±0.01 at the highest binder concentration of 50% while the lowest binder concentration of 10% had 77.96±0.02% volatile matter. The initial increase in volatile matter value with increase in starch concentration from 10 to 30% 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. This shows that the saw dust briquette from 30% binder concentration has a higher tendency to burn better than the others since volatile matter in biomass materials are directly related to the amount of heat liberated from such materials.

Ash content

The ash content of saw dust briquettes produced with 50 and 40% starch binder concentration had higher ash contents of 19.74±0.03 and 14.06±0.01, respectively; while those of 20 and 10% binder concentration were 11.10±0.02 and 11.63±0.04, respectively. The least ash content of 0.55±0.09 was obtained for saw dust briquettes with 30% starch concentration. 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 decreased calorific value and volatile matter. Ash in biomass are inorganic minerals that constitute problems in combustion resulting in particulate emission, slag, deposit formation and corrosion on boilers in factories. Therefore saw dust briquette with 30% starch concentration that had the least ash content is likely to cause fewer problems in combustion.

Fixed carbon

Saw dust briquettes produced with 30% starch concentration had the least fixed carbon percents of 0.55±0.09 while the highest fixed carbon values of 17.08±0.11% was observed for the briquettes with the highest starch concentration of 50%. This also indicated that the more the volatile matter the less 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. Since fixed carbon is the solid combustible residue left after a biomass material is heated and the volatile material is expelled, briquettes with lower values of fixed carbon will have better combustibility, hence the saw dust briquettes made with the 30% starch concentration are the best.

Table 1: Combustion properties of sawdust briquette

Binder Conc. (%)	Volatile matter (%)	Ash Content (%)	Fixed carbon (%)	Heating value (MJ/kg)
10	77.96±0.02	11.63±0.04	10.39±0.01	29.68±0.01
20	67.08 ±0.01	11.10±0.02	13.71±0.01	27.17±0.01
30	83.63±8.00	0.55±0.09	7.81±0.01	33.37±0.01
40	77.68±0.66	14.06±0.01	7.61±*0.01*	28.85±0.15
50	63.15±0.01	19.74±0.03	17.08±0.11	27.02±0.00

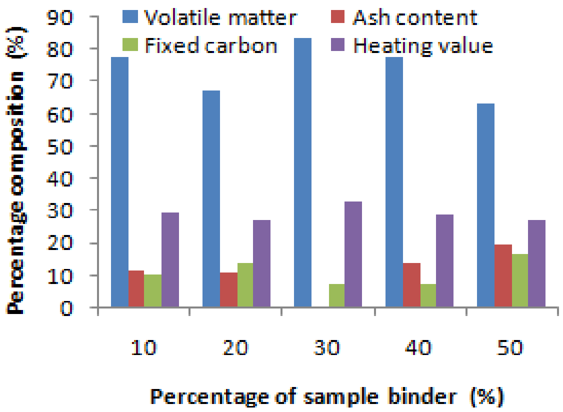

Fig. 1: Combustion properties of saw dust briquettes at different starch binder concentration

Heating value

The heating value of saw dust briquettes of 30% starch concentration is 33.37±0.01 MJ/kg which is the highest while the lowest value of 27.02±0.00 MJ/kg is obtained for saw dust briquettes having 50% starch concentration. This result clearly indicates that the 30% starch concentration briquettes posses better ability to release heat energy when combusted. Therefore, the decrease in heating value of the briquette with increase in binder concentration could be as result of initial movement of the liquid starch binder to pores spaces between the saw dusts. During the heating process the moisture (water content) contained in these pore 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 results of this study will go a long way in providing efficient way of utilizing biomass that are disposed in an open area and poorly designed landfill sites, this result in many negative social, economic and environmental consequences such as methane generation, contamination of ground and surface water sources and spread of diseases. In addition, burning process of these wastes in an unscientific way causes emission of huge amount of pollutants such as; carbon monoxide, nitrous oxide, nitrogen dioxide and particles (smoke carbon) in the atmosphere which are the main culprits of green house effect. Therefore, the use of huge amount of saw dust in production of briquette will generate energy and reduce the emission of greenhouse gas. Also understanding the combustion characteristics of saw dust briquette will help in determining the best binder concentration that would produce briquettes with the highest volatile matter and lowest ash content needed for sufficient heat generation for both domestic and industrial utilization.

Conflict of Interest

Authors declare that there is no conflict of interest.

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