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Evaluation of Charcoal Briquette Production from Organic Solid Waste Streams Generated in the Ramat Polytechnic, Maiduguri

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Abstract: *This study will evaluate the potential of charcoal briquette production from sawdust and leave falls generated within the Ramat Polytechnic Maiduguri campus. The composition of the materials to be used for briquette production will be 100% sawdust, 100% leaves, and a combination of 50% sawdust and 50% leaves with particle sizes of 1.18mm and 0.3mm. Clay and gum Arabic pastes will be used as binding materials. Bulk density, compressive strength, ash content and calorific value were determined to identify the briquettes with the greatest physical and combustion integrity. The highest density and compressive strength of 1.209g/cm3 and 2.31 N/mm2 were obtained from a briquette of leaves + clay binder with 0.3mm particle size, while the lowest ash content and highest calorific value of 2.6% and 24.20 mj/kg were obtained from a briquette of sawdust + leaves + clay and leaves + gum arabic with 1.18mm and 0.3mm particle size respectively. The obtained result would be scaled up for both domestic and small-scale applications.*

Keywords: *Briquettes, leaves, Sawdust, Particle size.*

1 Introduction

1.1 Background of the study

The demand for energy from renewable raw materials is receiving more attention at local, national and global scales than ever before. These could be attributed to the high rise in the price of conventional fuel, and environmental pollution leading to climate change. Renewable energy from biomass materials including municipal wastes, agricultural food and feed crops, energy crops and trees, agricultural crop wastes, wood wastes and other waste materials are considered as one of the major potential sources for energy production (EPA, 2009; Sivakumar and Mohan 2010). Studies have shown that renewable energy which is considered as energy source in many developed and developing countries could significantly improve the quality of air, water, land, economy and energy security at large (Balat, 2009; Uzun and Kanmaz, 2013). Research demonstrates that the conversion of renewable raw materials to energy could significantly reduce fossil fuel consumption and the emission of greenhouse gases (Laryea-Goldsmith et al., 2011). Interestingly, an increased awareness of environmental protection have increased the demand for clean and highly efficient utilization of coal being an important scientific and technological issue.

Therefore, the briquette is one of the development directions of clean coal technology (Wu *et al.,* 2011). The technology has attracted much attention and has become one of the important themes of energy research. Clean coal technology represents a series of new techniques aiming to decrease pollutant discharge and improve energy utilization efficiency as much as possible in the processing, combustion and conversion etc. of coal (Wang and Li, 2011). However, briquetting requires the addition of a binding material to hold the briquette together for transportation, briquette forming and storage, while binder plays an important role, the strength, thermal stability, combustion performance and cost of the briquette depend on the quality of the briquette binder used in the production. Similarly, it involves the compression of a material into a solid product of advanced bulk density, lower moisture content and outfit size and shape (Liu et al., 2017). Solid organic waste generated from Ramat Polytechnic Maiduguri and sawdust from timber shade is an important biomass for conversion to charcoal briquette. Therefore, this study will aim to evaluate the performance of produced briquettes ascertain the effect of the binding materials and determination of calorific values to serve as alternative energy with the capacity to replace conventional charcoal in terms of cost-effectiveness and sustainability.

2. MATERIALS AND METHODS

2.1 Materials

In this study, some of the materials and equipment used include sawdust, leaves, Gum Arabic, Cassava flour, forced air drying oven (VNB300, Memmert Germany), Drying cabinet (FSM 140, Ohaus core USA) Digital Analytical balance (PA214), Pioneer ohaus USA), Porcelain crucibles, Muffle furnace (P-Select 2000368, select HORN Ohaus USA),

2.1.1 Collection of Biomass Material

The sawdust sample to be used for this study was collected from a timber shade along Damboa Road while the leaves sample was collected from a dump site within the Ramat Polytechnic, Maiduguri Campus. Subsequently, the gum Arabic was purchased from a local market (Kasuwan Gamboru) in Maiduguri. The clay sample was collected at the polo field ground along Polo Road, Maiduguri.

2.2 Methods

2.2.1 Sample preparation

The sawdust and the leaves were screened from impurities like sand, metallic objects, grits and chips of wood. The sawdust was sun-dried to reduce moisture content. Thereafter, sawdust and leaves were artificially carbonized in an open drum at a temperature of 400oC for 3 hours. Cooled carbonized biomass, gum arabic and clay will be grounded into pulverized form and be settled using 1.18mm and 0.3mm sieve sizes to ensure steady grain size and ease of compression. The biomass material and the corresponding binders were mixed in a ratio of 1:1 where 25g of each sample was adopted for all materials using a digital weighing scale.

2.2.2 Production of briquettes

The mixture of materials to be used for the production of the briquettes were obtained using particle sizes of 1.18mm and 0.3mm as presented in Table 1 below.

Table 1: Materials for briquette production

Biomass	Binder
Sawdust	Clay
Leaves	Clay
Sawdust + Leaves	Clay
Sawdust	Gum Arabic
Leaves	Gum Arabic
Sawdust + Leaves	Gum Arabic

The binders were made into non-thick gel using the moisture content of each binder introductory to briquettes. The biomass and the binders were mixed as presented in Table 1 above. Each mixture was filled into a cylindrical mold and placed on a pressing hydraulic jack machine and compacted at a pressure of 20.96mpa read from the pressure gauge that was inserted at the pressing point of the machine which will helped in regulating the constant compaction pressure and prevention of oozing out of the binder. A total of twelve (12) cylindrical briquettes with a mean diameter of 2.24cm and height of 3.8cm were produced. The produced briquettes were sundried for 7 days.

2.2.3 Determination of physical and combustion properties of produced briquettes.

Some of the physical and combustion properties of the briquettes produced include; the density, compressive strength, Ash content and calorific value (CV) were evaluated.

2.2.4 Determination of density of produce briquette

The equivalent mass (m) of the material/object in grams (g) was divided by the volume of the object (v) in cm^3

$$d = \frac{m\ (g)}{v\ (cm^3)}$$

2.2.5 Compressive strength of produced briquettes

A briquette sample was inserted between two plates on a compressing machine subjected to compression. The ratio between the maximum breaking force and the cross-sectional area of the sample will be recorded by the pressure gauge in N/mm2 to indicate the resistance to breaking by compression.

2.2.6 Determination of ash content of produce briquettes

Approximately 3g of grated briquette sample was evenly spread on a weighed container (crucible) and placed onto a muffle furnace (P-select 200 368, select HORN) set at 350oC. The sample was kept at the above temperature until it appeared light grey. Hence, the crucible was removed and placed in a drying cabinet (FSM 140) which was left to cool and reweighed immediately.

$$AC\ (\%) = \frac{mc - ma}{mb - ma} \times 100$$

- ma = weight of porcelain crucible (g)
- mb = weight of porcelain crucible and sample (g)
- mc = weight of porcelain crucible and ash (g)

2.2.7 Determination of calorific value of briquettes (according to ASTM standard method)
The calorimeter was calibrated by combusting 1g of benzoic acid which has a known C.V. About 1g of the briquette sample was placed in a metal sample cup which was placed into a holding slot between two electrodes extending from the lid of a stainless steel container. Thereafter, a thin metal wire fuse was attached to the electrodes which forms a loop into the coal sample and then placed into "bomb container". Thus, the bomb containing the briquette sample will be transferred to a water bath where an electrical current was used to spark the sample which ignite the bomb. The sample ignite in turn and heated the water bath. Hence, the water change – bath temperature was used to determine the calorific value of the sample.

3.0 Result and Discussion
The result of the physical and combustion analysis of leaves, sawdust and mixture of leaves and sawdust with clay paste and gum Arabic paste as binders are presented in this section. The properties of the briquettes produced were limited to the determination of density, compressive strength, percentage ash content and calorific value.

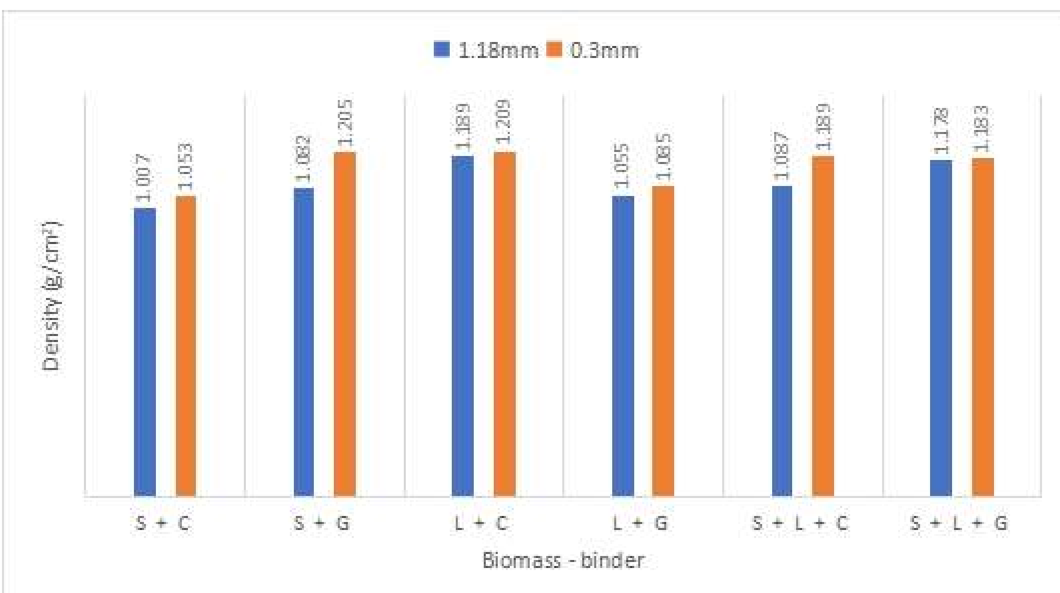

Fig 1 Density (g/cm3) of produced briquettes.

The density of the briquettes for the two particle sizes varied from 1.007g/cm^3 – 1.209g/cm3 as shown in Table 4.1 above. The results show that the density of the briquettes increased with a decrease in particle size. The implication of this is that the finer the particle, the less the pore spaces and the more mass of the material per given volume which is good for briquetting. The briquettes have obtained increased density which is a valuable factor in briquetting.

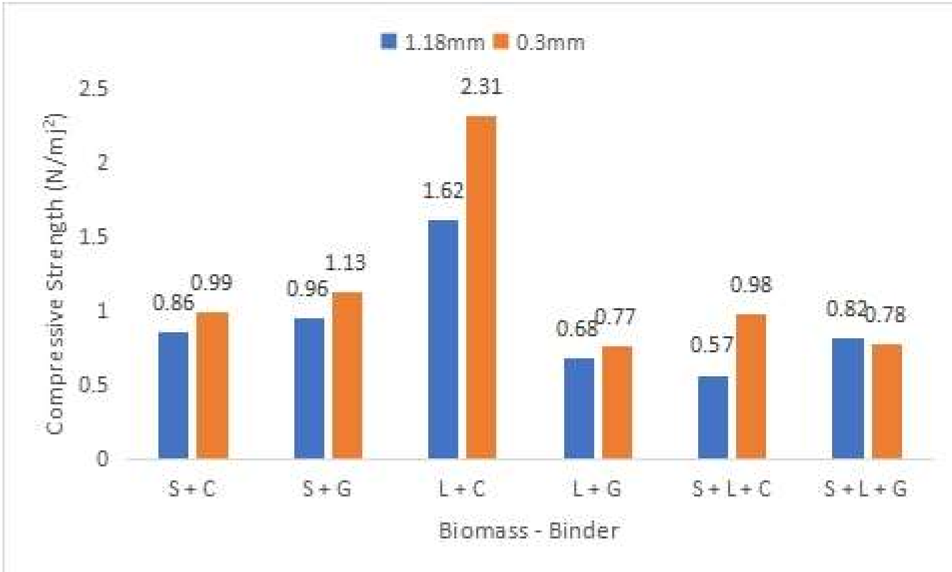

Fig 2 Compressive strength (n/mm2) of produce briquettes

Particle size has a clear effect on the compressive strength of the produced briquette. The briquette from a mix ratio of 1:1 of leaves with clay from 0.3mm particle size exhibited the best compressive strength (2.31N/mm2) while the least was obtained from briquettes of sawdust + leaves + Gum Arabic from 1.18mm particle size.

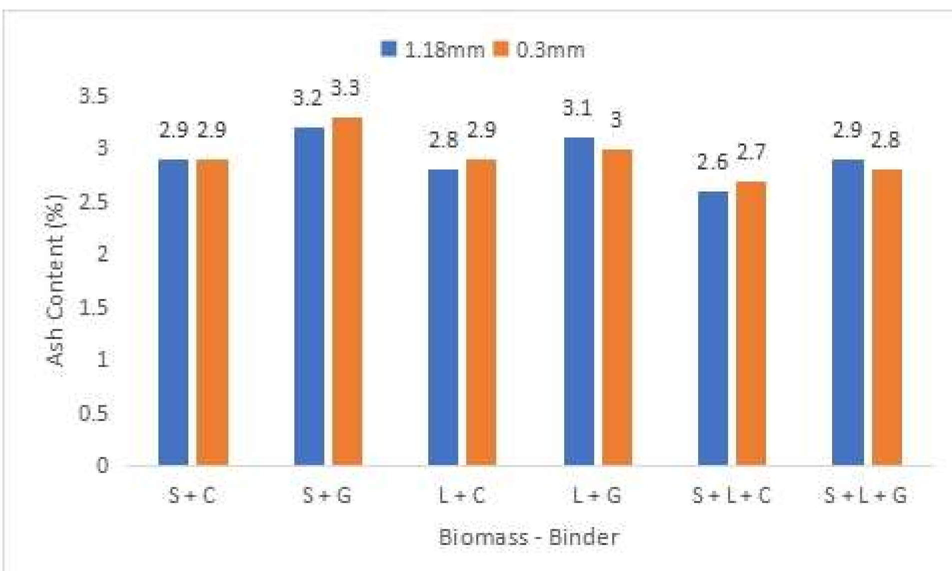

Fig 3 Percentage ash content (%) of produced briquettes.

Minimum to maximum range of between 2.6 – 3.3 per cent ash content was obtained from 1.18 and 0.3mm particle sizes as shown fig. 4.3 above low ash content offers higher heating value with less dust emissions that leads to air pollution (obi et al 2013). However, high ash content results in lower calorific value as it influences the burning rate as a result of minimization of heat transfer.

Fig 4 Calorific Value (mj/kg) of produced briquettes.

The result indicates that the calorific value obtained from this study ranged between 18.05 – 24.20mj/kg from 1.18 and 0.3mm particle size. The minimum value (18.05mj/kg) obtained is higher than the minimum value set by the wood pellet Association of Canada (Calorific value > 16.000mj/kg). the highest value obtained from this study is in a closer range to that of 24.50mj/kg obtained by Gilbert et al 2021. Calorific values obtained for produced briquettes in this study have shown a good combustion property that would be comfortably applied to domestic applications.

4 Conclusion

Evaluation of organic solid waste of produced briquettes yielded an improved physical and combustion properties it was clear that gum Arabic (binder). However, decrease in particle size has a clear impact on the performance of the produced briquettes. Thus, minimum to maximum calorific value of produced briquette is higher than that of dry wood (Within interval from 18.5 – 19.0mj/kg) (C.F. Neils en A/S on member of RVF briquetting system). Further investigation ion similar materials with higher fibre and organic content shoul be assessed and make compassion with conventional charcoal.

5 Contribution to knowledge

Excessive use of fossil fuels significantly contributes to climate change which further deteriorates the environment. Thus, study has offered an alternative source of energy that may serve as an alternative to fossil fuel and will reduce the emission of harmful gases.

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