CONSTRUCTION OF A MOULDER AND PRODUCTION OF BIOMASS BRIQUETTE FROM BAGASSE FOR USE AS A FUEL

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Abstract

The present research was carried out to produce briquette from sugarcane bagasse as an alternative to wood charcoal using a designed and fabricated hand-press briquette moulder capable of producing five briquettes at a time using Tapioca starch as a binder. After briquetting, the physical properties of the produced briquettes were determined by direct measurements and calculations, the proximate analysis were performed in accordance with ASTM analytical method and the average results show that; the percentage volatile matter, ash content and fixed carbon of the dried briquettes was found to be 92.01%, 5.32% and 2.67% respectively. Consequently, the average maximum and relaxed densities of the briquettes were recorded to be 838.55kg/m^3 and 226.00kg/m^3 respectively. With the aid of Cussons-Bomb calorimeter the calorific value of the produced briquette was determined to be 17009.22J/g. Results from different tests and analysis shows that the briquette produced will not crumble during transportation and handling, and the calorific value obtained is sufficient enough to provide heat required for house hold cooking and small scale industrial application.

Keywords: *Biomass, Briquette, Briquette moulder, Bagasse, Physical properties and Proximate analysis.*

1. INTRODUCTION

Energy is the engine of economic development of any country; its rate of consumption is a major indicator of the rate of economic growth. It is central to the development of the World's economy and environmental quality, providing power needed for industrial production, transportation and agriculture. Energy is important for the provision of essential services for the well-being of humanity in the process of heating, lighting and refrigeration.

Biomass is the third global primary energy source after coal and oil and is set to become an important contributor to the world energy [1]. Biomass refers to non-fossil biodegradable organic material from plant, animal and microbial origin. Biomass materials include products, by-products, residues and wastes from agricultural and forestry activities; non-fossil and biodegradable fractions from municipal and industrial wastes. Classical examples are trees, grasses, agricultural crops, agricultural wastes, wood waste and their derivatives, bagasse, municipal solid waste, waste paper, waste from food processing as well as aquatic plants and algae animal wastes [2].

Briquette is a block of flammable matter that can be used as a fuel to start and maintain a fire. Briquettes are produced through a process known as briquetting. This process involves the densification of loose biomass residues, such as sawdust, straw, rice husk etc, into high density solid blocks that can be used as a fuel. Briquetting, which is one of the ways densification of biomass has been achieved, can be considered for its economic reliability and ease of operation. Briquetted biomass can also be used to solve problem of air pollution caused from inefficient burning of loose biomass.

The aim of this present research is to fabricate a briquettes moulder for the production of biomass briquette to serve as an alternative to wood charcoal which provide much needed source of cheap fuel that is economical and cleaner in burning, and to determine the physical and proximate analysis of the produced briquette.

2. MATERIALS AND METHOD

2.1 Design Consideration

The manual briquette moulder was designed to produce five (5) briquettes at a time. The moulder consists of three basic parts thoroughly designed and fabricated as shown in the diagram below;

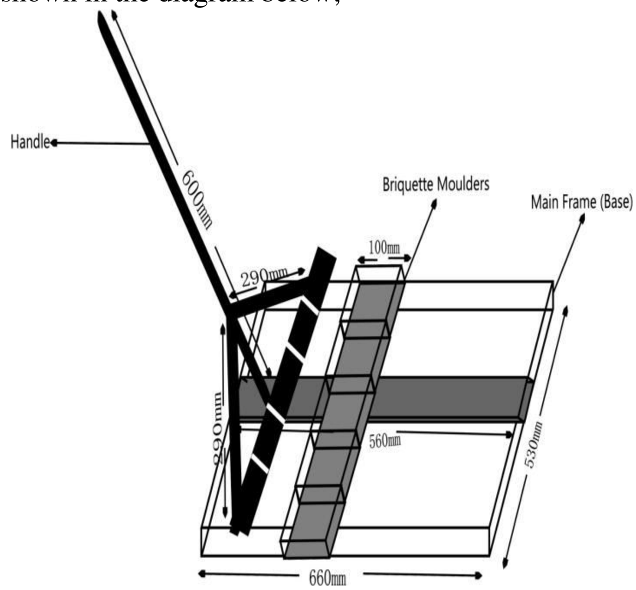

Figure 1: Schematic drawing showing dimensions of the designed briquette moulding machine

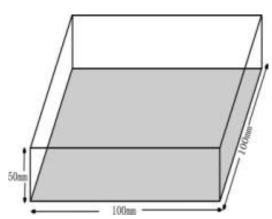

Figure 2: Schematic drawing of the briquette moulder.

2.1.1 Description of the Machine Parts

The manual briquetting machine consists of three main parts; the main frame (Base), the briquette moulders and the handle.

The main frame serve as the base plate of the machine that supports the compaction pressure as provided from the handle. It was made from black hollow pipe 50mm×50mm of various lengths welded together to produce a rectangular shape of dimension 660mm×530mm. The major function of the main frame (base) is, it serves as a chamber where the briquette compression processes occur. It also houses and supports the other parts the machine contained.

The area occupied by the main frame (A_f) of the briquetting machine is given by;

$$A_f = L_f \times b_f = 660mm \times 530mm = 0.318m^2$$

The briquette moulders was made from a flat bar of 50mm height and thickness of 5mm.The flat bar was cut into sizes of different lengths and welded together to produce five symmetrical moulding cavities connected on both sides.

The shape of the moulder is a rectangle with an area given by

$$A_m = L_m \times b_m \quad (1)$$

where;

A_m = Cross sectional area of the briquette moulders

L_m = Length of a the briquette moulders = 530mm = 0.53m

b_m = breadth of the moulders = 100mm = 0.10m

Hence, the area over which the pressure acts is given by

$A_m = 0.53m \times 0.10m = 0.053m^2$

The handle is one of the essential parts of the machine that maneuvers the movement of the upper part which enclosed the moulders. The machine handle was made from 1-inch galvanized iron (GI) pipe with a length of length 600mm welded at the centre of the upper mould cover and was braced with two similar galvanized iron pipes of length 290mm each.

2.1.2 Moulder Construction Processes

The construction of the briquette moulding machine and processes took place at Kabiru Abubakar Technical Services at Janguza Town, along Gwarzo road, Kano Nigeria. The Construction was carried out using locally available materials. The available necessary equipments used in the construction includes: Vices, Oxygen-acytelene cylinder, Measuring tape, Tri-square, Hack saw, Electric hand grinder, Electric welding machine, Electrode and Black paint.

Below is the diagram showing the briquette moulder during and after construction processes;

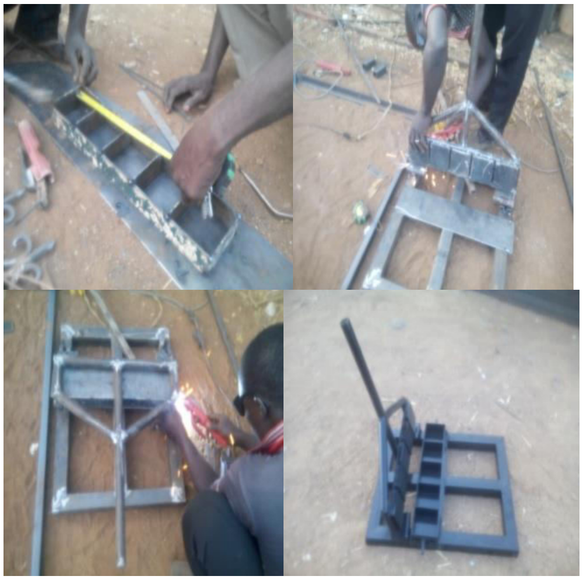

Plate 1: Moulder under and after construction processes.

Assuming an average person can apply a force intermittently with the arm;

According to [3], mass of an average person is m = 50kg

The torque produced by the handle T_h is given by;

$$L_h = {}^{T_h}/_{M_p} \qquad (2)$$

where;

L_h= Length of the handle = 600mm = 0.6m

Therefore;

$T_h = L_h \times M_p$ = 0.6m × 50kg = 294.3Nm

The mass of the carbon steel metal placed on the upper mould cover of the machine during compaction M_{CS} = 38.60kg, with a length L_{CS} = 25cm and breadth B_{CS} = 10cm

The force produced by the metal is given as;

$F_{CS} = M_{CS} \times g$ = 38.60kg × 9.81$\mathrm{m/s^2}$ = 378.67N

Hence, the pressure applied by the carbon steel metal to the moulding cavities of the machine is given by;

$P = {}^{F}/_{A} = {}^{378.67\mathrm{N}}/_{0.025\mathrm{m}^2} = 15146.80\mathrm{N/m^2}$

2.1.3 Materials preparation and Briquettes production processes.

Sorting
The sugarcane bagasse samples were collected from the fields and farmlands. The collected samples were initially screened from stones and other impurities that may inhibit proper briquette production. All unwanted materials or large size of biomass were removed to ensure that all feedstock's are of the required sizes for the process.

Crushing
Biomass crushing machine was used to grind the sorted biomass waste-like materials (Bagasse). During this process, the biomass materials were chopped and crushed into small pieces of sizes 2mm-8mm with 10-20% powdering components so as to enhance their workability and compactness as shown below;

Plate 2: Crushing of Bagasse

Starch preparation and mixing
Cassava starch (Tapioca) was prepared by combining 0.5litre of cold water with 0.25kg of cassava flour and mixed in a pot of boiling water. While boiling, the cassava flour with water mixture was gradually stirred until it was slightly lumpy and rather viscous. After cooling, 20% by weight of starch was poured into a container containing slightly wetted biomass sample and were mixed thoroughly with bare hands (for about 2-4minutes) until almost every particle is attached with the binder.

Compaction and drying
At this stage, the prepared mixture of the bagasse and starch was poured into the moulding cavities of the constructed briquette moulder and was slightly compacted by closing down the mould cover of the machine handle. The pressure was created by placing the carbon steel metal of mass 38.60kg on top of the mould cover which enclosed the moulders for a dwell time of 15minutes after which it was removed. The compressed biomass mixtures were ejected, placed on a tray and sun-dried for about fourteen days (2weeks) to produced solid fuel that can be burnt just like wood or charcoal.


Plate 3: Sun drying of the produced briquettes.

2.1.4 Physical Properties and Proximate analysis of the Produced Briquette

The briquettes obtained from the mould after drying were strong and well formed. Three (3) briquettes were randomly selected from each production batch for evaluation. The maximum and the relaxed densities of the briquettes were determined using the mould dimension. The average maximum density was obtained immediately after ejection from the mould and this was calculated as the ratio of the average mass to the volume of the briquette. The mass was obtained by using digital weighing balance, while the volume was calculated by taking the dimensions of the rectangular briquette (l×b×h). The relaxed density of the briquette was obtained after drying the briquette in the sun for about two weeks. It was calculated as the ratio of the briquette's mass after drying in the sun to its volume.

Density ratio was calculated as the ratio of the relaxed density to the maximum density:

$$\text{Density ratio} = \frac{\text{Relaxed Density}}{\text{Maximum Density}} \qquad (3)$$

And the relaxation ratio was obtained as the ratio of the maximum density to the relaxed density:

$$\text{Relaxation ratio} = \frac{\text{Maximum density}}{\text{Relaxed density}} \qquad (4)$$

The hardness of the briquettes can be determined in accordance with the shatter indices described by [4]. The briquette samples were dropped repeatedly from a height of 1.5m onto a concrete floor. The fraction of the briquette that remained was used as index of briquette durability in percentage. The shatter resistance of the briquettes can be calculated by using the following formula [5].

$$\text{Percentage weight loss} = \frac{W_1 - W_2}{W_1} \times 100$$

$$\text{Shatter resistance} = 100 - \%\ \text{weight loss} \qquad (5)$$

Where;

W_1 = Weight of briquette before shattering, g

W_2 = Weight of briquette after shattering, g

The proximate analysis of the briquette is a standardized procedure that gives an idea of the bulk components that make up a fuel. The procedure of the ASTM Standard [6] was adopted to obtain the percentage volatile matter (%VM), percentage ash content (%AC) and percentage fixed carbon (%FC). The volatile matter represents the components of carbon, hydrogen and oxygen present in the biomass briquette that when heated turns to vapour, usually a mixture of short and long chain hydrocarbons. It is determined by heating 2g of a dried ground sample of briquette in a furnace at 550℃ for 7 minutes. The amount of volatile matter in the biomass can then be calculated as percentage of the weight loss of the sample.

$$\%\ \text{Volatile Matter, V.M} = \frac{W_1 - W_2}{W_1} \times 100 \qquad (6)$$

where;

W_1 = Initial weight of the briquette dry sample, g

W_2 = Final weight of the dry briquette sample after heating in the furnace for 7minutes, g.

Ash is the non-combustible component of biomass briquette and the higher the fuel's ash content, the lower its calorific value. The ash content is determined by heating 2g of a dried ground sample of briquette in an open crucible in a furnace at 550℃ for 2hrs..

$$\%\ \text{Ash Content A.C} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \qquad (7)$$

where;

W_1 = Weight of empty crucible, g

W_2 = Weight of crucible + Sample taken, g

W_3 = Weight of crucible + weight of ash left in crucible, g.

The percentage of fixed carbon is determined by measuring the difference in percentage from the other quantities [7], and is given by:

$$\% \text{ Fixed Carbon FC} = 100 - (\%AC + \%VM) \quad (8)$$

AC = Ash Content

VM = Volatile Matter

The heating value (Calorific value) of the briquette samples was determined using Cussons-bomb calorimeter. The calorific value can be calculated for the fuel sample as analyzed below [8];

$$\text{Radiation correction RC} = nV' + \left[\frac{-V+V'}{2}\right] \quad (9)$$

where;

n = Number of minutes between the ignition time and attainment of maximum temperature.

V' = Rate of temperature fall in degrees per minute at the end of the test

V = Rate of temperature rise in degrees per minute at the beginning of the test

The actual temperature rise T_{rise} during the test is given by;

$$T_{rise} = T_{max} - T_{min} \quad (10)$$

where;

T_{max} = maximum temperature attained during the test

T_{min} = Initial temperature at the ignition point (IP) of the test

Corrected temperature rise (Δt) during the test is given by = RC + T_{rise}

And the water value W of the apparatus can be calculated using the equation below;

$$W = \frac{M_b \times CV_b}{\Delta t} \quad (11)$$

M_b = Mass of the benzoic acid

CV_b = Calorific value of the benzoic acid

Hence, the calorific value of the fuel sample can be determine by the equation (12) below

$$CV = \frac{\Delta t \times W}{M_s} \quad (12)$$

M_s= Mass of the fuel sample

3.0 RESULTS AND DISCUSSION

The results of the determination of physical properties and proximate analysis of the produced briquette were summarized in Table 1 and 2 as shown below;

Table 1: Physical Properties of the briquette

Serial No.	Parameters	Values	Units
1	Weight of the briquette (wet)	0.3354	Kg
2	Length/breadth and height of the briquette (wet)	0.1/0.1 and 0.04	M
3	Volume of briquette (wet)	0.0004	m^3
4	Maximum density	838.55	Kg/m^3
5	Weight of briquette (dry)	0.0814	Kg
6	Length/breadth and height of the briquette (dry)	0.0973/0.0986 and 0.0384	M
7	Volume of the briquette (dry)	0.00036	m^3
8	Relaxed density	226.00	Kg/m^3
8	Relaxation ratio	3.71	---
9	Density ratio	0.27	---
10	Shatter resistance	92.80%	---

From table 1 above, the maximum and relaxed densities of the briquette obtained re 838.55kg/m^3 and 226.00kg/m^3 respectively. These values are well compared and considered acceptable with that of corn cobs briquettes with maximum and relaxed densities values ranging from 533kg/m^3 to 981 kg/m^3 and 307kg/m^3 to 417kg/m^3 respectively [9] and 214.17kg/m^3 to 421.05kg/m^3 for the relaxed density of sawdust briquette [10]. This signifies that the briquette will not crumble during transportation, handling and storage because the value obtained for densities were quite high.

The relaxation and density ratio of the briquette obtained in this study are compared favourably well as they are close to the 2.887 relaxation ratio of corncobs [11], and density ratio of 0.71, 0.41 and 0.25 for coconut fibre, palm fibre and peanut shell respectively [12]. The 92.80% results recorded for the shatter resistance is nearly in agreement with the values 92.80% to 95.23% for sole briquette and 77.27% to 96.26% for the combined briquette [13].

Table 2: Proximate analysis of the briquette

Serial No.	Parameters	Value
1	Percentage Volatile Matter	92.01%
2	Percentage Ash Content	5.32%
3	Percentage Fixed Carbon	2.67%
4	Heat content (Caloric Value)	17009.22J/g

As shown in table 2 above, the 92.01% of percentage volatile matter fall within the range of values of some notable biomass residue like corncobs, groundnut shells and yam peels with 86.53%, 88.49% and 82.87% respectively [14], and 91.69% for sawdust briquette [11]. Consequently, the average value 5.32% obtained for the percentage ash content is in agreement with those found to exist within the range of values obtained for soy bean 6.58% [15] and saw dust 19.45% [11]. This low ash content of the bagasse briquette indicates it's suitability for thermal utilization and higher ash content in a fuel usually leads to a lower calorific value [16].

The percentage fixed carbon is the percentage of carbon available for char combustion. As reported in table 2 above, the percentage fixed carbon 2.67 for bagasse briquette exists within the range of values 2.57, 3.39 and 3.29 obtained by [14] for cassava peels, yam peels and groundnut shell respectively.

However, the heat value (Calorific value) 17009.22J/g obtained in this study was found to agree well and exist within the range of values obtained for cassava peel-12765kj/kg and yam peel-17348kj/kg [17]. This calorific value obtained is sufficient enough to produced heat required for house hold cooking and small scale industrial application.

4. CONCLUSIONS

Based on the experimental analysis and findings of this study, the following conclusions can be made;

- A hand-press briquette moulder suitable for the production of biomass briquettes on a small scale was designed, constructed and used in the production of biomass briquettes using a sugarcane bagasse.
- The briquettes produce will not crumble during transportation and storage because the values obtained for the relaxed densities are sufficient enough and the briquettes with higher densities were observed to have higher stability.
- Briquette production can be a viable business enterprise and source of income: Members of the community engaging on the job can become experts in recycling waste products to wealth, thereby providing the populace with new and cheap alternative source of cooking energy.

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