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Proximate Analysis of Biomass and Cotton Stalk Charcoal Briquettes Produced from Biu, Nganzai, and Zabarmari in Borno State using a Locally Fabricated Briquetting Machine

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Abstract - Biomass briquettes are a proven way of generating energy from waste. Different types of waste have been utilized in order to develop biomass briquettes. Therefore in this research work, briquettes of Millet chaffs, Rice husks, and Cotton stalk charcoal were produced and evaluated for use. The different briquettes produced were made by blending 150 g of the different Agro-waste each using 30 mL of gelatinous Cassava starch as a binder and Calcium Hydroxide ($Ca(OH)_2$), as a pollutant fixing agent. The Briquettes were produced manually in a cylindrical mold and a piston press to apply pressure on the compacted Agro-waste in the mould. The result of the proximate analysis indicates that the different briquettes have reasonable calorific value ranging from 146-200KCal/g. Their Ash contents ranges from 30.3-40.0%, Volatile matters 15.5-38.5%, and moisture contents 10.5-13.3%. The fixed carbon 31.2-50.6%. The analysis gave a contrasting combustible quality when the fifteen samples were compared. Based on the above results, use of briquettes like millet chaff, rice husk and cotton stalk charcoal can effectively substitute the existing source of fuel like firewood and fossil fuel products because of the reasonable calorific value and other parameters obtained from the proximate analysis.From the results obtained it can be seen that briquettes produced from millet chaff, rice husk, and cotton stalk charcoal using the manually fabricated mould briquetting machine would make good biomass fuels as it has an appreciable volatile matter and a low percentage ash content.

Keywords - Millet Chaff, Rice Husk, Cotton Stalk Charcoal, Cassava Starch, Briquette.

I. Introduction

Energy is important for the provision of essential services for humanity such as lighting, warming, heating and cooking [4]. The demand for energy has been increasing over the years in the developing countries where 1.8 million people in rural and urban centers lack access to commercial energy [9]. Biomass energy accounts for about 14 % of the total world energy compared to coal 12 %, natural gas 15 % and electric energy 14 %. In East Africa 84 % of the total energy used by 90 % of the population is derived from biomass sources such as charcoal, firewood, agricultural residues and animal/livestock wastes. Between 1970s and 1994s, production and consumption of charcoal doubled and is expected to increase by 5 % up to the year 2010s [9].

Life is a continuous process of energy conversion and transformation. Thus, access to energy is necessary to harness human life and to achieve overall economic, social and environmental aspect of human development [1]. About half of the world's household [11] still use solid fuel for cooking on a daily basis especially in the rural area of developing countries like Nigeria.

Compaction of bulky combustible materials for fuel making purposes has been a technology widely used by many countries. There have been several researches carried out on production of fuel briquettes for both domestic cooking and industrial application. One of the major driving forces behind these researches is the need to address the environmental consequences and health hazards associated with the use of solid fuels such as fuel wood and coal [13] and also effective means of recycling and managing agro waste.

Among the common types of briquettes widely used in some countries are biomass briquettes, coal briquettes and charcoal briquettes etc. however, blending coal with biomass (Agro waste) gives rise to a briquettes with better combustion properties and pollutant emission compare to the conventional coal briquettes. This briquettes known as Bio coal briquettes which is a type of solid fuel prepared by compacting pulverized coal, biomass (Agro-waste such as Rice chaff, maize cob, and saw dust), and binder [4]. According to [10] Sawdust or wood dust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. It can present a hazard in manufacturing industries, especially in terms of its flammability. Sawdust is the main component of particleboard. Sawdust has a variety of other practical uses, including serving as mulch, as an alternative to clay cat litter, or as a fuel.

The high pressure involved in the process ensures that the coal and the biomass particles are sandwiched and adhere together, as a result do no separate during transportation, storage and combustion. Bio-coal briquettes has a favorable ignition, better thermal efficiency, emits less dust and soot [3]. However, preserving the forest resources by substituting fuel wood with bio-coal, along with the use of the ash from these briquettes for soil treatment will compensate for the briquette. Therefore, Bio-coal and also agro-waste briquetting is considered to be a clean technology.

A. Benefit of agro waste briquettes

From traditional point of view, waste is potentially a resource and can be classified into various categories based on its sources such as municipal wastes, residential wastes, commercial wastes, industrial wastes, agro-wastes, hazardous wastes and other waste [7]. The daily wastes are generally regarded as worthless but can be recovered, recycled and reused. The following are qualities of a good solid fuel as enumerated by [8]. i. A good fuel should have a low ignition point ii. It should have a high calorific value. iii. It should freely burn with a high efficacy once it is ignited. iv. It should not produce harmful gases. v. It should produce least quantity of smoke and goes. These qualities are part of what is investigated in this work so as to achieve an increased energy density. The main purpose of briquetting material is to reduce the volume and thereby increasing energy density [6]. The energy characteristics associated with briquettes are how it act and what it produces when burned are important issues or

Parameters looked at when describing and comparing briquettes with other fuels. The calorific value varies with ash content and moisture content. Different ash and moisture contents in briquettes result in different calorific values [4]. Normally, the ash content of wood briquettes is about 40%, the resulting calorific value is 146– 200KCal/g as the normal moisture content in Swedish production is about 12.5% [5].

II. Materials And Methods

A. Materials

The materials required for solid fuel briquetting are: Agro-waste which comprises of Millet chaff, Rice husk, and cotton stalk charcoal, locally fabricated briquetting machine, and a mould, Prepared Gelatinous Cassava Starch, Calcium Hydroxide [$Ca(OH)_2$], analytical Weighing balance, Stop Watch, Oven, Crucible,

B. Biomass Collection

Millet chaff, Rice husk and cotton stalk charcoal are selected as raw materials because of their availability, low cost and abundance. The millet chaff were collected from a demonstration farm in Nganzai town, Nganzai local government area of Borno state , rice husk were collected from a demonstration farm in Zabarmari ward of Jere local government area of Borno state, while the cotton stalk charcoal were collected from a demonstration farm in Biu, Biu local government area of Borno State. The cotton stalk was carbonized following traditional method of wood carbonization.

The millet Chaff and Rice husk were pulverized into smaller sizes by pestle and mortar , to pass through 1mm sieve and stored for use, it was later sun dried for a period of ten (7) days until its moisture content was found to reduce.

C. Briquetting process

The modified method of [6] was used for the production of the briquette sample. The briquettes were produced using a locally fabricated briquetting machine. Briquettes of millet chaff, rice husk and cotton stalk charcoal were produced with a specific amount of $Ca(OH)_2$ added based on the mass of the waste to serve as a pollutant fixing agent. Certain amount of cassava starch paste was introduced based on the entire mass of the mixture to serve as a binder. During the production, specific quantity of hot water was added to the mixture to attain cohesion and homogeneity. A binding pressure was maintained throughout the production time using a piston press. After production, the briquettes were sun dried for ten days before analysis .Plates 1 to 3 shows the formed briquettes from agricultural wastes of: Biu, Nganzai, and Zabarmari areas of Borno State. The number of days of sun drying depends on the season and the geographic nature of the area.

D. Proximate analysis

Proximate analysis is the standard procedure that gives an idea of the bulk components that make up a fuel [2], it was done to determine the average of the percentage ash content, volatile matter, moisture content, fixed carbon content, and calorific value.

The procedure described by [1] was followed with slight modifications.

Plate 1: Briquettes of agricultural wastes from Biu

Plate 2: Briquettes of agricultural wastes from Nganzai

Plate 3: Briquettes of agricultural wastes from Zabarmari

E. Moisture content

The initial moisture content of each briquettes sample was determined according to the method Used by [1] with slight modifications. 18 g each the samples were weighed and dried at a temperature of 110°C in a hot air oven until constant weights of the samples were recorded. Using an analytical weighing balance the weight of each samples were recorded after and before putting them in the oven. The dried samples weight represents the weight of dry matter present in grams. The initial moisture content of each samples was calculated using Eqn. (1) and is

Expressed in percentage wet basis (% wb).

$$MC\ (\%\ wb). = \frac{w1-w2}{w1} \quad x \quad 100 \text{ ——————(1)}$$

Where Wi is the initial weight of the sample and W2 is the final weight or dry weight of the Sample.

F. Ash content

Six grams (6 g) portion of each sample were placed in a preweighed porcelain crucible and transferred into a preheated oven set at a temperature of 500°C for 4 hours after which the crucible and its content were transferred to a desiccator and allowed to cool. The crucible and its content were reweighed and the new weight noted. The percentage ash content was calculated thus:

$$AC\ (\%) = \frac{W2}{W1} \quad X \quad 100 \text{ —————— (2)}$$

Where, W2 = weight of ash cooling, W1 = Original weight of dry sample AC = Ash content

G. Volatile matter

Some Portion (18 g) of the sample was heated to about 300°C for 30 minutes in a partially closed crucible in an oven. The crucible and its content were retrieved and cooled in a desiccator. The difference in weight was recorded and the volatile matter was calculated thus.

$$VM = \frac{W1-W2}{W1} \ X\ 100 \text{ —————— (3)}$$

Where, VM = Volatile Matter W1 = Original Weight of sample W2 = Weight of the sample after cooling.

H. Fixed carbon

The method used by [2] was adopted. The percentage fixed carbon (PFC) was computed by subtracting the sum of PVM (percentage volatile matters) and PAC (percentage ash content) from 100 as shown in the Equation 4:

$$\text{Fixed Carbon} = 100\% - (PAC+PVM). \text{ —————— (4)}$$

I. Calorific value

The calorific value also called the heating value or energy value of the briquette samples is the amount of heat liberated per unit mass of the briquette. The calorific value was determined based on ASTM D5865 standards and in line with the method adopted by [1] with little modification. A calorimeter was used in this process; the Ballistic Bomb Calorimeter was first calibrated using a standard sample of benzoic acid whose known calorific value is 6.32 KCal/g. A known mass of sample of small quantity, 0.5 g of the different samples was placed in crucibles. The bomb body was screwed in position and the thermocouple wire was plugged into the bomb body. The pressure release valve was closed and oxygen is admitted into the bomb until the pressure rose to 25 bars. The firing knob was depressed and released to fire the bomb. Heat was released and the maximum deflection of galvanometer scale is recorded. The maximum deflection obtained in the galvanometer was converted to energy value of the sample material by comparing the rise in galvanometer deflection with that obtained when a sample of known calorific value of benzoic acid is combusted as shown in equation:

Heat released from sample,

$$Q = \frac{\text{Galvanometer deflection X Calibration}}{\text{0riginal weight of sample}}$$

This is equal to

$$Q = \frac{(\theta 3 - \theta 1)\ \gamma}{Z} \ kcal/g \text{ —————— (6)}$$

Where, θ1 is galvanometer deflection without sample, θ3 is Galvanometer deflection with sample, Mass of sample = Z g, Calibration constant= γ

The whole experiment will be repeated for all the different briquette samples.

III. RESULTS AND DISCUSSION

A. Proximate Analysis

The result of the proximate analysis of the formed briquette is presented in table 1 to 5 below.

Volatile matter refers to the part of the biomass that is released when the biomass is heated up to 300^{0}C. During this heating process the biomass decomposes into volatile gases and solid ash. The agricultural wastes typically has a volatile matter (from13.5 to 38.5%) as shown on table 4.This signifies easy ignition of the briquettes and proportionate increase in flame length as described by [2]. The high volatile matter content (38.5%) in A2 indicates that during combustion, most of the formed briquettes will volatilize and burn as gas during combustion.

Ash, which is the inorganic matter left out after complete combustion of the biomass was found to be (30.5 to 40.0%) as shown on table 3. This is the percentage of impurity that will not burn during and after combustion. The low ash content in A2, A5, and C5 (30.5%) indicates that it is suitable for thermal utilization. Higher ash content in a fuel usually leads to lower calorific value [2]. The fixed carbon of the formed briquettes as shown on table 5 is the percentage of carbon available for briquette combustion. For the formed briquettes, it was found to be (31.2 to 50.6%). The low fixed content makes the briquettes to prolong cooking time by its low heat release. As such the fixed carbon gives a rough estimate of the heating value of a fuel.

The moisture content of the formed briquettes was (10.5 to 13.3%). This result was within the limits of 15% recommended by [14], for briquetting of agro-residues. The high heating value calculated for briquette produced from A5 was 200KCal/g indicated on table1. This energy value is sufficient enough to produce heat required for household cooking and small scale industrial applications.

Table: 1 Determination of Calorific Values of Briquettes Samples

S/N	Briquette Samples	$\theta_3(\Omega)$	$\theta_1(\Omega)$	Mass (g)	γ(constant)	Q (KCal/g)
1	A1	14.6	0.0	0.5	5	146
2	B1	15.7	0.0	0.5	5	157
3	C1	16.2	0.0	0.5	5	162
4	A2	18.0	0.0	0.5	5	180
5	B2	15.0	0.0	0.5	5	150
6	C2	14.9	0.0	0.5	5	149
7	A3	15.3	0.0	0.5	5	153
8	B3	14.8	0.0	0.5	5	148
9	C3	15.5	0.0	0.5	5	155
10	A4	17.0	0.0	0.5	5	170
11	B4	17.5	0.0	0.5	5	175
12	C4	16.5	0.0	0.5	5	165
13	A5	20.0	0.0	0.5	5	200
14	B5	16.0	0.0	0.5	5	160
15	C5	18.5	0.0	0.5	5	185

Table: 2 Determination of Percentage (%) Moisture Content of Briquette Samples

S/N	Briquette Sample	Wi (g)	Wf (g)	MC (%)
1	A1	18.0	16.0	11.1
2	B1	17.0	15.0	11.8
3	C1	17.5	15.5	11.4
4	A2	15.0	13.0	13.3
5	B2	16.5	14.5	12.1
6	C2	16.2	14.2	12.3
7	A3	16.7	14.7	11.9
8	B3	16.0	14.0	12.5
9	C3	17.4	14.4	11.5
10	A4	18.7	16.7	10.6
11	B4	18.5	16.5	10.8
12	C4	18.3	16.3	10.9
13	A5	18.9	16.9	10.6
14	B5	17.9	15.9	11.2
15	C5	19.0	17.0	10.5

Table: 3 Determination of Percentage (%) Ash Content of Briquette Samples

S/N	Briquette Samples	Initial Weight of Dry Sample (g)	Weight of ash at cooling (g)	AC (%)
1	A1	6.0	2.4	40.0
2	B1	6.4	2.2	33.9
3	C1	6.4	2.2	34.4
4	A2	6.6	2.0	30.3
5	B2	6.2	2.2	35.4
6	C2	6.5	2.1	32.3
7	A3	6.4	2.2	34.4
8	B3	6.4	2.0	34.8
9	C3	6.3	2.0	31.7
10	A4	6.4	2.1	32.8
11	B4	6.5	2.2	33.8
12	C4	6.4	2.4	37.5
13	A5	6.6	2.0	30.3
14	B5	6.3	2.0	31.7
15	C5	6.6	2.0	30.3

Table 4: Determination of Percentage (%) Volatile Matters of Briquette Samples

S/N	Briquette Samples	Initial Weight (g)	Weight at Cooling (g)	VM (%)
1	A1	18.1	14.7	18.7
2	B1	18.5	16.0	13.5
3	C1	18.7	15.2	18.7
4	A2	18.2	11.2	38.5
5	B2	18.4	12.4	32.6
6	C2	18.9	13.9	26.5
7	A3	18.8	14.4	23.4
8	B3	18.0	15.0	16.6
9	C3	18.3	14.8	19.1
10	A4	18.6	14.5	22.0
11	B4	18.4	18.8	25.0
12	C4	18.6	15.7	15.6
13	A5	18.0	14.3	20.5
14	B5	18.5	13.7	25.9
15	C5	18.8	15.3	18.6

Table 5: Determination of Percentage (%) Fix Carbon of Briquette Samples

S/N	Briquette Samples	AC (%)	VM (%)	PFC (&)
1	A1	40.0	18.7	41.3
2	B1	39.1	20.5	40.4
3	C1	34.4	18.7	46.9
4	A2	30.3	38.5	31.2
5	B2	35.4	32.6	32.0

6	C2	32.3	26.5	41.2
7	A3	34.4	23.4	42.2
8	B3	34.8	16.6	48.6
9	C3	31.7	25.9	42.4
10	A4	32.8	22.0	45.2
11	B4	33.8	25.0	41.2
12	C4	37.5	15.6	46.9
13	A5	33.9	13.5	52.6
14	B5	31.7	25.9	42.4
15	C5	30.5	19.1	50.6

IV. Conclusion

Based on the result obtained from this work, A5 (cotton stalk charcoal of Biu blended with rice husk of Biu /cassava starch paste, 4:4:2 wt/wt ratio) gave the highest calorific value within the time limit as shown in table1 and A1 (cotton stalk of Biu) showed the lowest. The study provides information about the comparison by proximate analysis of the fifteen briquette samples collected in Biu, Nganzai, and Zabarmari in Biu, Nganzai, and Jere Local Government Area, Borno State. From the result obtained and the view of [1] moisture content plays a vital role in the burning characteristics of the briquettes. Based on the result obtained, use of briquettes like Millet Chaff, Rice husk, and Cotton stalk charcoal may effectively substitute the existing source of fuel like firewood and fossil fuel because of the reasonable calorific value obtained. The quality of the studied briquettes depends on their ability to provide enough heat at all times, generate less/little ash, and capable of igniting easily without causing damage to nearby materials. They may be used as a flammable material in brick kilns, paper mills, chemical plants, distilleries, pharmaceutical units, dyeing houses, food processing units, oil mills etc [1].

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