



## Study on the Combustion Properties of Bio-Coal Briquette Blends of Cassava Stalk

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### ABSTRACT

This study was carried out to investigate the properties of bio-coal briquette produced from blending cassava stalk and coal. The cassava stalk and coal lumps were carbonized at 160 °C, pulverized and used to produce bio-coal briquettes of 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 100 % biomasses. The briquettes were produced mechanically using a manual briquetting machine with force and compression pressure of 276.36 N and 31.67 N/m<sup>2</sup> respectively using starch as a binder while Ca(OH)<sub>2</sub> was the desulphurizing agent. Proximate analyses of raw cassava stalk showed ash content (5.48 %), volatile matter (45.72 %), fixed carbon (25.34 %), moisture content (23.46 %) and calorific value (25834 kJ/kg). For the raw coal, the proximate analyses results are moisture content of (3.25 %), volatile matter of (20.12 %), ash content of (10.12 %) and calorific value of (29573.13 kJ/kg). The briquettes were sun-dried for five days and analyzed. For the briquettes produced, the 40 % bio-coal briquette sample with values; ash content (25.13 %), fixed carbon (41.36 %), moisture content (3.36 %), volatile matter (30.15 %), calorific value (25898.18 kJ/kg), water boiling test (2.98 min), burning time (22.79 g/min), ignition time (36.68 s) and compressive strength (10.78 N/mm<sup>3</sup>) showed improved combustible qualities.

**Keywords:** briquette, cassava stalk, binder, blend, bio-coal, fuel

### INTRODUCTION

In many countries of the developing world, the use of wood fuel as a source of energy is on the increase. It has been observed that the rate of consumption of this energy source in the country has been on the increase since the rural dwellers that constitute about 70 % of the population cannot afford the currently available alternative fuels to wood. The practice results in accelerated desertification in the northern part and erosion menace in the southern part of Nigeria. Both effects constitute serious ecological challenges (Olorunnisola, 1999).

The intention for complete substitution of wood fuel by other sources such as electricity, solar, gas and kerosene will certainly take a few decades to materialize. In the interim, the development, production and active utilization of agro-residue briquettes will certainly be a step in the right direction. The briquetting of agro-residues is one of the numbers of ways that has been developed to solve the problem of over dependence on wood as source of fuel. Briquetting thereby puts the huge volume of waste from agriculture and agro processing to some useful purposes (Johannes, 1982).

The following are advantages associated with coal briquette fuel:

- i. Bio-coal briquettes are very low in price as compared to traditional energy resource such as diesel, petrol and lignite.
- ii. They are less polluting than pure lignite briquettes.
- iii. Burning of briquettes could be clean and smokeless and does not cause widespread eye and respiratory diseases in women and children, who are mainly involved with domestic activities.
- iv. They generally have high calorific value associated with a high bulk density.
- v. Bio-coal briquettes have lower moisture content and offer excellent combustion that does not cause ash-fly as against when the fuel material was in the raw state.
- vi. The biomass materials are compressed into briquettes so that they can be used by energy producing companies to replace charcoal. These burn just like charcoal but they do not produce any harmful effects to the environment (Ugwu and Agbo, 2010).

Briquetting is a densification process of loose organic materials such as rice husks, cassava stalk, sawdust, corn cob, tea waste, cashew nut shell, coconut shell, groundnut shell, oil palm fiber, coffee husk and coal aimed at improving handling and consumption characteristics for domestic and industrial use. Through the waste-to-wealth scheme, some or many agricultural residues that

are generated in large quantities can be turned into useful products as alternative energy resource. This will go a long way in making more lands available for better use rather than dumpsites and to create a clean, friendly and healthy environment for all and sundry. By the application of briquetting, which can be regarded as an attempt to link up two large or complex worlds, that of agriculture and that of fuel supply and use (Ogbuagu and Okeke, 1999).

According to Kaliyan and Morey (2009) the main purpose of briquetting a raw-material is to reduce the volume and there-by increase the energy density. When densification has taken place, there are two quality aspects that need to be considered. Firstly, the briquette has to remain solid until it has served its purpose (handling characteristics). Secondly, the briquette has to perform well as a fuel (fuel characteristics).

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The world economy measures the standard of living of every nation and the level of its industrialization in terms of energy production and consumption. The level of energy consumption in sub-Saharan African countries is said to be 0.08 KW per capita as compared with the consumption in developed economy put at 7.0 KW per capital. Thus, if there are energy needs in our energy scenario, the overdependence on the highly favored energy source especially petroleum products can be reduced, this will eventually lead to the increase in the standard of living of the growing population. Energy is thus an integral part of our economic, environment and political life and has a major role to play in the realization of people’s social and economic aspiration for a better life (Ogbuagu, 1993). Gammage *et al.* (1993) studied the burning characteristics of different fuels used in Pakistan. Comparison of different fuels and coal briquettes was conducted on a typical indoor stove in-use in Pakistan. The results depicted that coal briquettes emit less harmful gases as compared to raw coal and other conventional fuels.

The aim of the work is to produce smokeless blends of bio-coal briquettes from mixtures of coal and cassava stalk with starch as binder, while Ca(OH<sub>2</sub>) serves as the desulphurizing agent. To characterize and investigate the changes in the physicochemical parameters of the bio-coal briquettes as the compositions were varied.

**MATERIALS AND METHODS:**

Cassava stalk was collected from farms in Abakaliki after harvesting the cassava tuber, Sub-bituminous coal from Onyeama mine was sourced at Nigeria Coal Corporation, Enugu. Bio-coal briquettes were produced containing 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 100 % biomass.

**Preparation of pulverized coal:**

The lumps of coal obtained from the coal mine was sun-dried, carbonized at 160 °C for 20 minutes, ground to powdery form to pass through sieve of 4 mm and stored in polyethene bags in an aerated area to prevent caking (Zakari *et al.*,2013).

**Preparation of cassava stalk:**

The cassava stalk was sun-dried, carbonized at 160 °C, pulverized and ground to powdery form to pass through sieve of 4 mm and stored in polyethene bags in an aerated area to prevent caking (Zakari *et al.*,2013).

**Production of the briquette samples**

The briquettes were produced using a manual hydraulic briquetting machine with three cylindrical moulds. Briquettes of coal and cassava stalk of different compositions were produced with 30 g of Ca(OH)<sub>2</sub> added as desulphurizing agent based on the quantity of coal added, starch paste formed with hot water was added as binder. Specific quantity of water was added to get a homogenous mixture. The force and compression pressure of 276.36 N and 31.67 N/m<sup>2</sup> respectively were maintained for 5 minutes before the briquettes were removed from the mould. After production, the briquettes were sun dried for 7days before analyses (Katimbo *et al.*,2014).

**CHARACTERIZATION OF THE BRIQUETTES:**

**Combustion analysis:**

The combustion analysis was carried out to determine the combustion characteristics of the briquette fuel.

**Ignition time (s):** The different samples were ignited at the edge of their bases with a burnsen burner. The time taken for each briquette to catch fire was recorded as the ignition time using a stopwatch (Kim *et al.*, 2001).

**Burning time (min):** This is the time taken for each briquette sample to burn completely to ashes. Subtracting the time is turned to ashes completely from the ignition time gives the burning rate (Kim *et al.*, 2001).

$$\text{Burning time} = \text{Ashing time} - \text{Ignition time} \dots\dots\dots (1)$$

**Water boiling test (min):** This was carried out to compare the cooking efficiency of the briquettes. It

measures the time taken for each set of briquettes to boil an equal volume of water under similar

conditions. During the process, 100 g of each briquette sample was used to boil 250 ml of water using small stainless cups and domestic briquette stove (Kim *et al.*, 2001).

**Calorific value:** The calorific value of the raw coal, cassava chalk and the briquettes were

determined using Oxygen Bomb Calorimeter of model-OSK 100A. The calorific value (kJ/kg) of the samples under test was calculated from the temperature rise in the calorimeter vessel and the mean effective heat capacity of the system (Sumner *et al.*,1983)

$$VI = (Ee + W_1) TR - C / S \times 4.1868 \dots\dots\dots (2)$$

Where Ee is the water equivalent of the calorimeter (581 g), W<sub>1</sub> = quantity of water in the vessel, TR = Temperature rise °C, C = correction factor from ignition 154 Cal, S = weight of sample in grams (g).

**PROXIMATE ANALYSES:**

**Moisture content:** The moisture contents of the raw coal, rice husk and briquettes were determined. A portion 2 g each of the samples was weighed out in a wash glass. The samples were placed in an oven for 2 hours at 105 °C. The moisture content was determined according to ASTM standard (1992).

$$MC = \frac{W_1 - W_2}{W_1} \times 100 \dots\dots\dots (3)$$

W<sub>1</sub>= Initial weight, W<sub>2</sub>= Weight after drying

**Ash content:** The ash contents of the raw coal, rice husk and briquettes were also determined. A portion 2 g were placed in a pre-weighed porcelain crucible and transferred into a preheated muffle furnace set at a temperature of 600 °C for 1 hour

after which the crucible and its contents 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 using ASTM standard (1992).

$$AC = \frac{W_2}{W_1} \times 100 \dots\dots\dots (4)$$

W<sub>1</sub> = Original weight of dry sample, W<sub>2</sub> = Weight of ash after cooling.

**Volatile matter:** The volatile matter of the raw coal, rice husk and briquettes were also determined. A portion 2 g of the sample was heated to about 300 °C for 10 minutes in a partially closed crucible in a muffle furnace. The crucible and its content

were retrieved and cooled in a desiccator. The difference in weight was recorded and the volatile matter was calculated using ASTM standard (1992).

$$VM = \frac{W_1 - W_2}{W_1} \times 100 \dots\dots\dots (5)$$

W<sub>1</sub> = Original weight of the sample. W<sub>2</sub> = Weight of sample after cooling.

**Fixed carbon:** The fixed carbon of the raw coal, rice husk and briquettes were also determined. The

fixed carbon was determined using the formula according to ASTM standard (1992).

$$FC = 100 - (\%VM + \%AC + \%MC) \dots\dots\dots (6)$$

Where VM = Volatile matter, AC = Ash content, MC = Moisture content.

**Determination of the Compressive Strength:** Compressive strength in cleft of briquettes was determined in accordance with ASTM, (2008) using an Instron Universal Strength testing machine with load cell capacity of 100 kN. The cross-head speed was 0.305 mm/min. A sample of

briquette to be tested was placed horizontally in the compression test fixture and a load was applied at a constant rate of 0.305 mm/min until the briquette failed by cracking. The compressive strength in cleft was then computed as follows:

$$\text{Compressive strength in cleft (N/mm)} = \frac{3 \times \text{The load at fracture point (N)}}{[l_1(\text{mm}) + l_2(\text{mm}) + l_3(\text{mm})]}, \dots\dots\dots(7)$$

Where  $l_1$ ,  $l_2$  and  $l_3$  were lengths of briquettes at points one, two and three, respectively in (mm).

### RESULTS AND DISCUSSION:

From the results obtained in Table 1, according to Loo and Koppejan (2008), the higher the fuel's ash content, the lower the calorific value. The results show that as the amount of biomass increased the ash content increased during pyrolysis. The ash content of the briquette samples increased as the biomass was briquetted with coal. The fractional heat contribution of the volatiles is more for biomass as such it makes biomass a more reactive fuel than coal, giving a much faster combustion rate during the devolatilization phase (Demirbas, 1999). The values ranged from 18.14 - 46.05 % for the briquettes from (0-100 %) cassava stalk blends. The loose combustible biomass aided the fast ignitable property of the briquettes produced. The fixed carbon of a fuel is the percentage of carbon available for char formation during combustion. Since coal contained higher amount of fixed carbon (66.51 %) the briquettes with higher percentage composition of coal had higher values of carbon content. The higher the number of carbon content of the briquettes the higher the calorific values, while the briquettes

with low carbon content do have lower calorific values. The findings of this study compared favourably with that of Ajueyitsi and Adegoke (2003). The production of briquettes from mixtures of coal and rice husk, coal and corn cob by varying their compositions resulted in briquettes with reduced fixed carbon content.

The calorific (heating) value is the standard measure of the energy content of a fuel (BSI, 2005). The result shows that bio-coal briquette blend (40 %) had the highest calorific value of 25898.18 kJ/kg, this signifies that the biomass can be blended with coal to produce fuel for heating purposes. The ignition of a briquette sample occurred when the briquette was lighted, combusts and heat propagated through the block of briquette. The results showed improved ignition time for the briquette blends, thereby reducing the ignition time from 46.22-21.19 s. The briquettes with more composition of biomass ignited faster than coal briquettes because of the porous nature of the briquettes which allowed more passage of oxygen which supports combustion.

**Table 1:** Physiochemical Parameters of Bio-Coal Briquettes of Cassava Stalk

Samples	Ash content (%)	Volatile matter (%)	Fixed carbon (%)	Moisture content (%)	Calorific value (kJ/kg)	Ignition time (s)	Burning time (min)	Water boiling test (min)	Compressive strength (N/mm <sup>3</sup> )
0%	23.15	18.14	56.36	2.35	25425.26	46.22	27.54	1.56	7.84
10%	23.62	20.52	53.19	2.67	25534.11	41.24	26.66	1.89	8.54
20%	24.21	24.07	48.81	2.91	25619.43	38.32	24.34	2.15	9.34
30%	24.92	27.16	44.70	3.22	25743.38	37.25	23.56	2.76	9.87
40%	25.13	30.15	41.36	3.36	25898.18	36.68	22.79	2.98	10.78
50%	25.75	32.96	37.51	3.78	24917.60	34.26	21.26	3.34	10.34
60%	26.02	36.21	33.66	4.11	23684.39	32.55	20.78	3.78	10.12
70%	26.65	40.12	28.88	4.35	23352.97	31.02	19.35	3.99	9.65
80%	26.95	42.11	26.08	4.86	23058.22	28.23	18.67	4.32	8.78
90%	27.22	44.78	22.75	5.25	22809.27	25.67	17.58	4.76	8.17
100%	27.60	46.05	20.63	5.72	22506.81	21.19	16.26	4.94	7.97

The compressive strength of briquettes is one of the indices used to assess its ability to be handled, packed and transported without breaking (Onuegbu *et al.*,2010). The values for the compressive strength in cleft for briquettes produced with starch as the binder ranged from 7.84-10.78 N/mm<sup>3</sup> to record the highest values. This is probably due to the nature of biomass with the presence of cellulose which helps to bind the briquette together and probably reduce the brittleness of the briquette.

## CONCLUSION

This work considered the production and analysis of bio-coal briquettes produced from cassava stalk. The study therefore offered solution to the problems associated with open disposal of cassava stalk wastes after harvest by production of biocoal briquettes from them. The briquettes produced ignited faster, generated sufficient heat with significant calorific value, friable, transported and stored easily. The briquetting technology has a great potential for converting waste biomass into fuel for household use in an affordable, efficient and environment friendly manner. The briquetting process is economical, cheap and affordable to the rural dwellers and low income earners. The briquette sample 40 % briquette blend yielded optimum combustible values when compared with the other blends of briquettes.

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