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PRODUCTION AND ANALYSIS OF THE HEATING PROPERTIES OF COAL AND RICE HUSK BRIQUETTES USING $CaSO_4$ AS A BINDER

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ABSTRACT

This work involves the production of briquettes from coal and rice husk. The different briquette samples were produced by blending varying compositions of coal and rice husk at the following ratios of 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 using calcium sulphate as a binder and calcium hydroxide as the desulphurizing agent. The briquettes were produced mechanically using a manual briquetting machine with pressure maintained at 5MPa. Results of the proximate analysis showed that of the different compositions that 60% coal:40% rice husk briquettes with following values for ash content 25.92%, fixed carbon 47.18%, moisture content 3.82%, density 0.474g/cm^3, volatile matter 23.08%, porosity index 42.53%, calorific value 118.44KJ/g, water boiling test 2.14mins, ignition time 33.10secs, burning time 19.85mins and sulphur content 7.04% exhibited optimum combustible quality when compared with other compositions of briquettes produced.

Keywords: Briquette, Biomass, Coal, Rice Husk.

INTRODUCTION

A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel (Grainger *et al*., 1981). In the production of briquettes, the materials can be compressed without addition of adhesive, while in others adhesive materials called binders are added to assist in holding the particles of the material together depending on the type of raw material used for the production (Mohammed, 2005).

In an attempt to produce a better and more efficient briquette to reduce gases that contributes to green house effect, briquetting process has focused more on the production of smokeless solid fuels from coal and agricultural waste. The use of organic briquettes (biomass briquettes) started more recently compared to coal briquettes which are dated back to eighteenth century (Choudburl, 1983). The following are common types of briquettes in use, coal, peat, charcoal, and biomass briquettes. Recently, researches showed that blending of coal and biomass will give rise to a briquette with better combustion properties and environmentally friendly. Bio-coal briquettes are prepared by blending coal, biomass, binders and sulphur fixation agent (Lu *et al*., 2000). In the process, calcium hydroxide $Ca(OH)_2$ acts as sulphur fixation agent. The de-sulphurizing agent in the briquette reacts with the sulphur present in the coal and converts about 60-80% of it into the ash, while lime (CaO) as a de-sulphurizing agent captures up to 90-95% of the total sulphur in the coal leaving only 5-10% emitted as sulphur oxide which is more or less not harmful to the environment (Someha *et al*., 1988).

OBJECTIVE OF THE STUDY

To produce smokeless briquettes that can serve as an alternative to fuel wood and determine the combustible properties of the different briquette samples produced.

CHARACTERISTICS OF THE BRIQUETTES

The main purpose of briquetting material is to reduce the volume and thereby increase the energy density. When densification takes place, there are two quality aspects that need to be considered, firstly, the briquette has to remain in solid form until it has served its purpose (handling characteristics). Secondly, the briquette has to perform well as a fuel (fuel characteristics). The energy characteristics are other important issues when describing and comparing briquettes with other fuels. The energy characteristics describe how the briquette act and what it produces when burned. The calorific value of briquettes is an important measure of the amount of energy released from every briquette when burned. Briquettes are normally priced by weight, but still, the calorific value is the most important factor in determining the competitiveness of the fuel. The calorific value varies with ash content and moisture content. Different ash and moisture contents in briquettes result in different calorific values. Normally, the ash content of wood briquettes is about 0.7%. The resulting calorific value is 17-18KJ/kg as the normal moisture content in Swedish production is about 10% (Eriksson *et al*., 1990).

MATERIALS AND METHODS

Materials

Pulverised coal, rice husk, calcium sulphate, calcium hydroxide, electronic weighing machine, manual briquetting machine, electric milling machine, stop watch, muffle furnace, oxygen bomb calorimeter machine model-OSK 100A.

Methods

The Collection of Samples

The coal was collected from Onyeama mine and identified at Nigeria coal corporation Enugu, Nigeria. The rice husk was collected from a rice mill industry at Ogoja road Abakaliki in Ebonyi state, Nigeria.

Preparation of the Coal Sample

The coal sample was sun dried for five days to reduce its moisture content, broken into smaller sizes using a hammer. The coal samples were then ground in an electric milling machine to pass through 1mm sieve and stored.

Preparation of the Biomass

The biomass (rice husk) was collected, sun dried for five days to reduce the moisture content, ground and sieved through 1mm sieve and stored.

Preparation of the Briquette Samples

The briquettes were produced using a manual hydraulic briquetting machine with three cylindrical mould of 1.5kg. Briquettes of coal and rice husk of different compositions were produced with a specific amount of $Ca(OH)_2$ added based on the mass of coal was used as the desulphurizing agent and a certain amount of calcium sulphate based on the entire mass of the mixture was used as the briquette binder. During the production, specific quantity of water was added to the mixture to attain homogeneity. The pressure was maintained at 5MPa throughout the production time. After the production of these briquettes it was sun dried for 7days before analysis.

Proximate Analysis of the Briquettes

Calorific Value: The calorific value was determined using Oxygen Bomb Calorimeter of model-OSK 100A. Moisture content, ash content, volatile matter, fixed carbon, density, sulphur content in line with the ASTM D-3173 specification were also carried out on the briquettes. The calorific value (KJ/kg) of the samples under test is calculated from the temperature rise of the VI in the calorimeter vessel and the mean effective heat capacity of the system. (Sumner et al., 1983)

$$[(Ee + W_1)\, TR - C]/S \times 4.1868 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where;

The water equivalent of the calorimeter (581g)

W_1 = Quantity of water in the vessel

TR = Temperature rise ^{o}C

C = Correction factor from ignition 154 Cal

S = Weight of sample in grams (g).

Moisture Content: A portion (2g) each of the samples was weighed out in a wash glass. The samples were placed in an oven for 2 hours at 105ºC. The moisture content was determined using:

$$MC = \frac{W_1 - W_2}{W_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

W_1 = Initial weight

W_2 = Weight after drying. (ASTM 1992)

Ash content: A Portion (2g) were placed in a pre-weighed porcelain crucible and transferred into a preheated muffle furnace set at a temperature of 600ºC for 1hour 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 thus:

$$AC\,(\%) = (W_2/W_1) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

W_2 = Weight of ash after cooling.

W_1 = Original weight of dry sample.

AC = Ash content (Aloko and Adebayo, 1997).

Volatile Matter: A portion (2g) of the sample was heated to about 300ºC for 10minutes 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 thus:

$$VM = \frac{W_1 - W_2}{W_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

VM = Volatile matter
W_1 = Original weight of the sample.
W_2 = Weight of sample after cooling.

Fixed Carbon: The fixed carbon was determined using the formula

$$FC(\%) = 100 - (\%VM + \%AC + \%MC) \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where;
VM = Volatile matter
AC = Ash content
MC = Moisture content

Density: A calibrated graduated cylinder was used for the estimation of destiny. The cylinder was packed with the samples and compacted. The density was thus calculated thus:

$$Density\ (g/cm^3) = \frac{Mass(g)}{Volume\ (cm^3)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Ignition Time

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.

Burning Time

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.

$$Burning\ rate = Ashing\ time - Ignition\ time$$

Water Boiling Test / Burning Efficiency

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.100g of each briquette sample was used to boil 250ml of water using small stainless cups and domestic briquette stove.

Total Sulphur Content

The different samples of the briquettes (1g) were pulverized and mixed with 3g of a mixture of magnesium oxide and anhydrous sodium carbonate mixed in the ratio of 2:1. The mixture was heated to 400^oC for two hours in a muffle furnace, cooled and digested in water. Barium chloride was added to precipitate the sulphate as barium sulphate. The precipitate was filtered and amount of sulphur was determined gravimetrically (ASTM, 1992).

Table 1: Results of Proximate Analysis of the Various Briquette Samples

Briquette sample (%)	Moisture Content (%)	Density (g/cm^3)	Sulphur Content (%)
100% CD	2.47	0.824	9.87
80%CD 20%RH	2.71	0.684	7.18
60%CD 40%RH	3.82	0.474	7.04
40%CD 60%RH	4.21	0.374	6.72
20%CD 80%RH	5.17	0.304	5.91
100% RH	5.94	0.244	4.12

Key

CD = Coal dust,

RH = Rice husk

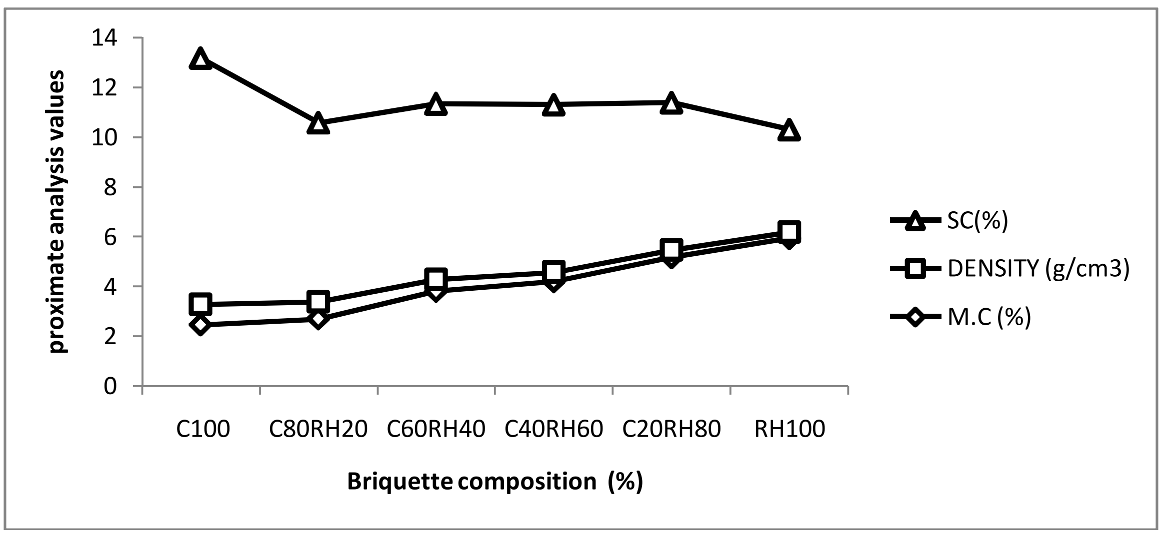

Fig 1: Plot of Sulphur Content, Density and Moisture Content of the Respective Briquettes

Table 2: Results of Proximate Analysis of the Various Briquette Samples

Briquette Sample (%)	Volatile Matter (%)	Ash Content (%)	Fixed carbon (%)	Porosity Index (%)
100% CD	10.44	29.63	57.46	25.10
80%CD 20%RH	17.32	26.38	53.59	34.01
60%CD 40%RH	23.08	25.92	47.18	42.53
40%CD 60%RH	32.05	24.86	38.88	59.98
20%CD 80%RH	38.64	23.45	32.74	66.72
100% RH	42.53	19.23	32.30	73.65

Key
CD = Coal dust
RH = Rice husk

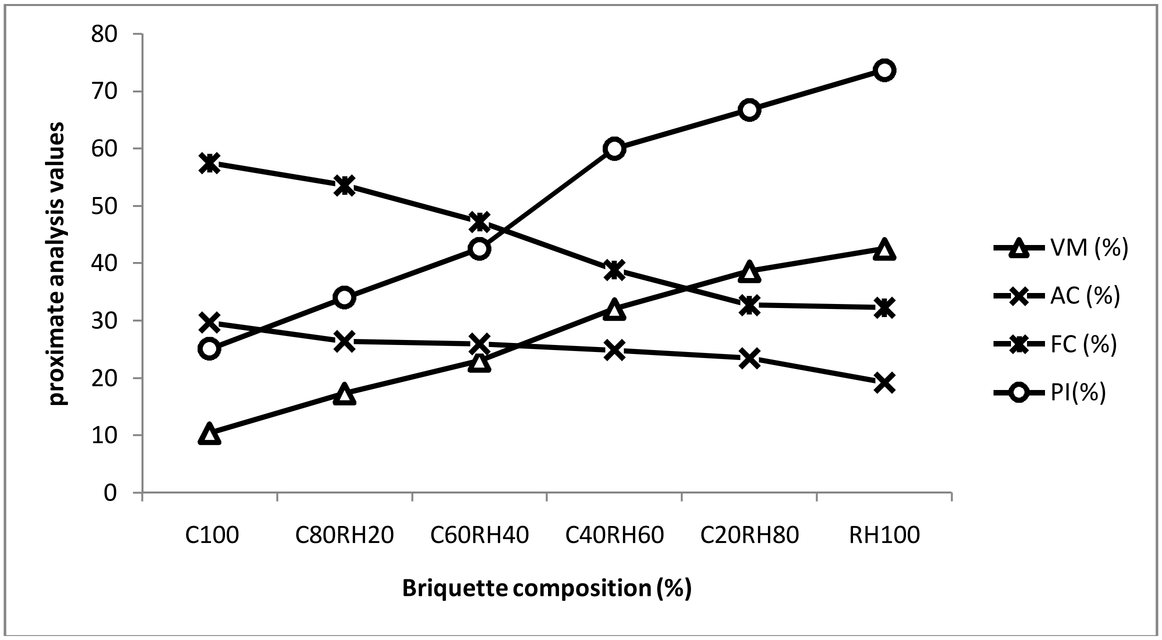

Fig 2: Plot of Porosity Index, Fixed Carbon, Ash Content and Volatile Matter of Respective Briquettes

Table 3: The Results of the Calorific Values of the Samples

Briquette Sample	Calorific Values KJ/g
100%CD	132.93
80%CD20%RH	127.52
60%CD40%RH	118.44
40%CD60%RH	95.84
20%CD80%RH	82.22
100%RH	69.45

Key
CD = Coal dust
RH = Rice husk

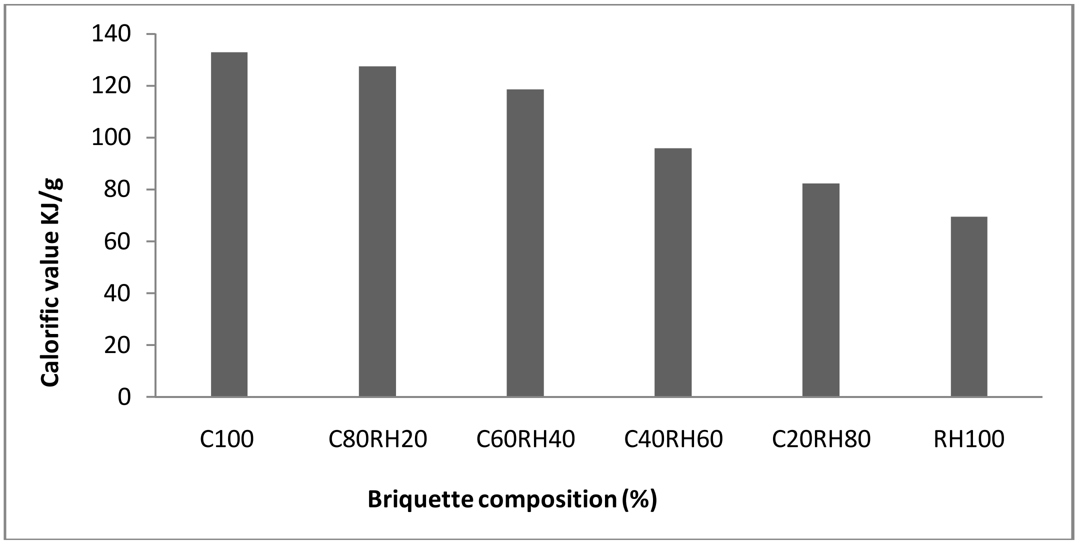

Fig. 3: Plot of the Calorific Values (KJ/g) of the Briquettes.

Table 4: The result of burning rate, burning time and ignition time

Briquette samples	**Water boiling test (min)**	**Burning time (min)**	**Ignition time (secs)**
100%CD	1.44	36.84	49.68
80%CD20%RH	1.60	23.75	41.35
60%CD40%RH	2.14	19.85	33.10
40%CD60%RH	2.85	18.96	28.67
20%CD80%RH	3.28	16.34	25.67
100%RH	4.07	15.68	24.33

Key
CD = Coal dust
RH = Rice husk

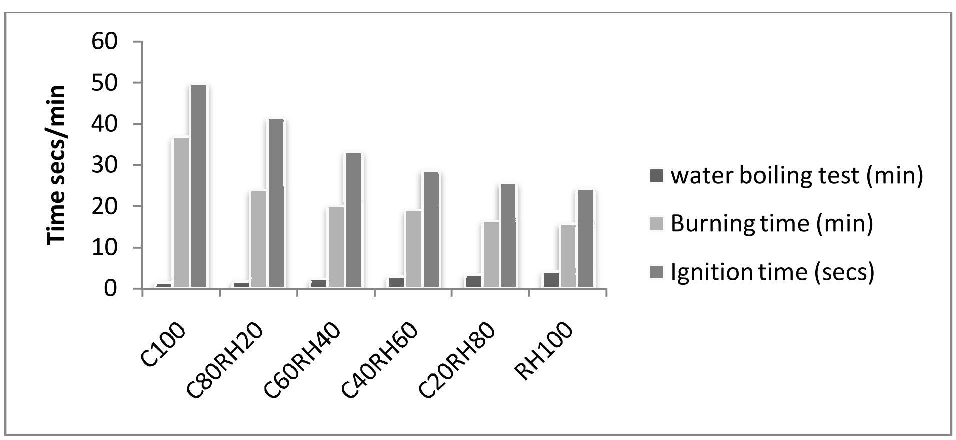

Fig. 4: Plot of the Water Boiling Test, Burning Rate and Ignition Time of the Respective Briquettes Produced

DISCUSSIONS

The proximate analysis show that moisture content values increased with the amount of rice husk added with 100% rice husk briquettes having the highest value because rice husk is more coarse than coal. The density decreased with addition of rice husk to the coal and 100% coal briquettes having the highest value since coal particles are much held together. The results of the sulphur content showed that 100% coal briquettes had the highest sulphur content but with the briquetting of coal and rice husk, increasing the amount of the sulphur fixing agent $Ca(OH)_2$ the sulphur content decreases. The results also show that the more the free particles of combustible material are, the more likely the volatile matter produced. Since particles of rice husk are less bonded to each than coal particles, 100% rice husk briquettes will generate more volatile matter upon heating than 100% coal briquettes. To reduce the volatile matter and make the briquettes more suitable for combustion the composition of coal and rice husk were varied to yield briquettes with reduced volatile matter. The ash contents of briquettes is higher in 100% coal briquettes than 100% rice husk briquettes because coal contains more non-combustible compounds than rice husk. The blending of the coal and rice husk will produce briquettes with reduced ash content. Fixed carbon gives an indication of the proportion of char that remains after the devolitization phase. The production of briquettes from coal and rice husk by varying their compositions results in briquettes with reduced carbon content. The porosity index shows that briquettes of biomass in which the particles are more adhered to each other will have a lower porosity index values than those with loose particles. Rice husk has more coarse loose particles unlike coal dust particles, as such the briquettes from mixture of coal and rice husk will have pores that will help in the passage of oxygen that is needed for combustion to take place. The moisture content is a measure of the amount of water in the fuel. In solid fuels, moisture can exist in two forms: as free water within the pores and interstices of the fuel, and as bound water which is part of the chemical structure of the material (Borman *et al.*, 1998). Moisture content is a very important property and can greatly affect the burning characteristics of the briquettes (Yang *et al*. 2005). The results shows that briquettes of 100% rice husk had the highest values of moisture content when compared to other compositions of briquettes. The result also shows that the briquetting of coal and rice husk reduces the moisture content. Since coal is denser than rice husks, the briquettes produced with higher composition of coal will have a higher density value than those briquettes with higher rice husk values. The lower the porosity index of the briquettes the higher the density of the briquettes produced, the values shows that 100% coal briquette has a higher density than 100% rice husk. The calorific value (or heating value) is the standard measure of the energy content of a fuel. It is defined as the amount of heat evolved when a unit weight of fuel is completely burnt and the combustion products are cooled to 298k. The ignition time of the briquettes shows that 100% rice husk briquettes are easily ignited unlike 100% coal briquettes. The blending of coal and rice husk produces briquette that ignites very fast, thereby solving the slow ignitability problem of coal briquettes. The water boiling test carried out on the briquettes shows that the briquettes made from blends of coal and rice husk briquettes burn faster than 100% coal briquettes and 100% rice husk briquettes. The differences in burning time for briquettes of 100% coal and those of coal and rice husk are not much, therefore blending will not only make the briquettes ignite very fast but will allow for longer cooking time.

CONCLUSION

In conclusion, bio-mass briquettes have drawn worldwide interest as an energy source because it does not negatively affect the environment. These bio-coal briquettes are very efficient since the quality of solid fuel depends on the following factors; providing sufficient heat as at time necessary, igniting easily without danger, generating less smoke and gases that are harmful to environment, generating less ash, as these constitute nuisance during cooking. The briquette sample 60% coal: 40% rice husk yielded optimum combustible values when compared with the other blends of briquettes.

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