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The Characterization of the Heating Properties of Briquettes of Coal and Rice Husk.

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Abstract: *In this work, smokeless briquettes of various compositions were produced using coal and rice husk, starch was used as the binder while Ca(OH$_2$) was the desulphurizing agent. The briquettes were produced in the following ratio of mixtures; coal and rice husk 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 respectively. The proximate analysis of the raw coal sample showed ash content 19.12%, moisture content 6.25%, volatile matter 41.12%, fixed carbon 33.51% and calorific value 117 KJ/g. the rice husk had the following values ash content 7.53%, moisture content 10.48%, volatile matter 68.74%, fixed carbon 13.25% and calorific value 65.24 KJ/g. The prepared briquettes were sun dried for seven days, subjected to various tests to assess their fuel quality. Of the briquettes produced, the 60% coal: 40% rice husk briquette showed the following values; ash content 20.26%, fixed carbon 50.06%, moisture content 4.42%, density 0.414 g/cm^3, volatile matter 25.26%, porosity index 40.7%, calorific value 142.86 KJ/g, water boiling test 2.15 minutes, burning time 20.43 minutes, ignition time 33.67 seconds and sulphur content 4.69%. The briquette showed improved properties with regards to combustible property when compared to the other briquettes produced with the same binder but different compositions.*

Key words: *briquette, biomass, coal, rice husk, starch.*

I. Introduction

Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. Rice husks are residues of rice harvesting and processing operations for which rather minimum utilization outlets have been found in Nigeria despite its vast potentials. Rice husk is the outermost layer of the paddy grain that is also called rice hull. It is separated from the brown rice in rice milling. Burning rice husk produces rice husk ash, if the burning process is incomplete carbonized rice husk is produced. Around 20% of the paddy weight is husk. In 2008 the world paddy production was 661 million tons and consequently 132 million tons of rice husk were also produced. While there are some uses of rice husk, it is still often considered a waste product in the rice mill and therefore often either burned or dumped on waste lands. Husk has a high calorific value and therefore can be used as a renewable fuel. Rice husk is produced in the first step in the milling process when the husk is removed from the grain in the husking stage of the rice mill (Beloilo, 2005).

Coal is burned in coal-fired plants to produce energy in the form of electricity. Domestically, coal is burnt in un-vented stoves producing heat energy for cooking and heating up homes. Over the years, it has been recognized that certain impurities in coal can have a significant impact on the types of emissions produced during coal combustion. However, various processes employed in converting coal into more useful forms emit considerable amounts of pollutants such as SO_2, NO_X, CH_4, etc (Rahman *et al*., 2000).

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 (Bhattacharya, 1985).

Bio-coal briquette is a type of solid fuel prepared by compacting pulverized coal, biomass, binder and sulphur fixation agent. The high pressure involved in the process ensures that the coal and the biomass particles are sandwiched and adhere together, as a result they do not separate during transportation, storage and combustion. During combustion, the co-combustion of the coal and the biomass gives a better combustion performance and reduces pollutant emission i.e bio-coal briquette has a favourable ignition, better thermal efficiency, emits less dust and soot (Somchai *et al.,* 1988). Briquetting can be regarded as a waste control measure. Depending on the material of interest, briquetting can be used to provide fuel source, as a preventive measure to many ecological problem. Certain materials like coal, agricultural waste such as rice husk, corn cob, paper and saw dust can be briquetted to serve as cooking fuel (Bhattacharya, 1985).

Furthermore, the presence of sulphur fixation agent otherwise known as desulfurizing agent ensures that most of the sulphur content of the coal is fixed into the ash instead of being liberated into the atmosphere as SO_2 (Somchai *et al*., 1988).

$$CaO_{(s)} + SO_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CaSO_{4(s)}$$

The ash of bio-coal has been shown to be effective for soil treatment and enrichment. However, preserving the forest resources by substituting fuel wood with bio-coal, along with the use of the ash from this briquette for soil treatment will compensate for fossil carbon emitted by the coal component of the briquette. Therefore bio-coal is considered to be a clean technology (Kwong *et al.*, 2007).

II. Objective Of The Study

To produce smokeless briquettes from coal and rice husk using starch as binder. To carryout proximate analysis of the briquettes to determine their combustible properties. To compare the results so as to determine the briquette composition with best combustible quality.

III. MATERIALS

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

IV. METHODS

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 moulds. Briquettes of coal and rice husk of different compositions were produced with a specific amount of $Ca(OH)_2$ 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 and mixed properly. The pressure was maintained at 5MPa for 15 minutes and was allowed to stand for 5 minutes before removal from the mould. After production, the briquettes were sun dried for 7days before analysis.

PROXIMATE ANALYSIS OF SAMPLES

Calorific value: The calorific value of the raw rice husk, raw coal and the briquettes were determined using Oxygen Bomb Calorimeter of model-OSK 100A. The calorific value (KJ/g) of the samples under test was calculated from the temperature rise VI in the calorimeter vessel and the mean effective heat capacity of the system. (Sumner *et al*., 1983)

VI= (Ee + W1) TR–C)/S x 4.1868

Where Ee is the water equivalent of the calorimeter (581g), W_1 = quantity of water in the vessel, TR = Temperature rise ^oC, C = correction factor from ignition 154 Cal, S = weight of sample in grams (g).

Moisture content: The moisture contents of the raw coal, rice husk and briquettes were determined. 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:

$$MC = \frac{W_1 - W_2}{W_1} \times 100$$

W_1= Initial weight, W_2= Weight after drying

Ash content: The ash contents of the raw coal, rice husk and briquettes were also determined. A Portion (2g) were placed in a preweighed 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 (%) = $(W_2/W_1) \times 100$.

W_1 = Original weight of dry sample, W_2 = Weight of ash after cooling.

Volatile matter: The volatile matter of the raw coal, rice husk and briquettes were also determined. 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:

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

W_1 = Original weight of the sample. W_2 = 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

FC (%) = 100 – (%VM + %AC + %MC)

Where VM = Volatile matter, AC = Ash content, MC = Moisture content (ASTM 1992).

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:

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

Total Sulphur Content:

The different samples of the briquettes was pulverized, 1g of the finely powdered samples was mixed with 5g of Na_2NO_3 and 0.2g of $NaNO_3$ in a crucible. The mixture was preheated at 400^oC for 30 minutes in an electric muffle furnance and then fused at 950^oC, after fussion, the crucible was allowed to cool and was placed on its side in a 150 cm^3 beaker. HCl was added to neutralize the Na_2CO_3 and boiled to precipitate the sulphate by treating with $BaCl_2$. The precipitate treated with drops of HF and H_2SO_4, ignited and weighed again. Total sulphur is determined by the expression (Jackson, 1958).

$$\% \text{ sulphur} = \frac{BaSO_4 (g) \times 13.7}{\text{Weight of sample}} \text{ X } 100$$

Porosity Index: The porosity of the briquettes was determined based on the amount of water each sample was able to absorb. The porosity index was calculated as the ratio of the mass of water absorbed to the mass of the sample immersed in the water (Montgomery, 1978).

$$\text{Porosity Index} = \frac{\text{Mass of water absorbed}}{\text{Mass of the sample}} \times 100$$

Ignition time (secs)

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 (mins)

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 (mins)

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. (Kim *et al*., 2001).

V. Results

Table 1. The results of proximate analysis of the raw coal and rice husk.

Samples	Moisture content(%)	Volatile matter(%)	Ash content(%)	Fixed carbon(%)	Calorific value (KJ/g)
Coal	3.25	20.12	19.12	57.51	117.18
Rice husk	8.48	42.14	7.53	41.85	65.24

Table 2. Results of proximate analysis of the various briquette samples

Briquette sample (%)	Moisture content (%)	Density (g/cm^3)	Sulphur content (%)
100% CD	2.78	0.724	6.21
80%CD 20%RH	3.37	0.594	5.52
60%CD 40%RH	4.42	0.414	4.69
40%CD 60%RH	4.55	0.334	4.42
20%CD 80%RH	5.68	0.274	4.14
100% RH	6.95	0.224	3.45

Key- CD= Coal dust, RH= Rice husk

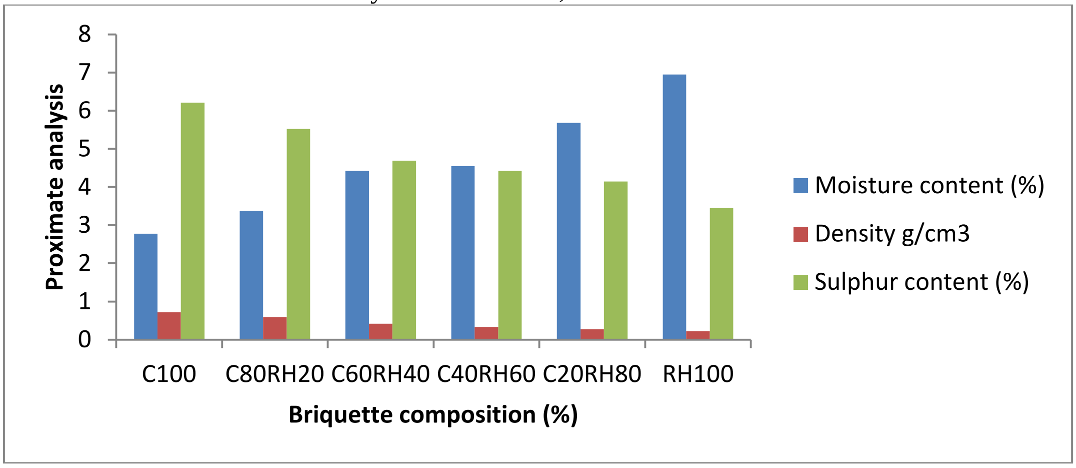

Fig. 1. The proximate analysis of the various compositions of briquette samples.

Table 3. Results of proximate analysis of the various briquette samples

Briquette sample (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)	Porosity index (%)
100% CD	13.40	22.06	61.76	24.96
80%CD 20%RH	21.13	21.79	53.71	33.66
60%CD 40%RH	25.26	20.26	50.06	40.76
40%CD 60%RH	36.13	19.45	39.87	50.48
20%CD 80%RH	43.86	18.91	31.55	62.52
100% RH	49.23	16.82	27.00	70.13

Key- CD= Coal dust, RH= Rice husk

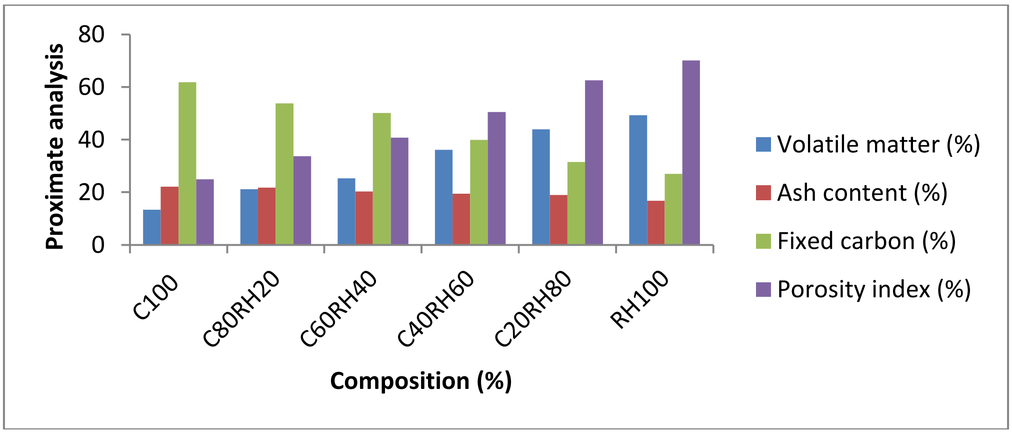

Fig.2 The plot of proximate analysis of the briquettes against composition.

Table 4. The results of the calorific values of the samples

Briquette sample	Calorific values(kj/kg)
100%CD	164.34
80%CD20%RH	151.51
60%CD40%RH	142.86
40%CD60%RH	126.25
20%CD80%RH	108.09
100%RH	90.23

Key- CD= Coal dust, RH= Rice husk

Table 5. The result of burning rate, burning time and ignition time

Briquette samples	Water boiling test (min)	Burning time (min)	Ignition time (secs)
100%CD	1.42	26.21	47.33
80%CD20%RH	1.62	24.15	41.00

60%CD40%RH	2.15	20.43	33.67
40%CD60%RH	2.91	19.22	29.67
20%CD80%RH	3.42	17.48	27.00
100%RH	4.12	16.17	23.33

Key- CD= Coal dust, RH= Rice husk

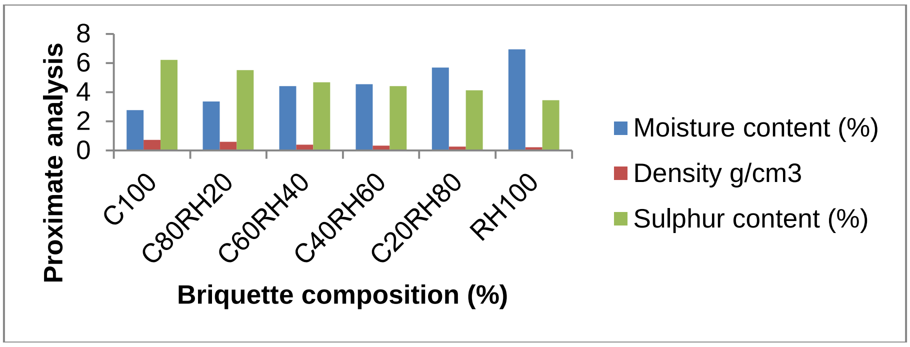

Fig.3 The plot of proximate analysis of the briquettes against composition.

VI. 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 had 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 glucosidic bond of starch which is easily broken contributes to the easy ignitable qualities of the briquettes produced. The particles of rice husk are less bonded to each than coal particles, 100% rice husk briquettes generated 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 results showed that briquettes of 100% rice husk had the highest values of moisture content when compared to other compositions of briquettes. The results also showed that the briquetting of coal and rice husk reduces the moisture content of the briquettes The result for porosity index showed that briquettes of biomass in which the particles are more adherred 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 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 showed that the briquettes made from blends of coal and rice husk briquettes burned faster than 100% coal briquettes and 100% rice husk briquettes. The differences in burning time for briquettes of 100% coal and the briquettes of 60% coal and 40% rice husk are not much, therefore blending will not only make the briquettes ignite very fast but will allow for longer cooking time.

VII. 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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