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The Study Of Briquettes Produced With Bitumen, $Caso_4$ And Starch As Binders.

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ABSTRACT : *The work was based on production and study of the properties of smokeless briquettes of various compositions with coal and rice husk. Different briquettes were produced with starch, bitumen and* $CaSO_4$ *as the binders while* $Ca(OH_2)$ *was the desulphurizing agent. 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 briquettes produced are in the following ratio of mixtures of coal and rice husk 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 respectively. The prepared briquettes were sun dried for seven days, subjected to various tests to assess their fuel quality. The briquettes produced with starch as the binder had better results for faster ignition time, lower amounts of sulphur emissions during burning, highest calorific values and longer burning time for all the different compositions.*

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

I. INTRODUCTION

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 do not separate during transportation, storage and combustion (Onuegbu *et al.*,2010) A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel (Grainger *et al*., 1981).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).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). 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).

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

II. OBJECTIVE OF THE STUDY

To produce smokeless briquettes from coal and rice husk using starch, bitumen and $CaSO_4$ as binders. To compare the results of the proximate analyses carried out on the briquettes to determine the binder with the best quality for use in briquette production.

III. MATERIALS

Pulverised coal, rice husk, bitumen, starch, $CaSO_4$, 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°C for 30 minutes in an electric muffle furnance and then fused at 950°C, 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).

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

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).

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: The results of ash contents of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	21.05	29.63	22.06
80% C + 20% RH	20.27	26.38	21.79
60% C + 40% RH	19.67	25.92	20.26
40% C + 60% RH	18.21	24.86	19.45
20% C + 80% RH	17.56	23.45	18.91
100% RH	16.23	19.23	16.82

Table 3: The results of fixed carbon of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	65.04	57.46	61.76
80% C + 20% RH	60.95	53.59	53.71
60% C + 40% RH	57.94	47.18	50.06
40% C + 60% RH	49.75	38.88	39.87
20% C + 80% RH	40.90	32.74	31.55
100% RH	37.37	32.30	27.00

Table 4: The results of moisture content of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	2.15	2.47	2.78
80% C + 20% RH	2.34	2.71	3.37
60% C + 40% RH	2.92	3.82	4.42
40% C + 60% RH	3.51	4.21	4.55
20% C + 80% RH	4.08	5.17	5.68
100% RH	4.68	5.94	6.95

Table 5: The results of density of the briquette samples

Briquette samples (%)	Bitumen (g/cm^3)	$CaSO_4$ (g/cm^3)	Starch (g/cm^3)
100% C	0.714	0.824	0.724
80% C + 20% RH	0.574	0.684	0.594
60% C + 40% RH	0.401	0.474	0.414
40% C + 60% RH	0.294	0.374	0.334
20% C + 80% RH	0.264	0.304	0.274
100% RH	0.201	0.244	0.224

Table 6: The results of volatile matter of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	11.76	10.44	13.40
80% C + 20% RH	16.44	17.32	21.13
60% C + 40% RH	19.47	23.08	25.26
40% C + 60% RH	28.53	32.05	36.13
20% C + 80% RH	37.46	38.64	43.86
100% RH	41.72	42.53	49.23

Table 7: The results of porosity index of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	22.02	25.10	24.96
80% C + 20% RH	31.33	34.01	33.66
60% C + 40% RH	38.74	42.53	40.76
40% C + 60% RH	47.61	59.98	50.48
20% C + 80% RH	56.95	66.72	62.52
100% RH	64.72	73.65	70.13

Table 8: The results of calorific values of the briquette samples

Briquette samples (%)	Bitumen (KJ/kg)	$CaSO_4$ (KJ/kg)	Starch (KJ/kg)
100% C	156.88	142.93	164.34
80% C + 20% RH	142.63	127.52	151.51
60% C + 40% RH	128.68	108.44	142.86
40% C + 60% RH	112.40	95.84	126.25
20% C + 80% RH	102.88	82.22	108.09
100% RH	84.21	69.45	90.23

Table 9: The results of water boiling test of the briquette samples

Briquette samples (%)	Bitumen (g/min)	$CaSO_4$ (g/min)	Starch (g/min)
100% C	1.63	1.44	1.42
80% C + 20% RH	1.84	1.60	1.62
60% C + 40% RH	2.25	2.14	2.15
40% C + 60% RH	3.17	2.85	2.91
20% C + 80% RH	3.75	3.28	3.42
100% RH	4.38	4.07	4.12

Table 10: The results of burning time of the briquette samples

Briquette samples (%)	Bitumen (min)	$CaSO_4$ (min)	Starch (min)
100% C	24.89	26.84	26.21
80% C + 20% RH	20.76	23.75	24.15
60% C + 40% RH	17.81	19.85	20.43
40% C + 60% RH	14.55	18.96	19.22
20% C + 80% RH	12.88	16.34	17.48
100% RH	11.71	15.68	16.17

Table 11: The results of ignition time of the briquette samples

Briquette samples (%)	Bitumen (sec)	$CaSO_4$ (sec)	Starch (sec)
100% C	37.00	46.66	47.33
80% C + 20% RH	27.67	39.33	41.00
60% C + 40% RH	21.67	33.10	33.67
40% C + 60% RH	19.33	28.67	29.67
20% C + 80% RH	17.67	25.67	27.00
100% RH	16.00	24.33	23.33

Table 12: The results of sulphur contents of the briquette samples

Briquette samples (%)	Bitumen (%)	$CaSO_4$ (%)	Starch (%)
100% C	8.22	7.87	6.21
80% C + 20% RH	8.02	7.18	5.52
60% C + 40% RH	7.78	7.04	4.69
40% C + 60% RH	7.43	6.72	4.42
20% C + 80% RH	6.29	5.91	4.14
100% RH	4.21	4.12	3.45

V. DISCUSSIONS

From the results of the proximate analysis, the briquettes of $CaSO_4$ had higher ash contents due to the presence of more non combustible compounds, as such they had lower calorific values when compared with briquettes of similar compositions produced with starch as binder. The briquettes made using the bitumen as binder had the lowest moisture content value because of the sticky nature of the binder that made absorption of water molecules into the pores of the briquettes difficult. The fuel briquette's density will affect its bulk thermal properties, the thermal conductivity will be reduced as the density is decreased (increased fuel porosity), but the lower the density, the less heat is required for a specific volume of fuel to reach the ignition temperature (Loo *et al.*, 2008). This effect is seen in the increased burning time of briquettes of binders like $CaSO_4$ which tend to exhibit greater burning time than those of starch. When the particles of a combustible material are loose, the briquettes produced would have more volatile matter during pyrolysis. Since rice husk are less bonded to each other than coal, 100% rice husk briquettes produced more volatile matter than 100% coal briquettes for the different binders under consideration. 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 298 k (BSI, 2005). When fuels contain compounds such as hydrocarbons, which have a lower degree of oxidation, this tends to raise the heating value of the biomass (Jenkins *et al*., 1998). The results showed that 100% coal briquettes of all the binders had the highest calorific value and progressed downward as rice husks was added to the coal for producing briquettes. The water boiling test measures the time it takes a given quantity of fuel to heat and boil a given quantity of water. The results showed that briquettes produced using bitumen as the binder took longer time to boil water when compared to the other briquettes. The reason being that the briquettes smoked more than the other briquettes made with different binders, and much heat energy was lost as smoke thereby affecting its water boiling property. The briquettes of $CaSO_4$ showed similar trend of values in the water boiling tests. From the results, 100% coal briquettes of the different binders had the longest burning time of all the briquettes produced followed by 100% corn cob briquettes while 100% rice husk briquettes of all the different binders had the least burning time. The briquettes of starch as the binder showed longer burning time for the different compositions when compared with other compositions produced with different binders. This might be due to the incombustible compounds that are present in the briquettes produced using $CaSO_4$ as binder. Another reason was the smoky nature of briquettes made from bitumen also succeeded in affecting the rate of combustion of the briquettes The addition of the desulphurizer in the coal and rice husk briquettes produced reduced the amount of sulphur content for the briquettes produced for different binders. On the average starch briquettes had the least values of sulphur content.

VI. CONCLUSION

In conclusion, bio-mass briquettes have drawn worldwide interest as an energy source because it does not negatively affect the environment. The results showed that the various briquette compositions produced with starch as binder showed remarkable values of low ash contents, higher calorific values, longer burning time and low sulphur contents when compared to the other binders used for the briquette production. The binder bitumen was not suitable due to the much smoke emitted during cooking. $CaSO_4$ is expensive, fouls stoves during cooking and not easily affordable. For the binders under consideration the use of starch as a binder is strongly recommended during briquetting.

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