COMPARATIVE STUDIES OF IGNITION TIME AND WATER BOILING TEST OF COAL AND BIOMASS BRIQUETTES BLEND

T.U. Onuegbu[1*], U.E. Ekpunobi[1], I.M. Ogbu[1], M.O. Ekeoma[2] & F.O. Obumselu[1]
[1]Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Anambra State,
[2]Department of Chemistry, Michael Okpala University of Agriculture, Umudike. Abia State, Nigeria
***Email:** onuzotesi@yahoo.com

ABSTRACT
This work is aimed at comparing the ignition time and water boiling test of coal briquette blends with *pennisetum purpurem (*elephant grass*)* and *imperata cylindrica* (spear grass). Proximate analyses and elemental compositions of the coal and biomass were determined. Different samples of briquettes were produced by blending varying loads of the plant materials with the coal in the ratio of 0:100, 10:90, 20:80, 30:70, 4:60, 50:50, and 100:0, using cassava starch as a binder and calcium carbonate ($Ca(OH)_2$) as a desulfurizing agent. The results of the properties tested were compared. Ignition time decrease with increase in the plant material while coal blends with *pennisetum purpurem* performed better. In the water boiling test determination, burning rates as well as specific fuel consumptions were also determined. There is a variation in the results obtained.

Keywords: *Biomass, coal briquette Ignition time water boiling test.*

1. INTRODUCTION

Rural Nigerians depend solely on fuel wood (charcoal, firewood and sawdust) for their energy needs for the past decades. Fuel wood gathering takes a significant proportion of the working days of women and children and has led to extensive deforestation desertification and environmental degradation. Rural dwellers that use these fuels have to seek for alternative fuel sources for their domestic uses. Vegetable matter (biomass) if not properly disposed litter the environment thereby causing air and water pollution. At present, owing to obvious limitations in the availability of fossil fuel, research work has shifted from conventional processing of coal, biomass and wastes into more convenient environmentally green solid fuel known as briquettes.

A briquette is a block of compressed coal, biomass or charcoal dust that is used as fuel [1]. Briquetting is a high pressure process which can be done at elevated temperature [2], or at ambient temperature [3,4] depending on the technology one applies. In some briquette techniques, the materials are compressed without addition of adhesive (binder less briquette) [5,6] while in some adhesive materials are added to assist in holding the particles of the material together[3,4]. Briquetting process has focused on the production of smokeless solid fuels from coal and agricultural wastes. However, briquetting of organic materials (agricultural wastes) requires higher pressure as additional forces is needed to overcome the material springiness of these materials. This involves the destruction of the cell walls through some combination of pressure and heat. Most recently, researcher showed that blending of coal and biomass will give rise to a briquette with better burning properties and environmentally friendly, and this type is called bio-coal briquette or bio-briquette.

Bio-coal briquette is a type of solid fuel prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent [7,8]. Futhermore, 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 sulphur (iv) dioxide [9]. During combustion, the co-combustion of the coal and the biomass gives a better combustion performance and reduces pollutant emission. Bio-coal briquette has a favourably ignition, better thermal efficiency, emits less dust and soot. [10].

Some of the biomass resources available for production of bio-coal briquettes include straw, sugar bagasse (fibrous residue of processed sugar cane), corn stalk, groundnut – shell, wheat straw, palm husk, forest wastes, rice husk, rice stalk, and various weeds cleared from farmland. Several researches on bio-coal briquettes have been carried out using some of these biomass resources and they include: production of bio-coal briquettes using sawdust,[11], rice straw[12], olive stone[13,14] and maize cob[8] etc.

Furthermore, researches have shown have shown that any grade of coal can be used for bio-coal production but tat requires additional cot of carbonization of low grade coal before briquetting is completed.

(Penisetum purpurium): (elephant grass) is an indigenous grass found all over the tropic. In Nigeria, it is one of the dominating grasses found in the farmlands and non-agricultural field. When fully grown, it is cane-like specie of grass and can grow up to 3 meters especially in wet land. Because of its high productivity (rapid growth), Brazil cultivates and utilizes it to produce charcoal, cellulose, bio fuels, also they use it as fuel source for thermoelectric power plant and furnaces. Spear grass (*imperata cylindrica*): Spear grass is one of the most dominant and noxious

weeds found in agricultural and non-agricultural fields. It is abundantly distributed in the forest/savannah transition zone especially where recurrent fire and farming activities prevents the natural vegetation from growing up to level that can shade out weeds. It is a potential fire hazard in plantation and arable crop farmland.
The aim of this work is to compare the ignition time and water boiling time of coal briquette blends with varying loads of *pennisetum purpurem* and *imperata cylindrica.*

Experimental

Materials and Methods

Pennisetum purpureum and *imperata cylindrica* were collected from a farmland at Emene, sub-bituminous coal from Okpara Mine was sourced from Nigeria Coal Corporation, Enugu, both in Enugu State, Nigeria, while calcium hydroxide was procured from BDHL England. Starch was processed from cassava obtained from a farmland at Emene. Manual briquette machine was fabricated at National Centre for Energy Research and Development, University of Nigeria, Nsukka, Enugu State, Nigeria.

Preparation of the biomass

The biomass (*Pennisetum purpureum* and *imperata cylindrica*) collected were air dried for ten days to reduce the moisture content of the materials. The materials were chopped and ground in an electric milling machine to pass through 4mm standard sieve and stored in a polyethylene bag.

Preparation of coal sample

The sub-bituminous coal sample was sun dried for two days to reduce its moisture content. It was broken into sizes that could enter the hopper of the milling machine using hammer. It was then ground in an electric milling machine to pass through 1mm sieve and kept in polyethylene bag.

Preparation of starch

Cassava tubers collected were washed, peeled, ground and pressed to extract the liquid content. The liquid was filtered and the filtrate was allowed to stay for two hours so that the starch would separate from the mixture. After that the upper liquid layer was carefully decanted. The starch was sun dried for five days to reduce the, moisture content.

Proximate Analysis of the Materials

The moisture content, ash content, volatile matter and the fixed carbon of the plant material and coal were determined in line with the ASTM D-3173 specification [8,9]. The calorific value was determined using Oxygen Bomb Calorimeter of model-XRIA. The total sulphur content was analyzed using Eschka method [8].

Preparation of the Briquette Samples

The briquettes were produced in the laboratory of National Centre for Energy Research and Development, University of Nigeria Nsukka, Enugu State. A manual hydraulic briquetting machine with six cylindrical moulds of 3.9cm diameter each was used. Briquettes of varied biomass concentrations were produced by blending the biomass at various concentrations; 0%, 10%, 20%, 30%, 40%, 50%, and 100% with the coal. For each set of briquette, 5% $Ca(OH)_2$ based on the mass of coal was used as the desulfurizing agent and 10% cassava starch based on the entire mass of the mixture was used as the binder. The pressure was maintained at 5MPa throughout the production. The samples were weighed using digital weighing balance.

Table 1: Formulation of various briquettes samples

Sample	Coal (%)	Biomass (%)
E_{00}	100	00
E_{10}	90	10
E_{20}	80	20
E_{30}	70	30
E_{40}	60	40
E_{50}	50	50
S_{10}	90	10
S_{20}	80	20
S_{30}	70	30
S_{40}	60	40
S_{50}	50	50

Note: E= Concentration of Elephant grass
S= Concentration of Spear grass

Characterisation of the samples
Moisture content, ash content and calorific values of briquette samples were determined.

Determination of the ignition time: Each briquette sample was ignited at the base in a drought free corner. The time required for the flame to ignite the briquette was recorded as the ignition time using stop watch [15,16].

Water boiling test: This was carried out to compare the cooking efficiency of the briquettes. It measured 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 100cm^3 of water using small stainless cup and domestic briquette stove [17]. During this test, other fuel properties of the briquettes like burning rate and specific fuel consumption were also determined [18]. Also, the level of smoke evolution was observed. Burning rate is the ratio of the mass of the fuel burnt (in grams) to the total time taken (in minute).

$$\text{Burning rate} = \frac{\text{mass of fuel consumed (g)}}{\text{Total time taken (min.)}} \quad \ldots\ldots(1)$$

The specific fuel consumption indicates the ratio of the mass of fuel consumed (in grams) to the quantity of boiling water (in litres).

$$\text{Specific fuel consumption} = \frac{\text{mass of fuel consumed (kg)}}{\text{Total mass of boiling water (litre)}} \quad \ldots\ldots(2)$$

2. RESULTS AND DISCUSSION

The results of proximate analyses of the raw material are shown in Table 2. From the results, it is clearly shown that the coal sample has higher calorific value (20/64kJ/g), fixed carbon (30.65%) and ash content (18.27%) than the biomass samples but lower volatile matter (43.44%). The calorific value of coal indicates that it will release more heat during combustion than the biomass while the biomass on their own side will ignite more readily and burn faster than the coal because of their higher volatile matter. Also, the high ash content of the coal is an indication that it contains more mineral (non combustible) matters than the biomass materials and its concentration will have great influence on the amount of ash that will be generated by bio-coal briquettes.

Table 2: The results of proximate analyses of various raw materials

Sample	**Moisture content**	**Ash content(%)**	**Volatile matter (%)**	**Fixed carbon (%)**	**Calorific value(kJ/g)**	**Total sulphur content (%)**
Coal	7.64	18.27	43.44	30.65	20.64	0.82
Pennisetum purpureum	9.26	5.18	70.10	15.46	15.11	0.23
imperata cylindrica	10.13	6.18	69.10	14.49	14.66	0.26

The results of moisture content, ash content and calorific values of briquette samples are in shown Table 2.

Table 2: Proximate analyses of bio- coal briquette samples

Briquette samples	Moisture content (%)	Ash content (%)	Porosity index	Calorific value(kJ/g)
E_0	7.00	23.01	0.560	20.39
E_{10}	7.00	20.54	0.850	19.54
E_{20}	7.00	18.49	0.930	19.82
E_{30}	7.00	17.53	1.170	19.38
E_{40}	7.50	16.00	1.480	18.67
E_{50}	8.00	15.22	1.55	18.53
E_{100}	8.00	4.35	3.860	15.98
S_{10}	7.00	20.97	0.730	20.58
S_{20}	7.50	19.03	0.903	19.48
S_{30}	7.00	16.97	1.080	20.92
S_{40}	8.00	16.50	1.360	19.54
S_{50}	7.50	13.40	1.490	18.09
S_{100}	8.00	6.09	3.520	16.13

The results of ignition time in Fig. 1 showed that the ignition time of the briquettes decreases with increase in biomass concentration. This can be explained from the fact that the biomass contains more volatile matter than the coal as shown in Table 2. Therefore, increasing its concentration in the briquette will definitely increase the ignitibility of the briquette. The coal briquette samples E0 took the longest time to ignite, 286.00sec. But with incorporation of biomass, the ignition time dropped progressively. The ignition time of S_{10}-S_{30} was shorter than that of E_{10}-E_{30} but later the ignition time of S_{40}-S_{100} become higher than that of E_{40}-E_{100}. The sample with relatively low ignition time will be more efficient.

Among the factors that control the burning rate of a material are chemical composition and geometry (bulk, packing, orientation) of the material. Biomass contains more volatile matter than the coal and it is more porous which allows for easy infiltration of oxygen and out flow of combustion products. Therefore, increasing the proportion of the biomass is expected to increase the burning rate of the briquettes.

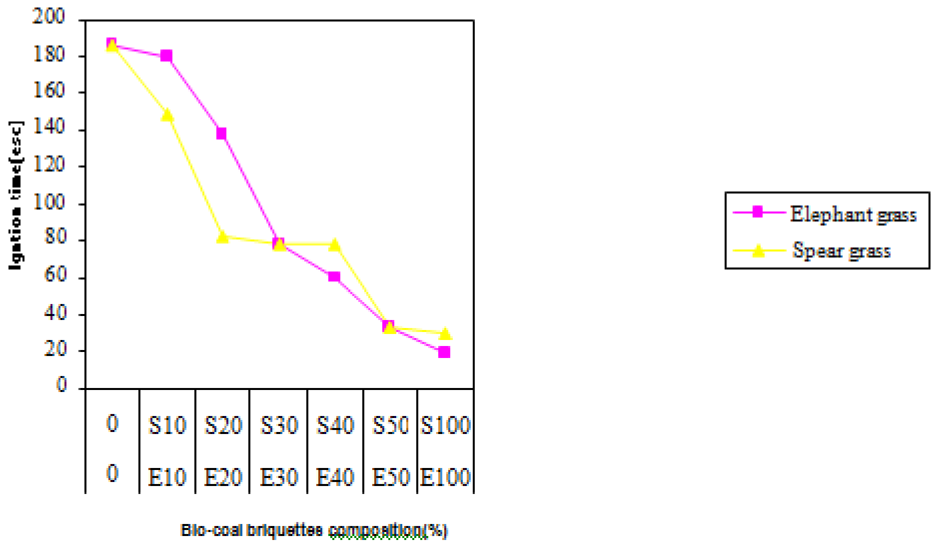

Fig.1: The Effect of biomass concentration on the ignition time of bio-coal briquettes

Fig.2-4 show the results of the parameters determined during the water boiling test. Provision of sufficient heat for the time necessary is an important quality of any solid fuel. The results of water boiling test showed that the time required for each set of briquettes to boil an equal volume of water decreases with increase in the biomass concentration up to 50% for both elephant grass and spear grass bio-coal samples as shown in Fig. 3. However, the fact that the briquette samples containing 50% biomass boiled water faster than the one containing 100% is a clear indication that somewhere beyond this concentration, the water boiling time will eventually begin to rise. The coal briquette, $E_{00,}$ took the longest time to boil water (26min) while the sample S_{50} took the shortest time (8.00min) for spear grass briquettes and E_{50} for the elephant grass briquette samples (6.46min.). The burning rate (how fast the fuel burns) and the caloric value (how much heat released) are two combined factors that controlled the water boiling time. This explaineds why sample S_{30} was able to boil water faster that Sample S_{40} even when the latter burns faster than the former. This means that the calorific value alone is not a single factor controlling cooking efficiency but burning rate is equally important. This equally explains why sample S_{30} (20.92KJ/g) was able to boil water faster than S_{40} (19.53KJ/g).

Again, the specific fuel consumption (SPC) which measures the quantity of the fuel required to boil 1litre of water also was shown to decrease progressively with increase in biomass concentration up to 50% except sample S_{40}. The lower the SPC the more economical the briquette will be. However, comparing the specific fuel consumption, the burning rate and the water boiling time, it is observed that the cooking efficiency of the briquettes increase with increase in biomass concentration (within the biomass range of 0% to 5%) and somewhere beyond this biomass range, the cooking efficiency will start to drop. They burn and boil water faster and less quantity of them were required to produce one litre of boiling water compared to other briquette samples. On the other hand, coal briquette E_{00} has the least cooking efficiency. It burns slowly without flame, took the longest time to boil the water and much quantity of it was needed to boil water. This is because of the fact that the briquette burns slowly, as a result, lots of the heat released was lost before the water boils.

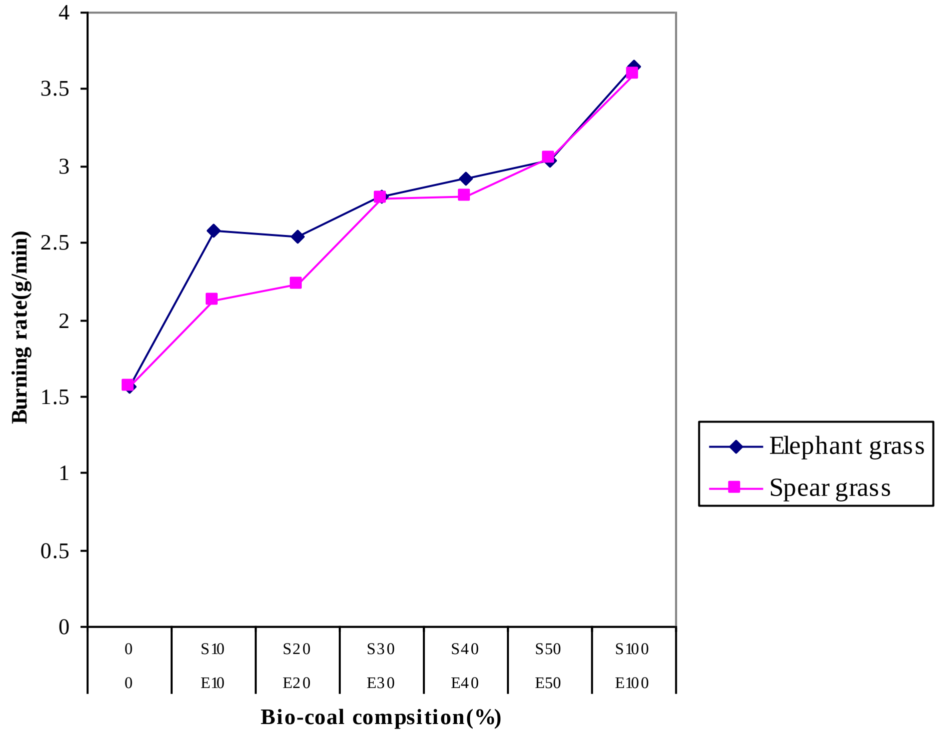

Fig. 2: The effect of biomass composition on the burning rate of bio-coal briquette

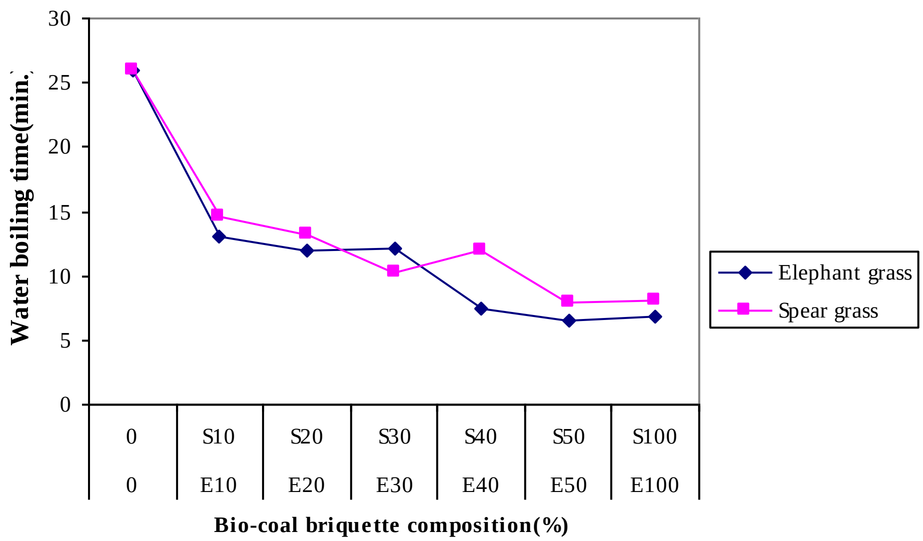

Fig.3: The effect ofbiomass concentration of the water boiling time

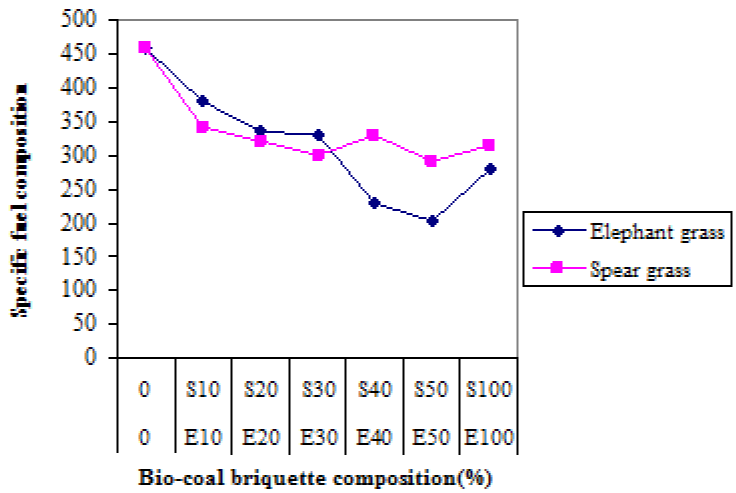

Fig. 4: The effect of biomass concentration on the specific fuel composition

3. CONCLUSION

In conclusion, these bio-coal briquettes are very efficient since the quality of any fuel briquette depends on the following factors, its ability to: provide sufficient heat at time necessary, ignite easily without any danger, generate less smoke, generate less ash (dust) as this will constitute nuisance during cooking and to be strong enough for safe transportation and storage. The properties were improved progressively with increase in biomass concentration up to 50%.

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