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ORIGINAL ARTICLE

Enhancing the Efficiency of coal Briquette in Rural Nigeria using *pennisetum purpurem.*

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Onuegbu T.U., Ogbu I.M., Ilochi N.O., Okafor I, Obumselu O.F. and Ekpunobi U.E: Enhancing the Efficiency of coal Briquette in Rural Nigeria using *pennisetum purpurem.*

ABSTRACT

This work studied the effect of elephant grass *pennisetum purpureum* on coal briquette. Proximate analyses and elemental compositions of coal and *pennisetum purpureum* were determined. Varying samples of briquettes were produced by blending different loads of plant materials with the coal in the ratio of 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0. The physical, mechanical and combustion properties of the briquettes were analyzed. Results of the analyses showed that ignition, smoke emission, cooking efficiency, water boiling time, burning rate and specific fuel consumption were enhanced. The optimum biomass concentration for improving the calorific value is between 20-30%. Beyond 50%, the cooking efficiency started declining.

Key words: Coal briquette, biomass, *pennisetum purpureum*

Introduction

Nigeria over dependence on petroleum and its derivatives for domestic and industrial purposes has led to instability in the prices of oil, gas and other sources of energy Onuegbu, (2010). Most rural Nigerians depend solely on fuel wood (charcoal, firewood and sawdust) for their energy needs for the past decades. At present, Nigeria consumes about 43×10^9 kg of fuel wood annually Ministry of Energy, (2009) and it will be more than this by the end of 2010 if the present trend continues Philip, (2007). Rural dwellers that use these fuels need to seek for alternative fuel sources for domestic uses. Vegetable matter (biomass), if not properly disposed litters the environment thereby causing air and water pollution. In the recent time, owing to obvious limitations in the availability of fossil fuel, research work has shifted from conventional processing of coal, biomass, and fuel wood to 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 Grainger and Gibson, (1981). In some briquette techniques, the materials are compressed without addition of adhesive (Mangena and Cann, 2007; Mangena and Korte (2004), while in some adhesive materials are added to assist in holding the particles of the material together (Mohammed, 2005; www.nedo.go.jp/sekitan/cc.eng). However, briquetting process has focused more on the production of smokeless solid fuels from coal and agricultural waste. Briquetting of organic materials such as agricultural waste requires significantly overcoming the natural springiness of these materials. This involves the destruction of the cell walls through some combination of pressure and heat.

The use of organic briquettes (biomass briquettes) started more recently compared to coal briquettes which dated back to eighteenth century Choudhurl, (1983). Briquetting of sawdust was widely spread in many countries in Europe and America during World War 11 because of fuel shortages. However, after the World War 11, briquettes were gradually phased out of the market because of availability and cheapness of hydrocarbon fuels. As time went on, the use of organic briquette was revitalized due to high energy prices in the 1970s and early 1980s mainly for industrial heating in U.S.A., Canada and Scandinavia. etc.

Common types of briquettes in use are coal briquettes, peat briquettes, charcoal briquettes, and biomass briquettes. Recently, researches showed that blending of coal and biomass will give rise to a briquette with

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better combustion properties and environmentally friendly. This type of briquette is known as bio-coal briquette (bio- briquettes). Bio-coal briquettes is prepared by blending coal, biomass, binder and sulphur fixation agent (Lu and Wang, 2000; Patomsok, 2008). In this process, calcium hydroxide ($Ca(OH)_2$) acts as both sulphur fixation agent and the binder (www.nedo.go.jp/sekitan/cc.eng). The de-sulphurizing agent in the briquette reacts with the sulphur content of the coal to fix 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 oxides Somchai *et al.*, (1988). The equation for the reaction is shown below:

$$CaO_{(s)} + SO_{2(g)} + ½O_{2(g)} \rightarrow CaSO_{4(s)} \quad (1)$$

Several researches have been carried out using sawdust, rice straw, olive stone, maize cob, etc (Blesa and Miranda, 2003; Mayoral and Izquiredo 2001). This work on the effect of *pennisetum purpureum* is aimed at determining the optimum biomass composition for production of bio-coal briquettes. The need to protect our forest, mitigate health hazards faced by the people from the use of fuel woods for cooking, seek for effective agro-waste management, has necessitated this research work.

Experimental

Materials and Methods

Pennisetum purpureum was 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.

Manual briquette machine was fabricated at National Centre for Energy Research and Development, University of Nigeria, Nsukka, Enugu State, Nigeria.

Methods

Preparation of the biomass

Pennisetum purpureum collected was air dried for ten days to reduce the moisture content of the material. The material was 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.

Analyses of the raw materials

Proximate analysis

Moisture content, ash content and volatile matter/fixed carbon were determined using standard methods (Testing and Materials, 1992; Moore and Johnson, 1999).

Determination of calorific value

Calorific value of the material was determined using oxygen bomb calorimeter as described earlier (Moore and Johnson, 1999). The mixture was pelleted with manual pelleting machine into a small cylindrical pellet with a 10cm length of tiny copper wire incorporated inside the pellet in such a way that both ends of the wire extended out. The mass of the pellet was determined using a digital weighing balance. The calorific value was calculated using the following formula.

Calorific value J/g = $^{E\ T\text{-}Q\text{-}VM}$ (2)

Q = L×2.3 (3)

Where M = weight of the sample, T = change in temperature (T_2-T_1), E = A constant 13039.308, L= change in the length of the copper wire.

Metallic ion content was assayed by means of Atomic Absorption spectrophotometer (AAS), model Pye Unicam 969

Determination of total Sulphur content (Eschka method)

1g of the pulverized sample was mixed with 3g of Eschka mixture.(a mixture of magnesium oxide and anhydrous sodium). The mixture was heated to a temperature of 800ºC for one hour and digested. The dissolved sulphate was precipitated as barium sulphate by adding barium chloride. The precipitate was filtered and the amount of sulphur was determined gravimetrically Mangena and Cann (2007).

Formulation of briquette samples

For each grass sample, sets of bio-coal briquettes of different composition were produced by blending the material at different concentrations, 10%, 20%, 30% and 50% with the coal. Also, biomass briquettes of the individual grass samples and coal briquettes of the coal sample were as well produced. The formulation of the briquettes samples are shown in Table 1.

Table 1: Formulation of briquette samples of coal blended with *pennisetum purpureum*.

Briquette sample	Composition of coal (%)	Compostion of *pennisetum purpureum*.(%)
E_{00}	100	0
E_{10}	90	10
E_{20}	80	20
E_{30}	70	30
E_{40}	60	40
E_{50}	50	50
E_{100}	0	100

The formulation was based on 400g of mixture of biomass and coal, 5% of calcium hydroxide $Ca(OH)_2$ based on the mass of the coal composition in each sample was used as sulphur fixation agent. 10% by mass of starch was used as binder and about 40-50% by mass of water was used.

Preparation of briquette samples

The coal and calcium hydroxide were properly mixed in a container, then the biomass was added and they were thoroughly mixed. The starch was prepared with 100cm^3 of hot water and added. Water was added until a homogenous mixture was obtained. Briquettes of varied biomass concentrations were produced by blending the biomass at various concentrations; 10%, 20%, 30%, 40% and 50% with the coal. Also, pure coal briquette and pure biomass briquettes of the individual biomass samples were equally produced as the control. The pressure was maintained at 5MPa throughout the production.

Characterization of the samples

Moisture content, ash content, calorific value of the briquette samples were determine using standard methods (Testing and Materials, 1992; Montgomery, 1978; Testing and Materials, 1992; Moore and Johnson, 1999). The density, porosity index, compressive strength, ignition time and water boiling test were measure as stated in a number of articles (Nigerian Industrial Standard, 1979; Nigerian Industrial Standard 53, 1979; Eboatu and Garba, 1990).

Results and Discussions

The results of the proximate analysis and elemental compositions of the raw materials are shown in Table 2 and 3.

Table 2: Results of proximate analyses

Sample	Moisture content	Ash content(%)	Volatile matter (%)	Fixed carbon (%)	Calorific value(kJ/g)
Coal	7.64	18.27	43.44	30.65	20.64
Pennisetum purpureum	9.26	5.18	70.10	15.46	14.66

From the results, it is clearly shown that coal sample has higher ash content (18.27%), fixed carbon (30.65%) and calorific value(20.64kg/J) than the p*ennisetum purpureum* but lower moisture content (7.64%) and volatile matter (43.44%). The higher calorific value of coal shows that it will release more heat during combustion than the p*ennisetum purpureum* while on the other hand p*ennisetum purpureum* ignites easily and burns faster than coal because of their higher volatile matter. The higher ash content of the coal indicates that it contains more minerals (non combustible matters) than the p*ennisetum purpureum,* the higher ash content will influence the amount of ash generated by the bio-coal briquette. Table 3 shows the results of elemental composition of the raw materials

Table 3: Elemental composition of the raw materials

Material	Zn	Mg	B	K	Al	Fe	Sb	Sn	S
Coal (%)	0.15	.025	ND	0.08	ND	0.32	0.003	0.14	0.82
Elephant grass (%)	0.07	0.10	ND	0.03	0.30	0.61	ND	ND	0.20

ND= Not detected

The results of the elemental composition of coal showed the presence of Zn, Mg, Fe, Sb, Sn and S, while Fe occurred in highest concentration (0.32%) and Sb has the least concentration (0.003%). The presence of B and Al were not detected. The biomass samples analyzed contained Zn, Mg, K, Al, Fe and S, while B, Sb and Sn were not detected. The effect of concentration of p*ennisetum purpureum* on the physico-mechanical and combustion properties of coal briquette samples were studied and summarized in Table 4.

Table 4: Results of physico- mechanical and combustion properties of briquette samples

Sample	Moisture Content (%)	Ash Content (%)	Density (g/cm^3)	Porosity	Compressive Strength (N/mm^2)	Caloific Value (kJ/g)	Ignition Time (sec)	Specific Fuel Consumption (g/l)	Water Boiling Time (min.)
E_{00}	7.00	23.01	0.804	0.560	0.92	20.39	186.00	460.00	1.57
E_{10}	7.00	20.50	0.698	0.850	1.09	19.54	180.00	378.40	2.58
E_{20}	7.00	18.49	0.658	0.930	2.93	19.82	138.00	335.20	2.54
E_{30}	7.00	17.53	0.583	0.170	3.85	19.38	78.60	330.00	2.80
E_{40}	7.50	16.00	0.537	1.480	6.78	18.67	60.00	230.33	2.92
E_{50}	8.00	15.22	0.491	1.550	7.45	18.53	33.00	202.50	3.04
E_{100}	8.00	4.35	0.319	3.860	3.50	15.98	19.20	280.64	3.65

The results in Table 4 show that there was a progressive decrease in the ash content as the biomass increases, since coal has higher ash content than the biomass as seen in the results of the proximate analysis of the materials. It is obvious that decreasing the coal contents and increasing the biomass will result in a decrease in the ash content, coupled with the fact that the quantity of $Ca(OH)_2$ used as desulphurizer decreases with decrease in coal content. Briquette with E_{00} has the highest (23.01%) ash content while E_{100} has the least(4.35%) ash content. Lower ash content is advantageous, excess ash constitutes nuisance during burning and the ash is capable of blocking air from penetrating the stove thereby retarding the burning rate of such briquette unless the stove should often be shaken to clear the ash during cooking.

Porosity index increases with biomass concentration, while the bulk density decreases in that order. Biomass is a fibrous material and also its particle sizes after pulverization were relatively higher than that of coal. These two factors made it more porous than coal, therefore, it is expected that increasing its concentration in the briquette will increase the number of voids in the matrix hence increasing the porosity. The increase in compressive strength as the biomass increases is attributed to biomass nature and its ability to reduce the brittleness of the briquette and this effect reach saturated point at the biomass concentration of 50%, beyond this composition the compressive strength starts to drop.

From the results, the optimum biomass concentration that improves the calorific value of the bio-coal briquette samples is 20%. Furthermore, it is evident that the ignition time of briquette decreases with increase in the biomass concentration. The coal E_{00} took the longest time to ignite, 186.00secs. The reason may be attributed to the fact that the biomass contains more volatile matter than the coal. The results of water boiling test carried out indicate that the burning rate increases with increase in biomass concentration. It is observed that some of the factors that control the burning rate of a material are chemical composition and geometry. Biomass contains more volatile matter than the coal and it is porous which allows for easy infiltration of oxygen and flow of combustion products. The results showed that the time required for briquettes to boil an equal volume of water decreases with increase in the biomass concentration and reached maximum at 50% and starts to rise at 100%. The Specific fuel consumption (SFC) 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% and at 100% it starts to increase.

Conclusion

Bio-coal briquette using elephant grass is very effective. The briquette samples produced provide sufficient heat, ignite easily, generates less smoke and dust and can be transported and stored easily. These properties were improved progressively with increase in biomass concentration up to 50%. For calorific value, the optimum biomass concentration was 20% but for domestic cooking bio- coal briquette consisting of 50% coal and 50% biomass is shown to be most efficient. Moreover, using agricultural waste for improving the properties of coal briquette will not only solve the problem of environmental degradation caused by burning of such waste but will also provide a cleaner fuel for domestic cooking compared to the conventional coal briquette.

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