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Production of blended biomass/coal briquettes for domestic energy used

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Abstract

The use of firewood and fossil fuel has led to deforestation and an increase in greenhouse gases which carbon dioxide is considered to be one of the major causes. Thus, this has been responsible for the urgent need for studies on a renewable and sustainable source of fuel energy that can solve this energy problem coupled with the high demand for energy. This research was intended to produce a blend of biomass/coal briquettes that will be utilized for domestic energy. Smokeless briquettes were produced from coal and rice husk under low-pressure densification using a manually fabricated hydraulic jack. The following ratio of coal to rice husks 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, and 10:90 was produced. Starch was used as the binder, while calcium hydroxide [Ca $(OH)_2$] was used as a fixation agent. Proximate analyses of raw coal and rice husk were carried out. Coal indicated fixed carbon (25.16 %,), volatile matter (58.11 %,) ash content (8.08%), moisture content (8.64 %) and calorific value (24.69MJ/Kg). Rice husk fixed carbon (70.37 %), volatile matter (5.46 %), ash content (16.58 %), moisture content (7.59 %) and calorific value (16.84MJ/Kg). This study indicate that biomass/coal briquettes are potential candidates for domestic energy use.

Keywords: Coal, Biomass, Rice husk, Briquettes

1. Introduction

Energy is a basic need for human consumption. The demand for energy has posed a serious challenge amidst the fast-growing population, coupled with the scarcity of firewood, kerosene and the high cost of Liquefied Petroleum Gas (LPG). This has forced people to use any available fuel energy that can solve their energy needs.

The use of firewood and fossil fuel has led to deforestation and an increase in greenhouse gases which carbon dioxide is considered to be one of the major causes. Thus, this has been responsible for the urgent need for studies on a renewable and sustainable source of fuel energy that can solve this energy problem coupled with the high demand for energy.

Researchers have explored the use of Agro waste as a source of fuel energy in form of briquette and found it to be a proven way to generate energy from waste material [1]. Biomass, particularly agriculture residues seem to be the most promising energy resources for developing countries [2]. The history of briquette dates back to 1897 when charcoal briquette was produced by Ellsworth B. A Zwoyer. It became popular because of its high demand at that time for barbecuing [3]. During the second worldwar, briquettes were used and found to be a valuable source of fuel energy due to their clean-burning nature and could be stored for a long time without degradation [4].

Briquettes are produced through the compaction under pressure, of loose materials (e.g charcoal dust, wood, corn cob, rice husk, coal etc) to reduce the volume and agglomerate the material so that the product remains in a compressed state [5].

Coal as raw material is the most affordable and widely distributed fossil fuel in the world with estimated reserves at 990 billion tons. Nigerian coal is estimated to be 2 billion tons [6, 7]. Coal has been found to be suitable for use in domestic heating and briquette making [7]. Rice husk is the membranous outer covering of the rice. Quantitatively it is the largest by-product of rice milling industry and constitutes one-fifth of paddy on dry weight bases [8].

Both coal and rice husk cannot be effectively utilized for energy conversion in their natural forms due to their uneven form, low density, high moisture content, problem in transportation, handling and storage. According to Efoma and Gbabo (2015) [8], transforming loose materials into briquettes is an effective way to solve these problems and contribute towards the alleviation of energy shortage and environmental degradation. For loose material to be used effectively, physicochemical characterization of the raw material (proximate and ultimate analysis) to determine parameters such as moisture content, heating value, and volatile matter among others will indicate both the positive and negative nature of the raw material. Therefore, this research work focused on investigating the potential of producing blended biomass/coal briquettes using manual Presses Densification.

2. Materials and Methods

2.1 Materials

The coal was obtained from Akunza, rice husk from rice mill factory and cassava starch from Lafia market in Lafia Local Government Area of Nasarawa State, Nigeria.

2.2 Methods

About 200 g of coal samples were collected and pulverised using a chisel and hammer and taken to the laboratory in plastic bags. Also, 200 g of rice husks were obtained, mixed with the coal and pounded with a pestle and mortar into a powder of particle size 60 mesh to obtain a homogeneous mixture for analysis [9].

2.3 Characterization of the Coal and Rice Husk

2.3.1 Determination of Moisture Content

The method described by Ryemshak *et al*., (2015) [10] was adopted in the determination of the moisture content of the coal and rice husk. Briefly, a porcelain crucible was pre-heated in an oven at 110 ºC for an hour, removed and allowed to cool in a desiccator. About 1.00 g of coal sample was weighed in the crucible and heated to 110 ºC for an hour in an oven, then removed and allowed to cool. The loss in weight was taken as the moisture content and calculated as:

$$\text{Moisture Content (\%)} = \frac{\textit{Weight loss due to moisture}}{\textit{Initial weight of the coal sample}} \times 100$$

2.3.2 Determination of Volatile Matter

The standard volatile matter crucible was pre-heated in a muffle furnace at 900 ºC for seven minutes, cooled in a desiccator and re-weighed. About 1.00 g of coal sample was weighed into the crucible and three drops of benzene were added. This was then heated in a furnace at 900 ºC for seven minutes with the lid on. The loss in weight is the volatile matter of the Coal sample which was calculated thus:

$$\text{Volatile Matter (\%)} = \frac{\text{Weight loss due to volatile}}{\text{Initial weight of the coal sample}} \times 100$$

2.3.3 Determination of Ash Content

The crucible was pre-heated in a muffle furnace for one hour at 825 ºC. it was cooled in the desiccator and re-weighed. About 1.00 g of coal sample was put into the crucible and heated in the muffle furnace (without lid) for one hour at 825 ºC, it was removed and allowed to cool in the desiccator and re-weighed. The incombustible residue constitutes the ash content which was calculated as follows:

$$\text{Ash Content (\%)} = \frac{\textit{Weight loss due to combustible constituents}}{\textit{Initial weight of the coal sample}} \times 100$$

2.3.4 Determination of Fixed Carbon

Fixed carbon was determined according to ASTM D5142 by subtracting the percentages of moisture, volatile matter and ash from the original mass of the sample [11].

Fixed Carbon (%) = *100 – (% moisture + % volatile matter + % ash)*

2.3.5 Determination of Calorific Value

About 1.00 g of coal sample was put in the crucible with fused wire tied across at two ends and carefully put into the bomb calorimeter. Oxygen gas was introduced into the bomb at a pressure of 540 Psi and placed in combustion chambers containing 200 mL of distilled water. The chamber was closed and a stirrer was put on to ensure a homogenous temperature in the chamber. The electronic thermometer measured the difference in water temperature between the pre-fire and the post-fire regime during the combustion of the sample in a bomb, the result was processed and displayed on the screen [10].

2.3.6 Determination of the Elemental Composition of Coal Using X-Ray Fluorescence (XRF)

About 2.00 g of coal ash was placed in a crucible and taken to a furnace and heated for 30 minutes at 970 ºC to remove moisture and other impurities, it was allowed to cool and 1.00 g of the coal sample was weighed again in a platinum crucible. About eight (8) small spoons of X-ray flux crystals containing 80 % lithium tetra borate, and 20 % lithium metaborate were mixed together with 1 cm^3 lithium bromated solution in a platinum crucible, crucible with the content and an empty platinum mould was placed closely in XRF burner or fusion machine (XRF Scientific VFD4000).

Oxygen Acetylene and compressor sources were connected to the machine at 4 bar 0.8 bar and 6 bar pressure respectively. The compressor bottle nozzle was opened so that water contaminants were removed, and then, the XRF burner was switched and regulated so as to make the fused beat within 15 minutes. Crucible content was drained into the oppositely placed platinum mould automatically after frequent shaking by the machine and cooling was performed immediately after 10 minutes.

The fused glass coal sample that was made from the burner was later removed and placed in an XRF detector machine which automatically detect the compositions of the sample metallic oxides on the computer screen attached to the machine when the machine was programmed as a reference curve [12].

Note: The above was repeated for the rice husk.

2.4 Production of Blended Biomass/Coal Briquette

2.4.1 Preparation of the Biomass Sample

The biomass (rice husk) was collected from a rice mill in Lafia Local Government of Nasarawa State, Nigeria. It was air-dried for three days to reduce the moisture content of the materials. The rice husk was pulverized using mortar and pestle and sieved using a 200-micron sieve [13].

2.4.2 Preparation of the Coal Sample

The Coal sample was sun-dried for two days to reduce moisture content. It was pulverized using mortar and pestle and sieved using a 200-micron sieve and kept in polyethylene bag [13].

2.4.3 Calcinations of Coal and Biomass
The coal and rice husk samples were measured and 500.00 g of each dried sample was treated thermo-chemically in the absence of oxygen. The dried samples were put in the crucible and placed in an oven at a temperature of 200-300 ºC for about an hour. The samples were transferred into a silver plate to reduce the temperature and avoid further combustion. The coal and rice husk partially decomposed and gave off volatiles while the solids that remained were the final product which made the feedstock favourable to combustion and gasification [14].

2.4.4 Preparation of the Starch as a Binder
Cassava tubers were collected, washed properly and peeled, then grounded and pressed to extract the liquid content. The liquid content was filtered and the filtrate was allowed to stand for three hours so that the starch will settle from the mixture then the upper liquid layer was carefully decanted.

The starch was sun-dried for four days to reduce moisture content [15]. The starch powder was made into a paste and a measured volume of hot boiling water was added to it while stirring to ensure the solute disperse in the water for homogeneity of the gel [16].

2.4.5 Preparation of Ca (OH)$_2$ (fixation agent)
Calcium hydroxide is a chemical compound Ca (OH)$_2$, also called slake lime is a powder or colourless crystal. Commercially produced when calcium oxide (CaO) (also known as quicklime) is mixed with water. This process is known as slaking of lime.

$$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(S)}$$ [17].

A specified amount of calcium oxide was weighed.

2.4.6 Coal-rice husk briquette formulation
The coal-rice husk briquettes were formulated using different ratios of coal and rice husk. The ratio of coal to rice husk were: 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, and 10:90. The quantity of binder was 10.00 g.

Table 1: Coal –Rice Husk Briquette Formulation

Ratio of Coal to Rice Husk	Coal (g)	Rice Husk (g)	Starch (binder) (g)	Water (mL)
90:10	599.4	33.3	10.00	250.00
80:20	532.8	66.6	10.00	250.00
70:30	466:2	99.9	10.00	250.00
60:40	399.6	133.2	10.00	250.00
50:50	333	166.5	10.00	250.00
40:60	266.4	199.8	10.00	250.00
30:70	199.8	233.1	10.00	250.00
20:80	133.2	266.4	10.00	250.00
10:90	66.6	299.7	10.00	250.00

A specified amount of coal, rice husk, Ca (OH)$_2$ and starch were weighed using a weighing balance into a 500.00 mL plastic basin. Coal, rice husk and starch gel were thoroughly mixed to make a paste that can agglomerate. The starch gel was prepared using 250.00 mL of hot water.

The locally fabricated briquetting mould of the hydraulic press briquette moulder (Fig 1) was filled with the weighed mixture. The lid of the moulder was closed and the mixture was briquetted by applying pressure on the hydraulic jack. The action moves the movable part of the mould up to the immovable part, the lid, causing the mixture in the mould to be compressed and agglomerate into a briquette. This was done for all the samples. The briquette was dried for two weeks to reduce moisture content using a solar dryer [13].

2.5 Locally Fabricated Hydraulic Press Briquette Moulder
The hydraulic press consists of a mould 11 cm by 3.5 cm in length and breadth with lid that open and close fitted on a metal stand and fasten to the ground. Inside the mould is a movable piston attached to a metal rod 60 cm in form of a lever connected to a fulcrum. From the fulcrum is a metal rod 1.5 m in form of another lever that is mechanically used to move the mass of the briquette upward as pressure is applied.

Fig 1: Locally Fabricated Hydraulic Press Briquette Moulder

Fig 2: Samples of Briquettes Produced

3. Result and Discussion
The results for the characterisation of the coal and rice husk are shown in Table 2. The low moisture content of coal as shown in Table 2 is associated with the maturity of the coal. Matured coal has low inherent moisture compared to less matured coal [18]. (Neksumi *et al.*,2018) [19] mention that coal with low moisture content is an indication of good quality.

The moisture content of the rice husk as shown on the tablet was 7.59 %. The low moisture content observed for the rice husk is due to the presence of rice grain which promotes protein denaturation and fibre solubility during briquette production [20]. The low moisture content of coal and rice husk will promote thermal efficiency in the briquette and help in preventing the decomposition of the briquette. Imeh *et al*, (2017) [20] has mentioned that is not desirable because high moisture content reduces its binding strength. Also, High moisture content causes slow ignition problems and incomplete combustion in briquettes [21].

The ash content for coal and rice husk as shown in the Table is 8.08 and 16.58 respectively. The result indicated low ash content for both even though that of rice husk is slightly higher. It has been reported by brian *et al.*, (2018) [18] that coals with low ash content are matured coal because high ash content affects the performance of coal and may also emit metal when combusted [9].

Table 2 shows that the fixed carbon of coal and rice husk is 25.16% and 70.03 % respectively. The low fixed carbon in coal is due to the high volatile matter as can be seen in Table 2. This is a result of the presence of low-boiling organic and mineral matter [18]. The high fixed carbon of the rice husk is an indication that the blended briquette will be a good source of energy. Fixed carbon determined the heating value and coke yield of coal [6]. Increasing the ratio of biomass (rice husk) will also increase the combustion property of the briquette.

Table 2: Characterization of Coal and Rice Husk

S/N	Parameter	Coal	Rice Husk
1	Fixed Carbon (%)	25.16	70.37
2	Volatile Matter (%)	58.11	5.48
3	Ash Content (%)	8.08	16.58
4	Moisture Content (%)	8.64	7.59
5	Calorific Value (MJ/Kg)	24,687	16,837

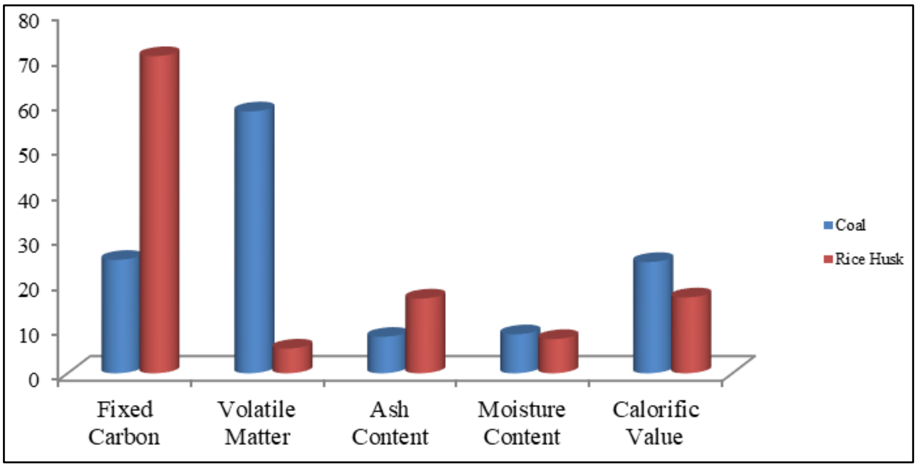

Fig 3: Characterisation Value of Rice Husk Constituents against Coal

Table 2 indicated a high volatile matter for the coal and as earlier stated, this is due to the presence of low boiling organic and mineral matter [18]. Volatile matter determines the rank of coal, soft coal has high volatile matter [14]. Akunza coal is sub-bituminous in nature because of its high volatile matter. Rice husk on the other hand has low volatile matter and high fixed carbon as indicated in Table 2. It is an indication that the blend could be utilized for domestic energy.

Nyakuma *et al.*, (2021) [6] stated that calorific value could be used to estimate the rank of coal, classification and suitability for various uses, and also determines the amount of heat energy of the coal. The coal calorific value is 24.69 MJ/Kg, by this, it is sub-bituminous in nature. Rice husk has a calorific value of 16.84 MJ/Kg. This shows that the two can be effectively used to make briquettes for domestic energy use.

The result of energy dispersive x-ray fluorescence analysis of the sample indicated in Table 3 has shown that coal contains heavy metals in the form of compounds or oxides.

Table 3: Chemical Analysis (ED – XRF) of Coal Sample

S/N	Chemical oxides	Amount in ash (%)
1	Al_2O_3	1.60
2	SiO_2	5.90
3	P_2O_5	0.36
4	SO_3	16.10
5	K_2O	0.12
6	CaO	11.20
7	TiO_2	1.60
8	V_2O_5	0.06
9	Cr_2O_3	0.17
10	MnO	1.10
11	Fe_2O_3	42.48
12	NiO	0.04
13	CuO	0.29
14	ZnO	ND

15	SrO	0.59
16	ZrO_2	0.14
17	BaO	0.40
18	Y_2O_3	0.22
19	WO_3	0,08
20	Au	0.003
21	PbO	ND

4. Conclusion
A blended biomass/coal briquette for domestic energy use was produced. The low moisture content of the coal and the rice husk makes it a potential candidate for the production of briquette. Also, the low ash content of the coal indicates that the coal is a matured coal as this will limit the emission of metals during combustion. Similarly, the high fixation carbon value of the rice husk means that the rice husk will be a good source of energy. The calorific values also indicated that the coal and rice husk can be blended for domestic energy. The results show that blended biomass/coal briquette can offer a solution to the energy problem amidst the growing population coupled with the scarcity of firewood, kerosene and the high cost of Liquefied Petroleum Gas (LPG).

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