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Characterization of Briquettes Produced from Blended Biomass/Coal for Domestic Energy Used

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A B S T R A C T

This work focused on the characterisation of briquettes produced from a blend of biomass/coal that will be utilized for domestic energy. Using a manually fabricated hydraulic jack, smokeless briquettes were produced from coal and rice husk under low-pressure densification. The following ratio of coal to rice husk 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. The briquette produced was dried for two weeks using solar energy and subjected to analyses to determine the quality of the fuel energy. The ignition time, burning rate, water boiling test, firewood water boiling test, water resistance, density, compressive strength and calorific value were analysed for the various ratios. The energy value fall within the range of (18.07MJ/Kg- 22.65MJ/Kg) if compare to other fuel energy source such as sub-bituminous coal (20.000-24.73MJ/Kg) shows the blended briquette could be used as reliable and affordable sustaining fuel energy for domestic use.

Keywords: coal; biomass; rice husk; briquettes

1. Introduction

Millions of households in Nigeria rely on the traditional use of firewood for their daily cooking needs. In spite of the fact that smoke from cooking fires causes over 95,000 deaths in Nigeria annually, this practice has persisted. After malaria and HIV/AIDS in Nigeria, it is the third biggest killer. The majority of poor families using three-stone fire spend much of their hours collecting wood; while others spend their food budgets on wood and charcoal. The cost of cooking for the poor has raise due to inefficiency in the combustion of wood which contributes to a high level of deforestation. About 2.3% of Nigeria's forest reserves have been lost between 1990 and 2010.

Nasirudeen *et al.*, (2022) mentioned that the most promising energy resource for developing countries is biomass. Coal and coal derivatives such as smokeless coal briquettes, bio-coal briquettes and biomass briquettes have been shown to have the highest potential for use as a suitable alternative to coal/fuel wood in industrial boilers and brick kilns for thermal application and domestic purposes. Global warming has become an international concern.

Briquetting is a high-pressure process that can be carried out at high temperatures or low temperatures based on the technology applied. In some briquette techniques, the materials are compressed without the addition of adhesive substances to improve the strength (binder-less briquette), while some are compressed at low temperatures with the addition of adhesive called binder to improve the properties and strength of the briquette. The purpose of briquetting is to convert cheap waste material into compact lump fuel that can have a satisfactory combustion effect. The present work reports the production of briquettes from blended biomass/coal for domestic energy use.

2 Materials and Methods

2.1. Materials

The coal was obtained from Akunza, rice husk from a rice mill factory in Lafia 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 according to the methods described elsewhere. Also, 200 g of rice husks were obtained, mixed with the coal and pounded with a pestle and mortar into a power of particle size 60 mesh to obtain a homogeneous mixture for analysis.

2.3 Production of Blended Biomass/Coal Briquette

2.3.1. 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.

2.3.2. Preparation of 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.

2.3.3. Calcinations of Coal and Biomass

The coal and rice husk samples were measured and 500 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 ^{0}C 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.

2.3.4. Preparation of the Starch as 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. 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.

2.3.5. 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.

$CaO_{(g)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(S)}$. A specified amount of calcium oxide was weighed.

2.3.6. 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 was: 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 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	250
80:20	532.8	66.6	10	250
70:30	466:2	99.9	10	250
60:40	399.6	133.2	10	250
50:50	333	166.5	10	250
40:60	266.4	199.8	10	250
30:70	199.8	233.1	10	250
20:80	133.2	266.4	10	250
10:90	66.6	299.7	10	250

A specified amount of coal, rice husk, Ca $(OH)_2$ and starch were weighed using a weighing balance into a 500 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 mL of hot water.

The locally fabricated briquetting mould of hydraulic press briquette moulder 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.

2.3.7. Locally Fabricated Hydraulic Press Briquette Moulder

The hydraulic press consists of a mould 11 cm by 3.5 cm in length and breadth with a lid that opens 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 the form of a lever connected to a fulcrum. From the fulcrum is a metal rod 1.5 m in the form of another lever that is mechanically used to move the mass of the briquette upward as pressure is applied.

Plate 1: Locally Fabricated Hydraulic Press Briquette Moulder

Plate 2: Samples of Briquettes Produced

2.4. Characterization of Biomass/Coal Blend Briquette Samples

2.4.1. Ignition

About 100 g of each briquette sample was ignited at the edge of their bases. The time for each briquette sample to start burning was recorded as ignition time using a stopwatch.

2.4.2. Burning rate

This is the time taken for each briquette sample to burn completely to ashes. About 100 g of each briquette sample was ignited at the base and allowed to burn completely to ashes. The time taken for each briquette sample to burn completely was recorded by a stopwatch.

2.4.3. Water boiling test for briquette

This measured the time taken for each briquette sample to boil in an equal volume of water under similar conditions. This was done to compare the cooking efficiency of the briquette. During the process, 200 g of each set of briquettes was used to boil 250 mL of water using small stainless cups and a fabricated domestic stove. The temperature reading was taken after every two minutes with mercury in a glass thermometer until the water started to boil. The time taken for each sample to boil was recorded by a stopwatch.

2.4.4. Water boiling test for firewood

The water boiling test for firewood was performed to compare the cooking efficiency of firewood with the briquettes. During the process, 200 g of firewood was used to boil 250 mL of water using a small stainless cup and a fabricated domestic stove. The temperature reading was taken every two minutes with mercury in a glass thermometer until the water started to boil. The time taken for each sample to boil was recorded by a stopped clock.

2.4.5. Water resistance test for briquette

The water resistance test was performed on each briquette sample according to the procedure described by (Sunday et al., 2020). A digital weighing balance was used to measure the initial weight of each briquette sample. About 100 g of each briquette sample was weighed and immersed in water for two minutes. A stopped watch was used to record the process. The briquettes were measured again and the relative change in weight was recorded. The percentage of water absorbed was calculated using the equation:

$$\% \text{ water absorbed briquette} = \frac{W2-W1 \times 100}{W1}.$$

Where W2 = final weight of briquette after immersion

W1 = initial weight of briquette before immersion.

2.4.6. Compressive strength

The compressive strength of the produced briquette (the maximum crushing load the briquette can withstand before collapse) was performed based on the method described by (Ajimotokan et al., 2019). The test was carried out 21 days after the briquettes were produced. The peak stress (compressive strength) displayed at the end of each test was recorded.

2.4.7. Density

The compressed density was determined immediately after the briquette samples were removed from the mould. The mass and dimension were measured using a digital weighing balance and veneer calliper to determine the density.

The relaxed density of the briquettes was determined 30 days after it was sun-dried. The density *p* of the produced briquette samples was calculated using the equation expressed as follows:

$P = m/v$

Where m = mass of briquette produced

V = volume of briquette produced

The volume will be computed using this equation

$V = \pi h\,(R - r)^2$.

3. Result and Discussion

The results for the characterisation of the briquette are shown in Table 2. The result shows that the Ignition time for a briquette with a higher ratio of rice husk is faster compared to the one with a high coal ratio. Ikelle *et al.,* (2017) have mentioned that biomass improves ignition time for briquettes.

Also, the result showed that briquette blends with high coal ratios take longer to burn, allowing for longer cooking time. Coal briquette combustion can be improved by mixing with biomass.

Table 2 shows the water boiling test which indicates the various time taken for briquette ratios to boil 1 litre of water with 100 g of briquette samples. The result shows that the water boils faster as the biomass ratio increases. The time taken for the briquette samples to cook faster is a function of the volatile matter, calorific and thermal efficiency.

However, firewood on the other hand burns faster than the briquette and boils 1 litre of water within a short time with 100 g of wood. This finding contradicted the findings of Nasirudeen *et al., (*2022), who mentioned that it took longer time for firewood to boil 1 litre of water.

Water resistant test was conducted to find out which category will withstand high humidity, exposure to moisture and will not degenerate on time. The result from Table 5 shows a decrease in water resistance as the ratio of the rice husk increases. This showed that blended biomass briquette lifetime in humid conditions is short, therefore, should be stored in a dry place.

Table 2: The Result of Ignition time Water Boiling Test, Burning Rate, Water resistance

S/N	Briquette Sample	Ignition Time (s)	Burning Rate (s)	Water boiling Test (min)	Water Boiling Test (Wood) (min)	Water Resistant (%)
1	90:10	12.1	252	14.6	1.32	13
2	80:20	11.4	235	13.7	1.92	12.8
3	70:30	11.4	224	12.8	2.56	12.6
4	60:40	9.3	181	12.2	2.88	10
5	50:50	8	155	10.8	3.19	16
6	40:60	7.4	143	9.0	3.51	27
7	30:70	7.2	128	7.0	3.85	25
8	20:80	6.0	119	5.8	4.14	30
9	10:90	4.1	11	5.1	4.44	37

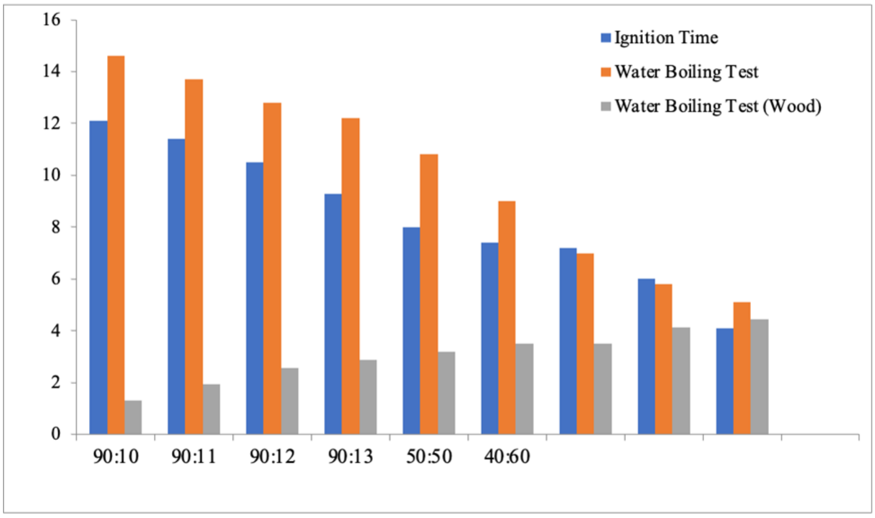

Figure 1: Plot of Ignition Time, Water Boiling Test and Water Boiling Test (Wood) against Ratio of Coal/ Rice Husk Briquette

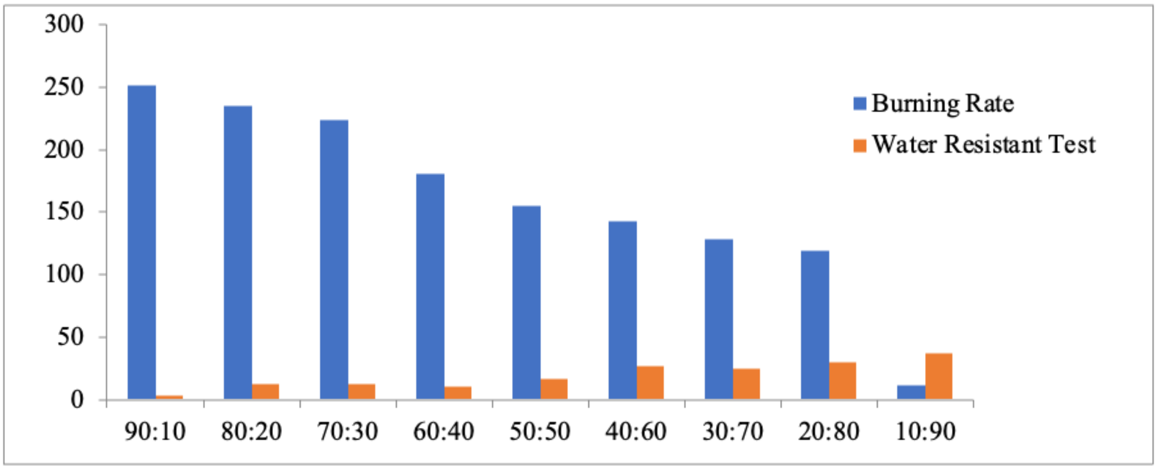

Figure 2: Plot of Burning Rate and Water Resistant against Ratio of Coal/ Rice Husk Briquette

The density of the coal ratios was also observed to decrease with an increased ratio of rice husk. Briquette with more coal ratio is noticed to have high density and more energy ratio.

From the result in Table 3, there is a gradual decrease in the compressive strength as the ratio of the rice husk is increased. This corresponds to the findings of Onuegbe *et al.,* (2011). It has been mentioned that compressive strength is used to test a briquette's ability to be handled, packed and transported.

The result for the calorific values of various ratios is indicated in Table 3. As observed, there is a gradual decrease in the calorific value as the ratio of rice husk increases. Briquettes with a high ratio of coal have high density compared to briquette samples with a high ratio of rice husk, the former has a longer burning time. Briquettes with higher burning times have more energy ratio.

Table 3: Results of Density, Compressive Strength and Calorific Value

Briquette Sample	Density (kg/m^3)	Compressive Strength (N/M^2)	Calorific Value (MJ/kg)
90:10	0.248	14.787	22.649
80:20	0.236	13.965	22.410
70:30	0.229	13.046	22.171
60:40	0.219	9.659	21.961
50:50	0.216	6.272	21.750
40:60	0.212	5.186	21.104
30:70	0.206	4.099	20.457
20:80	0.202	3.118	19.260
10:90	0.193	2.136	18.069

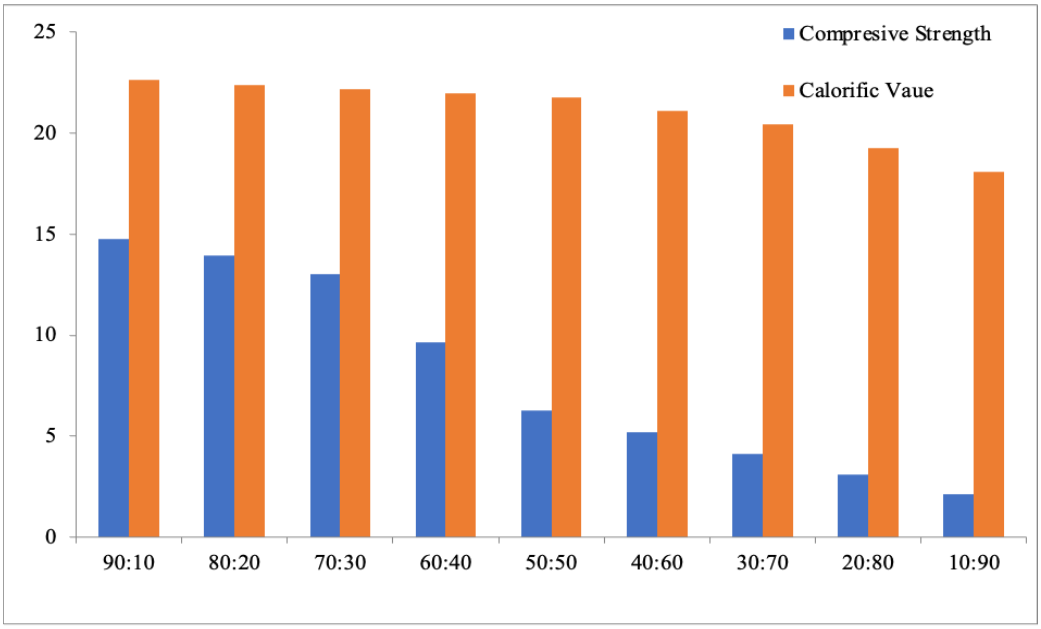

Figure 3: Plot of Compressive Strength and Calorific Value against Ratio of Coal/ Rice Husk Briquette

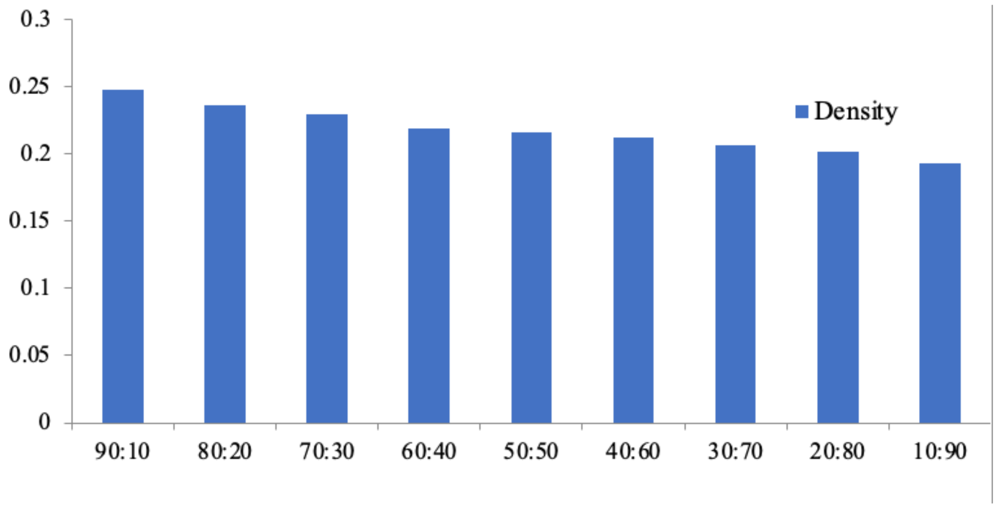

Figure 4: Plot of Density against Ratio of Coal/ Rice Husk Briquette

4. Conclusion

A blend of biomass/coal briquette for domestic energy use was produced and characterised. The result obtained showed that the briquette produced has good thermal properties and presents an attractive option as an energy source because it ignites fast, conserved sufficient heat energy with good calorific value and cooks faster while generating less smoke and gases that are harmful to the environment. Also, the result shows that the thermal efficiency increases as the ratio of biomass increases. The briquette can be transported and stored easily.

From this research, it can be concluded that waste biomass can be converted into solid fuel for energy use, because, the production of briquette is economical, cheap and affordable to rural dwellers and low-income earners. With the increasing energy crisis, and depletion issues coupled with environmental effects, biomass/coal briquette can be an acceptable potential substitute for cooking and other heating processes, due to the fact that Nigeria is rich in large reserves of coal and biomass.

5. Conflicts of Interest

The authors declare no conflict of interest.

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