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Development and Characterization of Agro-Allied Rice Husks and Groundnut Shell Waste Briquettes

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ABSTRACT

Briquetting of agro-residues can alleviate some of the problems of energy shortage being encountered world-wide. The briquettes are essentially manufactured to provide cheap energy to the various sectors. Most importantly, to the domestic households that are finding it difficult to purchase the other sources of energy because of their cost. In this research the briquettes were produced in a briquetting screw press – BSP, using a manually operated piston and cylindrical shape Mould. The individual materials were mixed thoroughly in a ratio of rice husk: groundnut shell (RH:GS) as follows: 100:00; 70:30; 50:50; 30:70; and 00:100. A fixed quantity of each mixture were separately hand-fed into a manually operated closed-end piston press to compact the briquettes. Thereafter, the briquettes were ejected and placed on drying racks and left in the sun for drying. The moisture content, ash content, volatile matter, fixed carbon, ignition time, flame propagation time, calorific value and water boiling test were investigated to determine the physical and thermal properties of the briquettes produced. The results of the investigation showed that moisture content of the briquettes ranged from 3.96 – 5.65%, the calorific value ranges from 130, 63.56 – 141, 62.87 kJ/kg, the range of ash content is 6.10 - 9.32 %, for fixed carbon is 7.67 - 20.20 %, the ignition time ranges from 238-270 sec and the ranges for water boiling test time is 10.57m, – 13.37m. These values satisfactorily compare well with values obtained by other researchers in the literature. Therefore, the rice husk - groundnut shell briquettes are good alternative source of thermal energy for cooking. It is an economical and also an environmental friendly source of energy and waste disposal.

Keywords: Briquette, Rice Husk, Groundnut Shell, Agro-residues, Energy.

1. INTRODUCTION

Wood in form of fuel wood, twigs and charcoal has been the major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption. The other sources of energy include natural gas 5.2%, hydroelectricity 3.1%, and petroleum products 41.3% [1]. As searches are conducted for a way out of future possible global energy crisis resulting from total exhaustion of conventional energy resources and global warming due to high carbon emission, decreasing availability of fuel wood and menace of desertification and deforestation drew our attention to the need to consider alternative sources of energy for domestic and cottage level industrial use. Such energy sources should be renewable and also should be accessible to low income class of society.

Biomass in form of agricultural waste can play a significant role in alternative energy generation and utilization. Briquetting of agro-residues can alleviate some of the problems of energy shortage being encountered world-wide. By general definition biomass is the organic matter in trees, agricultural crops, living organisms, human, plants materials and organic compounds used to produce heat or to generate electricity [2]. In a simpler term biomass is a plant materials and animal waste used as fuel or to generate electricity e.g. groundnut shell, coconut shell, rice husk, corn cob etc. [3] and [4] described briquetting as a process of compaction of residues into a product of higher density than the original material. Briquetting can be done with or without a binder. Doing without the binder is more convenient but it requires sophisticated and costly presses and drying equipment which makes such processes unsuitable in a developing country like Nigeria. In Nigeria, large quantities of agricultural and forestry residues produced annually are vastly under-utilized [1]. The common practice is to burn these residues or leave them in the nature to decompose. However, previous studies by [4] and [5] have shown that these residues could be processed into upgraded liquid fuel products such as briquettes. Briquette is an easy way to agricultural waste removal from the environment. The use of briquette will greatly reduce the falling of trees and prevent problems like soil erosion and desertification by providing an alternative to burning wood for heating and cooking. This work investigates briquetting of rice husk and groundnut shells.

2. MATERIALS AND METHOD

All the raw materials (rice husk, groundnut shell and starch) were sourced from Bauchi metropolis, Bauchi State capital. The apparatus and equipment used were screw press briquetting machine (designed and fabricated by the authors), digital weighing balance (NBL-2602e; 0.01g sensitivity), Bunsen burner, stopwatch, meter rule, grinding machine, Sieve, Petri dish, bomb calorimeter (IKA C2000/Kv600) and Plastic basin. The briquettes were produced in a briquetting screw press – BSP, using compaction pressure of 18 MPa and compression times of 60 seconds. The briquette's calorific value was determined in accordance with [6] standard. Moisture content in accordance with [7] standard and the ignition time was determined according to [8] and [9]. The samples for the ignition test were held under a 50 kW/m^2 heat flux for periods of over 10 seconds.

The mean compressed density of the briquettes was determined immediately after removal from the mould as a ratio of measured weight to calculated volume [4]. The weights of produced briquettes were determined using a digital weighing balance, while the average diameters and heights of the briquettes were taken at 2 different positions using calipers to determine the volume. The compressed and relaxed densities of the briquettes were determined at 0 minutes, 30 minutes, 1 hour, 24 hours and 7 days using the die dimensions and [4] standard method of determining densities. Density was determined for each briquette as ratio of briquette weight to volume. The density of briquette was determined immediately after ejection from the mould and this was calculated from the ratio of the mass to the volume of briquette. The relaxed density of the briquettes was determined in the dry condition. Relaxed density can be defined as the density of the briquette obtained after the briquette has remained stable. It is also known as spring-back density. It was calculated simply as the ratio of the briquette's mass to the new volume [10]. Equations (1) and (2) were used to determine the briquette's volume and density.

$$Volume\ of\ the\ Briquette = \frac{\pi(d_2^2 - d_1^2)L}{4} \quad \text{-------------------------------- 1}$$

Where, d_1 = Diameter of the briquette before drying (m)

d_2 = Diameter of the briquette after drying (m)

L = Length of the briquette (m)

$$Density\ of\ the\ Briquette = \frac{initial\ mass\ of\ material}{volume\ of\ cylinder}\ \frac{g}{cm^3} \quad \text{--------------------------------------2}$$

Percentage water resistance capacity of the briquettes when immersed in distilled water at room temperature for 2 minutes was determined and the relative change in weight of the briquettes was measured. Percentage water absorption (PWA) was calculated using the following relationship

$$PWA = \frac{M_i - M_F}{M_i} \quad \text{---------------------------- 3}$$

Where; M_i is the initial weight of briquette before immersion and M_f is the final weight of briquette after immersion.

$$Water\ Resistance\ Capacity\ (WRC)\% = 100 - PWA \quad \text{-------------------------- 4}$$

Volatile matter determination*:* The dried samples of the briquettes left in the crucibles were covered with a lid and placed in an electric furnace maintained at 925°C for seven minutes. The crucibles were first cooled in air, then inside a desiccator and weighed again. Losses in weights were reported as volatile matter on percentage basis [11].

$$Volatile\ Matter\ (VM)\% = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad \text{------------------------- 5}$$

Where, W_1 = weight of empty crucible (g); W_2 = weight of crucible + sample (g); W_3 = weight of crucible + sample after heating (g)

Ash content determination*:* The residual samples in the crucibles were heated without lid in an electric furnace at 700° C for one hour. The crucibles were then taken out, cool first in air then in desiccators and weighed. Heating cooling and weighing was repeated until a constant weight was obtained. The residues were reported as ash on percentage basis [11].

$$Ash\ Content\ (\%) = \frac{W_6 - W_4}{W_5 - W_4} \times 100 \quad \text{------------------------ 6}$$

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Where; W_4 = weight of empty crucible (g); W_5 = weight of crucible + sample (g); and W_6 = weight of crucible + ash (g).

Determination of fixed carbon (FC): [12] reported that the fixed carbon of a fuel is the percentage of carbon available for chart formation during combustion. This was determined using the following relationship;

$$Percentage\ FC = 100 - \%(VM + Ash\ Content) \quad \text{---------------------} \quad 7$$

***2.1* Briquette Production**:

All the residues were sun-dried until stable moisture contents of about 12% was achieved, which is within the acceptable operating limit for briquetting and then stored [13]. A sieve of 1.18 mm was used to obtain uniform grain size distribution for rice husk and groundnut shell particles. 5% by weight of cassava starch in form of gel was used as binder in line with works of [14]. The individual materials were mixed thoroughly in a ratio of rice husk: groundnut shell as follows: 100:00; 70:30; 50:50; 30:70; and 00:100. A fixed quantity of each mixture were separately hand-fed into a manually operated closed-end piston press to compact the briquettes. Thereafter, the briquettes were ejected and placed on drying racks and left in the sun for drying and proximate analysis was carried.

3. RESULTS AND DISCUSSION

3.1 Quality of the Briquette: The quality of the briquettes produced was determined by the calorific value, density, ignition time, moisture content, burning rate, carbon content and ash content.

***3.2 Density of Briquette*:** Briquette density influences the burning of briquettes, the higher the density of a briquette, the longer the burning time and the heat released as briquette density is significantly affected by raw materials particle size and moisture content [15]; [13].

3.3 Compressed and Relaxed Density

The compressed and relaxed density was determined in accordance with the American Society of Agricultural Engineering Standard (ASAE, S269.4.2003) and the result is presented in Table 2. All the briquettes showed promising values of compressed and relaxed densities, but 50:50 (RH:GS) briquette has the highest values of 3387.56kg/m^3, 1573.32kg/m3 and 2.15 for compressed density, relaxed density and relaxation ratio respectively. The density obtained for the produced briquettes in this work compares well with densities of notable biomass fuels such as coconut husk briquette - 630 kg/m3, banana peel - 600 kg/m3, groundnut shell briquette - 524 kg/m3 and melon shell briquette - 561 kg/m3 [4];[3];[16]. The relaxation ratio obtained is also good enough and it is close to the values obtained by [4], where a relaxation ratio of between 1.80 and 2.25 were achieved for briquetting of coconut husk and [16], where values of 1.97 and 1.45 were obtained for groundnut and melon shell briquettes respectively.

Table 2. Compressed Density, Relaxed Density and Relaxation Ratio of the Briquettes

Sample	Mixing Ratio (RH:GS)	Compressed Density (Kg/M3)	Relaxed Density (Kg/M3)	Relaxation Ratio
1	100 : 00	3289.98	1763.09	1.87
2	70 : 30	3198.48	1709.36	1.87
3	50 : 50	3387.56	1573.32	2.15
4	30 : 70	2999.86	1489.86	2.01
5	00 : 100	3098.68	1562.45	1.98

Calorific Value: The implication of high a calorific value is that more thermal energy is released during combustion. The calorific value was determined according to nationally adopted international standard STN ISO 1928 (441352), 2003, Solid fuels: Determination of the combustion heat by a calorimetric method in the pressure tank and calculation of the calorific value [13]. Calorific values were determined by calorimeter C5000 (IKA®-Werke GmbH & Co. KG, Germany). The calorific value of briquettes is one of the most influential factors affecting the burning rate of a briquette. The higher the calorific value, the easier and better burning efficiency. The calorific value obtained for all the samples were presented in Table 4. Furthermore, the calorific value of a briquette depends on the type of biomass materials used in its production. The calorific value of Rice husk and groundnut shell (RH:GS) briquette was in the range of 13146.38 to 14162.87 KJ/kg. RH:GS (100:00) briquettes had a higher Calorific value of 14162.87 KJ/kg. This was also in line with previous researchers [17], who reported calorific values of 2,765 kJ/kg and 17,348 kJ/kg for cassava and yam peels briquettes, respectively, [15] recorded Calorific value in the range of 23.13 to 21.23 MJ/kg for EFL briquettes and [18] reported 20.64 MJ/kg for coal briquette. The reason for this was because Rice husk

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produced less ash content meaning that almost all the content was used during combustion, thereby given off high heat energy content.

Table 3. Calorific Value of the Briquettes.

Sample	Mixing Ratio (RH : GS)	Calorific Value (KJ/Kg)
1	100 : 00	14162.87
2	70 : 30	13892.45
3	50 : 50	13483.76
4	30 : 70	13146.38
5	00 : 100	13063.56

Ignition Time: The mean Ignition time presented in Table 4 shows that the ignition time range between 238 to 270 seconds. Briquette with RH:GS (100:00) recorded a highest flame propagation time of 0.12 cm/sec, this is may be due to the rice husk low moisture content of 4% and high heating value of 14162.87 KJ/kg, while the briquettes from other mixing ratios recorded an average value of flame propagation time of about 0.08 cm/sec. In addition, Table 5 shows that the briquette with RH:GS (70:30) has the longest afterglow time of 270 secs, followed by briquette with mixing ration of (50:50) with an afterglow time of 263 secs while briquette (30:70) has the least afterglow time of 238 sec. The afterglow time and the flame propagation values are good enough and have the implication of that the briquettes will be ignited more easily and burn with intensity for a long time [19].

Table. 4. Mean Ignition time, Flame propagation time and Water boiling time of the briquettes.

Sample	Mixing Ratio (RH : GS)	Mean Ignition Time (S)	Flame Propagation Rate (cm/s)	Water boiling Time (Min)
1	100 : 00	245	0.12	10.57
2	70 : 30	270	0.09	11.23
3	50 : 50	263	0.10	11.77
4	30 : 70	238	0.09	13.37
5	00 : 100	247	0.08	12.98

Moisture Content of Briquette: The moisture content of the briquettes was in the range of 3.82 – 5.65 % dry basis. According to [20], moisture content plays a major role in determining density and strength of the densified biomass. An increase in the moisture content of biomass considerably decreased the pellet density. The result of the dry basis moisture content showed that RH:GS (70: 30) had the lowest moisture content, while RH:GS (30:70) had the highest moisture content of 5.65. This is because the high percentage of rice husk present in RH:GS (70: 30) allowed more compaction thereby eliminating void which could retain some form of moisture within its microstructure [11].

Table 5. Moisture content of the Briquettes.

Sample	Mixing Ratio (RH : GS)	Moisture Content (%)
1	100 : 00	3.96
2	70 : 30	3.82
3	50 : 50	4.60
4	30 : 70	5.65
5	00 : 100	5.41

Volatile Matter and Ash Content: The proximate analysis is shown in Table 6. The table shows that RH:GS (50:50) briquettes had the highest volatile matter of 80.13%. Similar result was obtained by [5]. Ash is an impurity that will not burn and is typically in the range of 5% to 40% [21]. The results showed that as the amount of groundnut shell was increased, the ash content increases in the blend in the range of (6.10 - 9.32 %). [12] reported that the higher the fuel's ash content, the lower the calorific value. The Table 6 showed that the hybrid briquettes produces from the blends of rice husk and groundnut shell resulted in producing briquettes with less fixed carbon content values ranging from 7.67 to 20.20 % and these findings compares favourably with the findings of [12] with 16.77 % for a groundnut shell briquette and 9.1 - 19.68 % for rice husk, sawdust and paper blend briquettes and groundnut shell, sawdust and paper blend briquettes by [22].

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Table 6. Proximate Analyses of Rice husk-groundnut shell Briquettes

Sample	Mixing Ratio (RH : GS)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)
1	100 : 00	69.74	6.10	20.20
2	70 : 30	72.20	6.23	17.75
3	50 : 50	80.13	7.60	7.67
4	30 : 70	78.06	7.63	8.66
5	00 : 100	74.26	9.32	11.01

4. CONCLUSIONS

This study showed that the various combination of materials in different proportions had a significant effect on both the physical and mechanical properties of the briquettes. The findings of this study showed that briquettes from a combination of rice husk and groundnut shell is a good alternative source of thermal energy to fossil fuel and it is an economical and environmental friendly waste disposal method for agro-wastes. Starch showed good potential as a binder and has combustibility characteristics. Briquette production from agro-wastes is cheap source of energy for domestic application.

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