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Density, Shatter index, and Combustion properties of briquettes produced from groundnut shells, rice husks and saw dust of *Daniellia oliveri*

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ABSTRACT

Objective: This study investigated the potential use of sawdust of *Daniellia oliveri (*African Copaiba Balsam Tree), Rice husk and Groundnut shells to make briquettes for energy generation.

Methodology and Result: Doughnut shaped briquettes were produced from three biomass materials at 15%, 25%, and 35% level of starch binder in binary and tertiary combinations. Density, Shatter index and Combustion properties of the briquettes were investigated. The compressed density of *Daniellia oliveri* + Groundnut briquettes was highly significant ($P<0.01$) at 2.32g/cm^3. The relaxed density was highly significant ($P<0.01$) among the biomass materials and binder levels. *Daniellia* + Groundnut briquettes recorded the highest relaxed density of 2.46g/cm^3 at 25% starch binder. *Daniellia* + Groundnut briquettes recorded the highest shatter resistance of 90.4. The specific heat of combustion of briquettes ranged from 4455.0Kcal/kg to 4734.0Kcal/kg.

Conclusion and Application of Results: The relative high heating values of the briquettes biomass materials indicate that they can be a very good alternative source of energy for domestic cooking. It is therefore recommended that sawdust of *Daniellia oliveri*, Rice husk and Groundnut shells that are usually discarded as waste in Nigeria could be converted to briquettes, which will serve as alternative source of energy for domestic cooking.

INTRODUCTION

Globally, 140 billion metric tons of biomass is generated every year from agriculture. This volume of biomass can be converted to an enormous amount of energy and raw materials (Jekayinfa and Scholz, 2009). Renewable energy sources are been sought for domestic cooking in developing countries because their non-renewable counterpart such as kerosene, LPG, are expensive. In addition, the high cost of non-renewable energy sources has made people to start deviating to the use of renewable energy sources for domestic cooking. The use of biomass fuel such as composite sawdust briquette has been proposed to be a good source of renewable energy for domestic cooking (Kuti and Adegoke 2008). This is because sawdust, i.e., the chief raw material in the production of composite sawdust briquette is readily available in large quantities as wastes in majority of the wood processing industries. It has been proposed that the conversion of sawdust wastes through briquetting process will go a long way in reducing waste disposal problems in majority of the wood processing industries. Furthermore, deforestation, which promotes pollution, will be drastically reduced if the use of sawdust waste is enhanced.

Energy availability in the rural as well as urban areas of Nigeria is fast becoming a great challenge with the high cost of cooking gas and kerosene and environmental problems associated with firewood (Oladeji, 2011a). A large number of waste products (maize, sorghum, and millet stalks; groundnut and maize husks) are generated in rural areas both on the farm and from household activities. Most of these wastes are mainly deposited on the farm or burnt with all the ecological problems associated with their disposal methods (Jekayinfa and Omisakin, 2005; Oladeji, 2011b). However, studies had revealed that, most of these wastes have been found to represent valuable energy (Jekayinfa and Scholz, 2009). The realization that deforestation and wood fuel shortages are likely to become pressing problems in many countries has turned attention to other types of biomass fuel. Agricultural residues are, in principle, one of the most important of these. They arise in large volumes and in the rural areas, which are often subject to some of the worst pressures of wood shortage (Eriksson and Prior 1990). If one or more efficient method of using the abundant agricultural and wood residues could be developed on a large cale, the energy situation could be sustainable and the deforestation problem could be controlled. The lack of capital among most households in the rural communities makes it difficult to move from either firewood or charcoal, to a more advanced energy sources where small initial capital investment can be used. Hence, the substitute of these fuels requires a minimal capital investment, be as cheap and accessible as charcoal and firewood and at the same time, be environmentally sustainable. Hence, the need for briquetting of agricultural residues and sawdust to serve as a cheap and affordable alternative fuel energy for domestic application. The abundantly available agricultural and wood residues can efficiently be used for resolving energy problems to a significant extent by adopting proper measures. Olorunnisola (2002) stated that biomass processing technologies like biomass combustion, gasification and briquetting/pelletizing are in place with potential viable local markets. He affirmed that it was evident that none of these alternatives can compete with the low capital investment that is required in briquetting technology. Several kinds of agricultural residues can be utilized properly by identifying loose residues to produce a compact product of different sizes. Briquetting is essentially a mechanical process requiring investment in equipment and training to ensure a product of reasonable quality that will perform the task for which it is intended. Russell, (1997) considered that briquetting is often seen as a relatively high-cost high-pressure technology, and that it is possible to use a low-cost low-pressure technique to produce acceptable briquettes. For rural communities the most suitable briquetting methods are those, which are based on available waste and building materials.

MATERIALS AND METHODS

Study area: The experimental process of briquette production was done at the Mechanical Engineering and Food Science Technology Laboratories of the Federal University of Agriculture, Makurdi, Benue State of Nigeria. The groundnut shells, rice husk and sawdust of *Daniellia oliveri* were collected in Makurdi area of Benue state where the materials are produced in large quantities. Groundnut shells were air-dried and ground using a grinding machine. The three-biomass residues were sieved to uniform sizes of 1.71mm, labelled and stored for briquetting.

Binder ratio: Cassava starch was used as binder for the briquettes. Three starch ratios notably 15%, 25%, 35% of the weight of sample as conducted by Sotannde *et al*. (2010) was used to determine the effect of binder concentration on physical and chemical characteristics of briquettes produced from groundnut shells, rice husk and *Daniellia oliveri* biomass materials.

Briquette production and quality evaluation: Groundnut shells, rice husk and sawdust of *Daniella oliveri* were used to produce briquettes at binary and tertiary combinations using doughnut shaped moulds. One hundred (100g) of dried ground and uniformly sieved sampled was mixed with cassava starch until a uniform mixture was obtained. The proportions of sample: binder ratio was 100:15; 100:25, 100:35 (Sotannde, *et al*. 2010).The sample-binder mixture was hand-fed into the steel mould for doughnut briquettes and covered at both ends with the disk. The sample – binder mix inside mould was then placed under the hydraulic press and compacted at the pressure of 10.70kg.cm-2, and kept under pressure for duel time of 5 minutes. At each level of binder, 15 replicates were produced. The diameter of the briquettes was thereafter taken at two different points with aid of digital callipers while the weight and thickness was recorded immediately. The briquettes were produced at binary and tertiary combinations using Groundnut shells Rice husk and *Daniellia oliveri* in equal proportion of mixtures as used by Tembe, *et al.* (2011) on briquettes produced from groundnut shells and rice husk as follows:

- Groundnut shells and Rice husk; 50:50.
- Groundnut shells and *Daniellia oliveri;* 50:50.
- Groundnut shells, Rice husk and *Daniellia oliveri* 33.3: 33.3: 33.3.

Determination of physical properties:

Density: Three briquettes were randomly selected from each production batch for evaluation of physical properties. The mean compressed density of the briquettes was determined immediately after removal from the mould as a ratio of measured weight to calculated volume (Olorunnisola, 2007). 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 callipers to determine the volume. The volume of the doughnut shaped briquettes was determined by subtracting the outer volume from the inner volume to obtain the actual volume of the briquettes. 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 ASTM, (2004) standard method of determining densities. Density was determined for each briquette as ratio of briquette weight to volume.

$$\text{Density} = \frac{\text{Weight of Briquettes}}{\text{Volume of briquette}}$$

Shattered Index: The durability of the briquettes was determined in accordance with the Shattered index described by Suparin *et al*. (2008).This involved dropping the briquette samples repeatedly from a specific height of 1.5m onto a solid base. The fraction of the briquette retained was used as an index of briquette breakability. The percentage weight loss of briquettes was expressed as a percentage of the initial mass of the material remaining on the solid base, while the shatter resistance was obtained by subtracting the percentage weight loss from 100 (Ghorpade, 2006 and Sengar, *et al*. 2012),

$$\text{Percentage weight loss} = \frac{\text{Initial weight before shatter – Weight of shattering}}{\text{Initial weight of briquette before shattering}}$$

Shatter resistance = 100 - Percentage weight loss

Combustion properties determination: The following combustion properties were used to determine the suitability of briquettes as cooking fuels, the combustion properties include the percentage Ash content, percentage Volatile matter, percentage fixed carbon, the heating value and % moisture content.

Percentage Moisture Content (% MC): Percentage MC was determined by measuring 2g of pulverized briquettes into a crucible (w1). The content was dried in an over at 110^{0}C -120^{0}C for 2hrs to obtain over dry weight (w2). Moisture Content was then calculated according to Davies and Abolude (2013) as:

$$\%MC = \frac{\text{Initial weight } (w_1) - \text{Dry weight } (w_2)}{\text{Initial weight } (w_1)} \times 100$$

Volatile matter (% Vm): Percentage Volatile matter was determined keeping the substance in crucible with oven dry weight (w2) in the furnace for 10mins at 400^{0}c to obtain weight (w3) after which the volatile matter in it have escaped. The method was used by (Emerhi, 2011). This was used in calculating percentage volatile matter thus:

$$\%VM = \frac{\text{Oven dry weight } (w_2) - \text{Weight of sample } (w_3)}{\text{Oven dry weight } (w_2)} \times 100$$

Ash content ash): In determination of percentage ash, 2g of oven dried pulverized briquettes were weighed in a crucible (w2), this was placed in the furnace for 3hrs at 600^{0}c to obtain the ash weight (w4). Percentage ash content % Ash contents was calculated as

$$\%Ash = \frac{\text{Weight of ash } (w_4)}{\text{Dry weight } (w_2)} \times 100$$

Fixed carbon (% fc): this was calculated by subtracting the sum of % volatile matter and % ash content from 100. % f c =100%- (% Vm +% Ash)

Specific heat of combustion (HC): Specific heat of combustion (HC) was calculated using the formula (Carre, *et al.* 1981):

HC=0.35[(147.6 x fc) + (144 x vm) +% Ash] Kcal/kg.

The data collected from sample tests were subjected to analysis of variance using the factorial designed in Completely Randomized Design (CRD).

RESULT AND DISCUSSION

Effect of Type of material on Density of briquettes: The type of briquette material had highly significant effect (P<0.01) on compressed density (density immediately after compression at 0 minutes). *Daniellia* + G/nut briquettes recorded the highest compressed density of 2.32g/cm^3 which was significantly higher than *Daniellia* + Rice husk briquettes with compressed density of 2.19g/cm^3 (Table 1). The lowest compressed density of 2.19 g/cm^3 for *Daniellia* + Rice briquettes was higher than 0.92 g/cm^3 obtained by Lensu, (2005) in his work on compacted straw particles. High values of compressed density could be linked to moisture present in the starch, which increased the mass per unit volume of the briquettes. The relaxed density (density at any point of drying from 30 minutes -7 days) was significantly high (P<0.01) for all briquette samples as presented in Table 1. The density values showed a progressive decline from 2.34 g/cm^3 for *Daniellia* + G/nut briquettes at 30 minutes to 1.42 g/cm^3 at 7 days of drying. A similar trend was observed for *Daniellia* + Rice briquettes, which declined from 2.14 g/cm^3 to 1.44g/cm3 at 30 minutes and 7 days respectively (Table 1). However the relaxed density of *Daniellia* + Rice + G/nut briquettes showed a slight increase from 2.13g/cm^3 at 30 minutes to 2.28g/cm^3 at 1 hour before reducing to 1.58g/cm^3 in 7 days (Table 1). The relaxed density of *Daniellia* + Rice + G/nut briquettes was still higher than that of compacted peat at 1.11 – 1.20 g/cm^3 as recorded by Lensu (2005), and higher than Obi, *et al*. (2013) who recorded the relaxed density of 0.7269g/cm^3. The variation in relaxed density from 30 minutes to 7 days of the briquette samples could be linked to the impact of moisture loss, which reduces the mass per unit volume of the briquettes but enhances physical properties of briquettes as reported by Obi, *et al*. (2013).

Table 1: Density of Briquette materials

Sample	0 min	30mins	1hour	24hours	7 days
Daniellia +G/nut	2.32	2.34	2.25	2.01	1.42
Daniellia + Rice	2.19	2.14	2.13	1.78	1.44
Daniellia + Rice+ G/nut	2.31	2.13	2.28	1.90	1.58
LSD	0.086	0.043	0.089	0.078	0.042

Plate 1: Doughnut shaped briquettes

Effect of Binder levels on Density of Briquettes: Different binder levels of starch did not cause significant differences (P>0.05) on compressed density of briquettes at 0min.However, the relaxed density of briquettes at 25% binder level was constant at 30min and 1hour and decreased rapidly to 1.51g/cm^3 in 7 days (Table 2). The relaxed density at 15% binder level showed a progressive decline from 2.21g/cm^3 at 30minutes to1.44g/cm^3 in 7days and the relaxed density 35% binder recorded 2.15g/cm^3 in 30minutes and increased to 2.28g/cm^3 in 1hour before decreasing to 1.41g/cm^3 in 7days. The relaxed density of 1.51g/cm^3 at 25% binder was higher than 1.10g/cm^3 for sawdust briquette, reported by Singh (2009). The result indicates that 25% binder level is the optimum binder concentration for briquette production, which agrees with Tembe, *et al.* (2011).

Table 2: Effect of Binder level on Density of Briquettes

	Density(g/cm^3)				
Binder levels	**0min**	**30mins**	**1hour**	**24hours**	**7days**
15%	2.24	2.21	2.15	1.83	1.44
25%	2.33	2.23	2.23	1.90	1.51
35%	2.25	2.15	2.28	1.96	1.41
LSD	NS	0.043	0.089	0.078	0.042

Weight loss and Shatter resistance of briquettes: The Weight loss of briquettes was highly significant (P<0.01). *Daniellia* + Rice briquettes recorded the highest weight loss of 34.6%, which was significantly higher than *Daniellia* + Groundnut with weight loss of 9.7% (Table 3). The shatter resistance was not significant (P> 0.12) for all the briquettes in (Table 3) *Daniellia* + Groundnut briquettes recorded the highest shatter resistance of 90.4%, which was higher than *Daniellia* + Rice briquettes with shatter resistance of

72.4%. The high shatter resistance and low weight loss of *Daniellia* + G/nut briquettes indicates high stability and resistance to handling stresses.

Table 3: Weight Loss and Shatter resistance of briquettes

Sample	Weight loss%	Shatter resistance%
Daniellia + G/nut	9.7	90.4
Daniellia + Rice	34.6	72.4
Daniellia + Rice+ G/nut	12.8	87.2
LSD	12.82	NS

Effect of Binder level on Weight loss and Shatter resistance of Briquettes: The weight loss of briquettes due to variation in binder level was highly significant (P< 0.01) (Table 4). Briquettes at 15% binder levels recorded the highest weight loss of 39.7% while 35% binder levels recorded the lowest weight loss of 0.9%. The shatter resistance was significant (P< 0.05) with 35% binder level recording the highest shatter resistance of 99.1%. This implies that briquettes produced with higher concentration of starch binders are more durable and resistant to handling stresses.

Table 4: Effect of weight loss at Binder levels of Briquettes

Binder levels	Weight loss%	Shatter resistance%
15%	39.7	67.3
25%	16.5	83.5
35%	0.9	99.1
LSD	12.82	18.31

Effect of Type of Materials on Combustion properties of Briquettes: Percentage Ash content: The percentage Ash content of briquettes was highly significant (P<0.01), *Daniellia* + Rice + G/nut briquettes recorded the highest Ash content of 11.27% (Table 5). The ash content in briquettes normally cause increase in combustion remnant in the form of ash which lowers the heating value of briquettes, low ash content offer higher heating value for briquettes (Obi *et al*. 2013). The Fixed carbon of briquettes was also significantly high (P<0.01). *Daniellia* + Rice + G/nut briquettes recorded the highest Fixed carbon (Fc %) of 32.11% while *Daniellia* + G/nut briquettes recorded fixed carbon of 24.26 % (Table 5). The Heat of combustion of briquettes was also highly significant (P<0.01). *Daniellia* + G/nut briquettes recorded the highest heat of combustion of 4710.0(Kcal/kg) which was higher than 4516.0(Kcal/kg) from *Daniellia* + Rice + G/nut (Table5). This indicates that any of the three (3) briquettes combinations could serve as an efficient briquette fuel since the heat of combustion values fall within the same range. The result is lower than 5210kcal/kg for *Anoeissus leiocaarpa* and 4908 kcal/kg for *Gmelina arborea* as reported by Egbewole *et al*. (2009) These values are however higher than 33.37 MJ.kg^{-1} recorded by Obi *et al*. (2013) in their work on briquetting machine. The percentage moisture content (MC%) of briquettes was also highly significant (P<0.01), *Daniellia* + G/nut briquettes recorded the highest moisture content of 12.94% while *Daniellia* + Rice + G/nut briquettes recorded 9.83% moisture content (Table 5). The percentage moisture content is within operating limits of 8-12% (Eriksson and Prior, 1990). The percentage Volatile matter (Vm%) of briquettes was also highly significant (P<0.01), *Daniellia* + G/nut briquettes recorded the highest percentage Volatile matter of 68.54% while *Daniellia* + Rice + G/nut briquettes recorded Vm% of 56.62% (Table 5). The percentage volatile matter of the briquettes was higher than normal value of 20% as reported by Ivanon *et al*. (2003).

Table 5: Combustion properties of Briquette materials

Briquette Samples	Ash%	Fc%	Hc(Kcal/kg)	MC%	VM%
Daniellia + G/nut	7.20	24.26	4710.0	12.94	68.54
Daniellia + Rice	9.91	25.55	4610.0	10.39	64.53
Daniellia + Rice + G/nut	11.27	32.11	4516.0	9.83	56.62
LSD	0.48	0.62	51.7	0.39	0.73

Effect of Binder levels on Combustion properties of Briquettes: The Ash content of briquettes was highly significant (P<0.01) on binder levels. 15% binder level recorded the highest ash content of 10.46% while 35% binder produced the lowest percentage ash content 8.43% (Table 6). Low ash content offers higher heating value for briquettes (Obi *et al*. 2013). The percentage Fixed carbon was also highly significant (P<0.01) on binder levels with 35% recording the highest fixed carbon of 28.34% (Table 6). Specific Heat of combustion was significant (P<0.01) among binder levels; 35% binder level produced the highest heat of combustion of 4653.0Kcal/kg (Table 6). Moisture content of briquettes was significant (P<0.05) among binder levels, 35% binder levels recorded the highest moisture content of 11.33% while 25% binder level recorded 10.83% moisture content (Table 6). The percentage moisture content of briquettes fall within accepted levels of 8-12% (Eriksson and Prior, 1990).The Volatile matter of briquettes was significant (P<0.01) among binder levels, 15% binder recorded the highest Volatile matter of 63.71% followed by 25% binder level of starch which was 62.76% (Table 6). The percentage Volatile matter is above the normal value of 20% by reported Ivanon *et al*. (2003).

Table 6: Combustion properties of Briquettes at varying binder levels

Binder levels	Ash%	Fc%	Hc(Kcal/kg)	MC%	VM%
15%	10.46	25.84	4577	11.00	63.71
25%	9.41	27.75	4606	10.83	62.76
35%	8.43	28.34	4653	11.33	63.23
LSD	0.48	0.62	51.7	0.39	0.73

CONCLUSION AND RECOMMENDATION

The study has shown that briquettes produced from binary and tertiary combinations of *Daniellia oliveri,* Rice husk and Groundnut shells produced high heating values ranging from 4710.0Kcal/kg to 4516.0Kcal/ which was higher than that of Elaigwu, *et al* (2010) who got 3215.25 – 4010Kcal/kg in his research on agricultural waste briquettes. The result was however lower than 5210kcal/kg for *Anoeissus leiocaarpa (*African birch) and 4908 kcal/kg for *Gmelina arborea (*gamhar, gumhar, gamari, beechwood, goomar teak, Kashmir tree).This makes the combination of briquettes from sawdust of *Daniellia oliveri* and residues from rice husk and groundnut shell a good substitute for fuel. Briquettes produced at thirty five (35%) starch binder level recorded the highest combustion properties. It is therefore recommended that briquette production using sawdust and agricultural residues of *Daniellia oliveri,* Rice husk and Groundnut shells be done at binary and tertiary levels because of high heating value from the combinations. Starch binder level of 35% is also recommended for briquette production from the combinations because of the relative stability and high combustion properties of produced briquettes.

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