Physical and Combustion Properties of Briquettes Produced from Composite Materials of *Daniela Oliveri, Gmelina Arborea* and Bambara Nut Shells in Benue State, Nigeria

International Journal of Pure Agricultural Advances
Vol. 2, No. 1, 1-6, 2018
e-ISSN: 2523-9538
Check for updates

(Corresponding Author)

Tembe, E.T.[1]
Ekhuemelo, D.O.[2]
Asue, M.W.[3]

[1,2,3]*Department of Forest Production and Products, University of Agriculture Makurdi, Makurdi, Benue State, Nigeria*
[1]*Email: emmatembe@gmail.com Tel: +2348179617810*
[2]*Email: davidekhuemelo@yahoo.com Tel: +2347031332803*
[3]*Email: asuemoses@gmail.com Tel: +2347067249224*

ABSTRACT

Composite biomass materials from *Daniela oliveri*, *Gmelina arborea* and Bambara nut shells were used to produce briquettes in binary combination of *Daniela oliveri* with bambara nut shells and *Gmelina arborea* with bambara nut shells in a ratio of 1:1. Bambara nut shells were first ground into fine particles and sundried for 7 days, cassava starch was used as binder in the proportion of 25% starch to 100g of composite material. Briquettes were produced using a cylindrical mould at a pressure of 2 kNm^{-2} and used to determine the compressed (density at 0 minute after processing)) and relaxed densities (density at 30 minute, 1 hour, 24 hours and 7 days after processing), Shattered index and combustion properties (% moisture content, % fixed carbon, % volatile matter, % ash content and specific heat of combustion). The result showed a gradual reduction in compressed and relaxed densities as drying time increased from 0 minute to 7 days because of a reduction in the relaxation. Composite briquettes from *Gmelina arborea* with bambara nut shells recorded a higher relaxed density of 0.59 g/cm^3 in 7 days and a significantly higher shatter resistance and weight loss of 99.93 % and 0.07% respectively. Composite briquettes from *Daniela oliveri* with bambara nut shells produced a higher significant effect of 11388.8 Kcal/kg compared with *Daniela oliveri* with bambara nut shells with Specific Heat of Combustion of 10944.0 Kcal/kg. Briquettes produced from composite materials of *Daniela oliveri* with bambara nut shells and *Gmelina arborea* with bambara nut shells therefore suitable for used as alternative cooking fuels in rural and sub-urban communities in Nigeria.

Keywords: *Ash content, Briquettes, Combustion properties shatter resistance, Weight loss.*

DOI: 10.20448/813.21.1.6
Citation | Tembe, E.T.; Ekhuemelo, D.O.; Asue, M.W. (2018). Physical and Combustion Properties of Briquettes Produced from Composite Materials of Daniela Oliveri, Gmelina Arborea and Bambara Nut Shells in Benue State, Nigeria. International Journal of Pure Agricultural Advances, 2(1): 1-6.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
History: Received: 20 December 2017/ Revised: 12 January 2018/ Accepted: 17 January 2018/ Published: 22 January 2018
Publisher: Online Science Publishing

1. INTRODUCTION

Biomass energy is occupying a predominant place as an energy source in rural areas of Nigeria. The importance of using agriculture residues and sawdust waste as primary source of energy is attractive because of abundance, local and environmental friendly nature (Jekayinfa and Omisakin, 2005). Large amount of sawdust residues and other biomass wastes are generated in the communities but poorly managed by allowing it to decompose or are burnt in the field causing environmental pollution and degradation (Tembe, 2015). Before promoting the use of new fuel, it is good to understand its performance. The performance of any solid biomass fuel such as sawdust briquette can be evaluated effectively when it is characterized in order to determine parameters such as the moisture content, ash content, density, volatile matter, and heating value among others (Oladeji, 2010). The use of biomass fuel such as composite materials has been proposed to be a good source of energy for domestic cooking (Tembe, 2015). This is due to the fact that sawdust, i.e., the raw material in the production of composite materials is readily available in large quantities as wastes in majority of the wood processing industries. This study is therefore designed to determine the fuel value of briquettes produced from mixed materials of *Daniellia oliveri*, *Gmelina arborea* sawdust and Bambara nut shells.

2. MATERIALS AND METHOD

2.1. Study area

The briquettes were produced and assessed for physical and combustion properties in Federal University of Agriculture Makurdi, Benue State of Nigeria. The study area is located in the Guinea savannah region of North Central Nigeria. Sawdust from two species of trees *Gmelina arborea* and *Daniellia oliveri* and one species of agricultural crop residue Bambara nut shells was used for this study. The binding agent was cassava starch, a compression/ compacting machine and a cylindrical briquetting mold or die was used. The experimental design was a 2x3 factorial in Completely Randomized Design (CRD) Differences between means were determined using least significant different (LSD).

2.3. Briquettes Production Process

The saw dust samples of the three collected species were naturally dried for one week to remove the moisture content and sieved with 3.35mm mash into uniform size, while 50g of sawdust was measured from each of the 2 species and mixed with 50g of uniformly sieved ground bambara nut shells. Twenty five (25) g of cassava starch binder was prepared using 200 ml of boiled water and mixed at binder ratio of 25% of the bulk weight of briquette materials. The briquettes were produced in binary combination using *Daniellia oliveri* sawdust with bambara nut shells and *Gmelina arborea with* bambara nut shells in 1:1 ratio. A cylindrical die (mould) with height of 5cm and 4 cm diameter was used in producing cylindrical shaped briquettes. The die (mould) was hand-filled with 100g weigh of sample together with cassava starch as a binder; the sample starch moisture was compressed using hydraulic compressive press at a pressure constant of $2kNm^{-2}$.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/rulers to determine the volume. The compacted briquettes were air dried for 7 days and used for assessment of physical and combustion properties. The parameters investigated were Density, Shattered Index and Combustion properties.

2.4. Determination of Physical Properties

i. Density

Ten briquettes were randomly selected from each production batch for evaluation. The mean compressed density of the briquettes was determined immediately after removal from the mould as a ratio of measured weight to calculate volume (Olorunnisola, 2007). The weights of the produced briquettes were determined using digital weighing balance, while the average diameters and lengths of the briquettes was taken. The volume of the cylindrical shaped briquettes was determined using the formula.

$V =. \underline{\Pi d^2 \times l}$ .... equation 1

Where; d= diameter, l=length, $\Pi = 3.14$

The compressed density (at minute after processing) and relaxed densities of the briquettes were determined at 30 minutes, 1hour, 24hours and 7days using the dimensions and ASTM Standard (E711_87) (2004) standard method of determining densities. Density was determined for each briquette as ratio of briquette weight to volume.

$$\text{Density} = \frac{\text{weight of briquettes}}{\text{Volume of briquette}} \quad \text{.........equation 2}$$

ii. Determination of Shattered Index of Briquettes

The durability of the briquettes was determined in accordance with the Shattered Index described by Suparin *et al.* (2008). The briquette samples were dropped 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 durability rating of the briquette was expressed as a percentage of the initial mass of the material remaining on the solid bass (Mohod *et al.*, 2008).

$$\text{Percentage weight loss} = \frac{\text{Initial weight before shatter} - \text{weight after shatter}}{\text{Initial weight of briquette before shattering}} \times 100 \quad \text{...equation 3}$$

Shatter resistance = 100 - %weight loss ....equation 4

iii. Determination of Combustion properties

The combustion properties included the percentage; Moisture content, Ash content, Volatile matter, fixed carbon, and the heating value.

iv. Percentage of Moisture Content (%Mc)

The Moisture content of samples was measured by oven dry method. Two (2)g of pulverized briquette samples (w_1) was measured and kept in oven at 103 °C for 3hours (Sengar *et al.*, 2012) to obtain oven dry weight (w_2). The oven dry sample was kept in the dessicator to cool at room temperature without absorbing moisture from the atmosphere. The moisture content of sample was calculated by using following formula:

$$\%MC = \frac{W_1 - W_2}{W_1} \times 100 \quad \text{..........equation 5}$$

Where;

W1 = Initial weight of sample (g), W2 = Dry weight of sample (g),

v. Determination of the % Volatile Matter in the Samples

Volatile matter is defined as those products, exclusive of moisture, given off by a material as gas or vapour. The volatile matter of the sample was determined by measuring 2g of the oven dry weight (W_2) to be preheated in the furnance for 4minutes at 400^{0}c to obtain charred weight, this method was used by Egbewole *et al.* (2009). The percentage volatile matter (%VC) was calculated thus;

$$\%Vm = \frac{\text{Dry weight } (w_2) - \text{weight of sample } (w_3)}{\text{Dry weight } (w_2)} \times 100 \quad \text{......equation 6}$$

vi. Percentage of Ash content

This was determined by placing the charred weight (w_3) in the furnance for 3 hours at 600^{0}c to obtain ash weight (W_4). Percentage ash content was estimated using the formula below by Carre *et al.* (1981).

$$\%\text{ Ash content} = \frac{\text{Ash weight } (W_4)}{\text{Dry weight } (W_2)} \times 100 \quad \text{...........equation 7}$$

vii. Percentage of Fixed Carbon (%FC)

This was calculated by subtracting the sum of %Volatile matter and %Ash content from 100 as stated by Bailey and Blankenhorn (1982).

$$\%FC = 100\% - (\%Vm + \%Ash) \quad \text{...........equation 8}$$

viii. Specific Heat of Combustion (HC)

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

$$HC = 0.35((147.6 \times FC) + (144 \times Vm) + (\%Ash))\ \text{Kcal/kg} \quad \text{..........equation 9}$$

3. RESULTS AND DISCUSSION

3.1. Effect of Briquette Type on Density of Briquettes Produced

The effect of briquette type produced significant effect on the compressed density (density at 0 minutes) and relaxed densities at 30 minutes, and 7 days. There was a general decline in density of briquettes as drying time increased from 0 minute to 7 days. The compressed densities at 0 minutes were higher than the relaxed densities at 30 minutes, 1 hour, 24 hours and 7days (Table 1) which could be related to the effect of moisture contained in the starch binder which increased the mass per unit volume of the briquettes immediately after removal from the die. The moisture content loss due to drying of the briquettes from 30 minutes to 7 days resulted to the observed reduction in density values as drying progressed (Maninder *et al.*, 2012; Obi *et al.*, 2013). The relaxed densities ranged from 0.57g/cm^{3}to 0.59g/cm^3 in 7days with *Gmelina arborea* with Bambara nut briquettes producing a higher relaxed density of 0.59g/cm^3.

Table-1. Effect of Briquettes Type on Density of Briquettes produced

Briquette Types	Density (g/cm^3) 0 min	Density (g/cm^3) 30mins	Density (g/cm^3) 1hr	Density (g/cm^3) 24hrs	Density (g/cm^3) 7days
G withB	1.03	0.95	0.93	0.76	0.59
D withB	1.08	0.98	0.93	0.82	0.57
LSD	NS	0.027	NS	NS	0.0102

Note:
G - *Gmelina arborea*, B - Bambara nut shells and D - *Daniellia oliveri*

3.2. Effect of Briquette Type on Shattered Indices of Briquettes

Shattered resistance of briquettes determines the breakability when they are exposed to hard surfaces, the higher the shatter resistance accompanied by low weight loss, the more durable is the briquette sample (Sotannde *et al.*, 2010). The shatter resistance of the briquettes was significant with *Gmelina arborea* with Bambara nut briquettes recording a higher shatter resistance of 99.91% while *Daniellia oliveri* with Bambara nut briquettes recorded a lower shatter resistance of 99.86%and weight loss of 0.04%. The higher shatter resistance of *Gmelina arborea* with Bambara nut briquettes shows high durability of the briquettes and easy of handling during transportation (Tembe, 2015). The briquettes with low shatter resistance have to be handled with care to reduce the damage during packaging and transportation (Sotannde *et al.*, 2010; Obi *et al.*, 2013).

Table-2. Effect of Briquette Type on Shattered Index of Briquettes

Briquettes type	Shattered Resistance (%)	Weight loss (%)
G with B	99.91	0.09
D with B	99.86	0.04
LSD	NS	NS

Note: G -*Gmelina arborea*,
B - Bambara nut shells
D - *Daniellia oliveri*

3.3. Effect of Briquette Type on Combustion Properties

The effect of briquette type on combustion properties of briquettes was significantly related to Moisture content, Ash content, & Heating value. *Gmelina arborea* with Bambara nut briquettes recorded the highest percentage ash content of 3.51% which was significantly higher than *Daniella oliveri* with Bambara nut briquettes. High Ash content of briquettes could be related to lower densities of the biomass materials (Obi *et al.*, 2013). Briquettes type had no significant effect on percentage fixed carbon of briquettes, *Gmelina arborea* with Bambara nut briquettes recorded a higher percentage fixed carbon while *Daniellia oliveri* with Bambara nut briquettes recorded the lowest percentage fixed carbon. Percentage of moisture content was significant due to effect of briquette type. *Daniellia oliveri* with Bambara nut briquettes recorded a higher %MC of 5.17% compared with briquettes from *Gmelina arborea* with Bambara nut which recorded a lower value of 4.03%. This could be linked to the fact that different materials have varied moisture retention abilities as reported by Eriksson and Prior (1990). Heating value of the briquette was significant, *Daniellia oliveri* with Bambara nut briquettes produced a higher heating value of 11388.9 kJ/kg (Table 3).The result was lower than 23991kcal/kg for *Terminalia supaba* briquettes as reported by Emerhi (2011).

Table-3. Effect of Briquette Types on Combustion Properties of Briquettes

BT	%MC	%AC	%FC	%VM	SH Kcal/kg
G with B	4.03	5.51	27.0	67.5	10944.0
D with B	5.17	4.30	26.9	68.8	11388.9
LSD	1.109	0.785	NS	NS	1998.8

Note: BT=Briquette Type

4. CONCLUSION AND RECOMMENDATIONS

The result showed a progressive decline in compressed and relaxed density of briquettes as drying time increased from 0 minutes to 7 days. Composite briquettes from *Gmelina arborea* with Bambara nut recorded a higher density of 0.59g/cm^3 in 7days while *Daniellia oliveri* with Bambara nut briquettes produced a lower density of 0.57g/cm^3 in 7 days. The effect of species was significant on shattered resistance of briquettes, *Gmelina arborea* with Bambara nut briquettes recorded a higher value of 99.91% and lower weight loss of 0.09%. *Daniellia oliveri* with Bambara nut briquettes had a higher heating value of 11388.9Kcal/kg while, *Gmelina arborea* with Bambara nut had a lower heating value of 10944.0Kcal/kg. The production of briquettes from composite materials like sawdust of *Gmelina arborea*, *Daniellia oliveri* and Bambara nut shells is hereby recommended due to the high heating values and resistance to stress.

REFERENCES

ASTM Standard (E711_87), 2004. Standard test method for gross calorifc value of refuse-derived fuel by the bomb calorimeter. Annual Book of ASTM Standards ASTM International: 105.

Bailey, R.T. and P.R. Blankenhorn, 1982. Calorific and porosity development in carbonized wood. Wood Science, 15(1): 19-18. *View at Google Scholar*

Carre, J., L. Lacrosse and J. Herbert, 1981. Critical analysis of the dry process improvement of lignocellulosic for energy producing purpose. A Final Report Submitted to the Commission of the European Communities General Directorate of Development and Ministries, Belgrade L. Agriculture Centre de Reseaeches Agronomiques de IE tat de Gembloux (CRN) France: pp: 25.

Egbewole, Z.T., O.A. Sotannde and K.S. Aina, 2009. In: Combustion efficiency of briquettes produced from wood sawdust. An alternative for energy generation. Proceedings of the 2nd Biennial National Conference of the Forests and Forest Products Society, 11: 385-400.

Emerhi, E.A., 2011. Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders. Advances in Science Research Journal, 2(6): 236-246. *View at Google Scholar*

Eriksson, S. and M. Prior, 1990. The briquetting of agriculture of agricultural wastes for fuel. F.A.O. Environment and Energy Paper II, FAO Rome.

Jekayinfa, S.O. and O.S. Omisakin, 2005. The energy potentials of some agricultural wastes as local fuel material in Nigeria. Agricultural Engineering International: CIGR E Journal of Scientific Research and Development, 7: 1-10.

Maninder, S.K. Rupinderjit and G. Sonia, 2012. Using agricultural residues as a biomass briquetting: An alternative source of energy. Journal of Electrical and Electronics Engineering, 12(2): 303-307. *View at Google Scholar | View at Publisher*

Mohod, A.G., Y.P. Khandetod and A.G. Powar, 2008. Processed cashew shell waste as fuel supplement for heat generation. Short article. Energy for Sustainable Development, 8(4): 73-75. *View at Google Scholar | View at Publisher*

Obi, O.F., C.O. AKubuo and W.I. Okonkwo, 2013. Development of an appropriate briquetting machine for use in rural commuties. International Journal of Engineering and Advanced Technology, 2(4): 578-582. *View at Google Scholar*

Oladeji, J.T., 2010. The briquetting of agricultural wastes for fuel. Pacific Journal of Science and Technology, 11(1): 101-106. *View at Google Scholar*

Olorunnisola, A., 2007. Production of fuel of briquettes from waste paper and coconut husk admixtures. Agricultural Engineering International E- Journal, 6(1): 27-35. *View at Google Scholar*

Sengar, S.H., A.G. Mohol, Y.P. Khandetod, S.S. Patil and A.D. Chendake, 2012. Performance of briquette machines for briquette fuel. International Journal of Energy Engineering, 2(1): 28-34. *View at Google Scholar*

Sotannde, O.A., A.O. Oluyege and G.B. Abah, 2010. Physical and combustion of briquettes from sawdust of azadirachta indica. Journal of Forestry Research, 21(1): 63-67. *View at Google Scholar | View at Publisher*

Suparin, C., S. Suwit and K. Prattana, 2008. Development of fuel briquettes from biomass lignite blends. Chiangi Journal of Science, 35(1): 43-50. *View at Google Scholar*

Tembe, E., 2015. Heating value of briquettes produced from bambara groundnut shells. An Unpublished Ph.D Thesis. pp: 30-205.