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PHYSICAL AND COMBUSTION PROPERTIES OF BRIQUETTES PRODUCED FROM DRY LEAVES OF *Tectona grandis* AND MIXTURE OF *Tectona grandis* AND *Daniella oliveri* SAWDUST

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Abstract:
This study was carried out to determine the physical and combustion properties of briquettes produced from the leaves of Tectona grandis and mixture of Tectona grandis and Daniella oliveri sawdust. The different samples were made in single and binary combination in a ratio of 100: 0 and 50:50 respectively, using cassava starch as binder. The briquettes were produced mechanically using a hydraulic machine at pressure of KN/m^2.The data collected was analyzed using a 2x3 factorial CRD. The compressed densities were determined at 0 minutes and relaxed densities at 30mins, 24hrs, and 7days; Tectona grandis had a higher relaxed density of 0.57g/cm^3 in 7days of drying. The briquettes produced from binary combination of Tectona grandis with Daniella oliveri had a higher shatter resistance of 99.50% and weight loss 0.49%. The effect of combustion properties on briquette type was significant except for percentage of moisture content and fixed carbon. Briquettes produced at binary combination of Tectona grandis with Daniella oliveri had a lower moisture content, ash content, fixed carbon content and volatile matter of 7.17%, 18.66%, 9.2% and 72.2% respectively. The heating value of Tectona grandis with Daniella oliveri briquettes at 11297MJ/kg was higher than Tectona grandis briquettes with 10721MJ/kg. The effect of particle sizes on combustion properties was significant except on percentage moisture content and fixed carbon, briquettes produced at particle size of 1.70mm recorded the lowest percentage ash content of 9.5%, but highest heating value of 11055MJ/kg. Briquettes produced from leaves of Tectona grandis and sawdust of Daniella oliveri are good alternative briquette biomass materials for domestic cooking by low income earners.

Key words: *briquettes; combustion properties; density; moisture content; fixed carbon; shattered index.*

INTRODUCTION

Fuelwood utilization is considered as the main source of energy for the rural communities and briquettes made from other biomass resources are a great substitute for wood (Sotannde *et al.* 2010). A wide range of biomass energy sources exist in the communities in form of firewood, forest waste, dung, vegetable matter and agricultural residues. The composition of the briquettes varies in location due to the availability of raw materials which are gathered and compressed into briquettes for ease of burn and transportation (Tembe 2015). Compared to fossil fuels, the briquettes produce low of net total greenhouse gas emissions because the materials used are already a part of the carbon cycle (Obi *et al*. 2013). Briquette production is becoming attractive in rural settings because it saves saving time, energy, and environment and creating more incomes. Biomass briquettes utilize fuel wood alternatives from resources that are commonly available and usually discarded as waste can be made relatively quickly at a low cost and applied in a wide variety of settings, making the briquettes appropriate, sustainable and renewable. In this study biomass from dry leaves of *Tectona grandis* and sawdust of *Daniella oliveri* were used to produce briquettes that can serve as substitute for fuelwood in rural communities.

OBJECTIVES

This study aimed to determine the physical and combustion properties of briquettes produced from the

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leaves of *Tectona grandis* and mixture of *Tectona grandis and Daniella oliveri* sawdust.

MATERIALS AND METHOD

Study Area

The experimental process of briquette production was done at the Mechanical Engineering and Food Science and Technology Laboratories of the Federal University of Agriculture, Makurdi Benue State of Nigeria. Benue state is located between latitude 6º 35' 8º 10N and longitudes 7º - 47' 10E. The state lies between the floor plains in the middle belt region of Nigeria. The elevation which is generally undulating rises from Benue valley below 100m east wards and south wards to the western region of Cameroonian highlands and Nsukka escarpment respectively.

Sample Collection and Preparation

The dry leaves of *Tectona grandis* and *Daniellia oliveri* were collected in Makurdi area of Benue state where the materials were produced in large quantities. Dry leaves were air dried and grounded using a mortar and pestle. The three biomass residues were sieved to three sizes of 1.70mm, 2.36mm, and 3.35mm respectively and stored for briquetting. Cassava starch was prepared as binder for the briquettes at a ratio of 25% (100:25) to the weight of sample as conducted by Sotannde *et al*. (2010) and Tembe (2015).

Briquette Production and Quality Evaluation

Ground dry leaves of *Tectona grandis* and sawdust of *Daniella oliveri* were used to produce briquettes at single and binary combination using cylindrical shaped mould. One hundred (100g) of dried ground sample was mixed with cassava starch until a uniform mixture was obtained (Sotannde *et al*. 2010).

The proportions of sample

The sample binder mixture was hand fed into the steel mould for cylindrical briquette and covered at both ends with the disk. The sample binder mix inside the mould was the placed under the hydraulic press and compacted at the pressure of 2KN/m^2 and 10 replicates were produced. The diameter of the briquettes were thereafter taken at two different points with aid of calipers while the weight and thickness was recorded immediately. Then briquette were produced at binary combination using *Tectona grandis* (100%) and *Tectona grandis* with Daniella oliveri (50:50%) in equal proportion of mixture as used by Tembe, (2015).

DETERMINATION OF PHYSICAL PROPERTIES

Density

Four samples were selected from the production batch for evaluation of physical properties. The mean compressed density of 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 calipers. The compressed and relaxed densities of the briquettes were determined at 0 minutes, 30 minutes, 24 hours and 7 days using the die dimensions and ASTM E711_87, (2004) standard method of determining densities. Density was determined for each briquette as ratio of briquette weight to volume at the same moisture content.

$$\rho = m/V \quad (1)$$

where:

ρ = density, kg/m^3
m = mass, in kg
V = volume, in m^3

Shattered Index

The durability of the briquettes was determined in accordance with the Shattered index described by Suparin *et al*. (2008).The briquettes 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 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 and Moule 2006, Sengar *et al*. 2012).

$$\%\,WL = \frac{w_1 - w_2 \times 100}{w_1} \quad (2)$$

where:

%WL - Percentage weight loss.
w_1 - Initial weight before shatter.
w_2 - Final weight.

Shatter resistance = 100 - Percentage weight loss (3)

Combustion Properties Determination

The following combustion properties were used to determine the suitability of briquettes as cooking fuels, the combustion properties include the % Ash content, % Volatile matter, % Fixed carbon, % Moisture content and the Specific heat of combustion (Heating value).

Percentage Moisture Content (% Mc)

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

$$\%MC = \frac{w_1 - w_2}{w_1} \times 100 \quad (4)$$

where:

% MC - Percentage Moisture Content.
w_1 - Initial weight.
w_2 - Dry weight.

Percentage Volatile matter (% Vm)

Percentage Volatile matter was determined by keeping the substance in crucible with oven dry weight (w_2) in the furnace for 10mins at 400ºC to obtain weight (w_3) after which the volatile matter in it had escaped. The method was used by (Emerhi 2011). This was used in calculating percentage volatile matter thus:

$$\%VM = \frac{w_2 - w_3}{w_2} \times 100 \quad (5)$$

where:

% VM - Percentage volatile matter.
w_2 - Oven dry weight.
w_3 - Weight of sample.

Ash content (% Ac)

2g of oven dried pulverized briquettes were weighed in a crucible (w_2); this was placed in the furnace for 3hrs at 600ºC to obtain the ash weight (w_4). Percentage ash content was calculated as:

$$\%\,Ash = w_4 / w_2 \times 100 \quad (6)$$

where:

% Ash - Percentage ash.
w_4 - Weight of ash.
w_2 - Dry weight.

Percentage Fixed carbon (% Fc)

This was calculated by subtracting the sum of % Volatile matter and % Ash content from 100.

$$\%\,Fc = 100\% - (\%Vm + \%\,Ac). \quad (7)$$

where:

% Fc - Percentage Fixed carbon.
% Vm - Percentage volatile matter.
% Ac - % ash content.

Specific heat of combustion (HC)

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

$$HC = 0.35[(147.6 \times Fc) + (144 \times Vm) + \%\ Ash] \quad MJ/kg \tag{8}$$

where:

HC - Specific heat of combustion.
Fc - Fixed carbon.
Vm - Volatile matter.
% Ash - Percentage ash.

The data collected from sample tests were subjected to analysis of variance using 2x3 factorial analyses in CRD.

RESULTS AND DISCUSSION

Effect of Briquette Type on Density of Samples

The effect of briquette type on density was significant (Table 1). There was a reducing trend in density from compressed density at 0 mins to relaxed density at 7days. Briquette produced from leaves of *Tectona grandis* had higher density of 0.57g/cm^3 compared with briquettes produced from binary combination (50:50) *Tectona grandis* with *Daniella oliveri* with relaxed density of 0.53g/cm^3. The decreasing trend in density from compressed density at 0mins to relaxed density at 7days was due to reduction in moisture content of briquette produced. The higher relaxed density of 0.57g/cm^3 for briquettes produced from *Tectona grandis* may be due to the compactness of particle material after pressure was applied. The values in this study are higher than the values of 0.319g/cm^3 and 0.367g/cm^3 of elephant grant and spear grass briquettes respectively as obtained by (Onuegbu *et al.* 2011).

Table 1

Effect of Briquette Type on Density of Samples

Briquette type	Compressed density(g/cm^3) 0mins	Relaxed density (g/cm^3) 30mins	Relaxed density (g/cm^3) 24hrs	Relaxed Density (g/cm^3) 7days
Tectona grandis	0.8	0.72	0.63	0.57
Tectona grandis with *Daniella oliveri*	0.7	0.69	0.68	0.53
Least significant difference (LSD)	15.28	0.3852	0.03787	0.03439

Effect of Briquette type on Shatter Index

The effect of briquette type was significant on both Weight loss and Shatter resistance of briquettes (Table 2). *Tectona grandis* with *Daniella oliveri* briquettes recorded a lower % Weight loss and higher % Shatter resistance of 0.49% and 99.52% respectively. This may be related to the cumulative effect of higher densities of the individual biomass materials. This indicates higher durability of *Tectona grandis* with *Daniella oliveri* briquettes and ability to withstand stress in service (Tembe 2015).

Table 2

Effect of Briquette type on Shatter Index

Briquette type	Weight loss (%)	Shatter resistance (%)
Tectona grandis	2.73	97.30
Tectona grandis with *Daniella oliveri*	0.49	99.52
Least significant Difference (LSD)	1.065	1.078

Effects of Briquette Type on Combustion Properties

Briquette type recorded significant effect on percentage Volatile matter (% Mc), Ash content (% Ac) and Specific Heat of Combustion (SHC). Briquettes produced from *Tectona grandis* had higher % Moisture content, % Fixed carbon and % Ash content values of 7.25%, 13.2%, 19.41% respectively, while the % Volatile matter of the briquettes was lower at 67.4% (Table 3). The Specific heat of Combustion (Heating value) of the briquettes from binary combination of *Tectona grandis* with *Daniella oliveri* was 11297MJ/kg which was higher than 10721MJ/kg for *Tectona grandis* briquettes. The moisture content measures the amount of water in and therefore very vital property determining the burning characteristics of briquettes (Yang *et al.* 2005). The low moisture content obtained from the result can be attributed to the low relative humidity of the environment. The ash content describes the inorganic portion of fuel. Briquettes produced from *Tectona grandis* had higher ash content which could be attributed to the increased amount of inorganic matter of the fuel material. Fixed carbon indicates the proportion of char that remained after the burning phase. The briquettes produced from *Tectona grandis* had higher fixed carbon content; this can be attributed to the increased amount of carbon in the fuel material. Volatile matter describes the amount of combustible material present in a fuel. Briquette produced from *Tectona grandis* with *Daniella oliveri* had higher volatile matter above the operating limit of 20% (Ivanon *et al*. 2003).

The heating value measures the amount energy in a fuel. The briquettes produced from *Tectona grandis* with *Daniella oliveri* had a higher heating value which may be due to the combined effect of higher carbon content or lignin carbon of the individual biomass materials.

Table 3

Effects of Briquette Type on Combustion Properties

Briquette type	Mc (%)	Vm (%)	Fm (%)	Ac (%)	SHC (MJ/kg)
Tectona grandis	7.25	67.4	13.2	19.41	10721
Tectona grandis with *Daneillia oliveri*	7.17	72.2	9.2	18.66	11297
LSD	NS	8.07	NS	6.91	1.078

Conclusion and Recommendation

Briquettes produced from the binary combination of *Tectona grandis* with *Daniella oliveri* had a higher relaxed density of 0.57g/cm^3 in 7days. Effect of Shatter index and combustion properties was significant except for % Moisture content and fixed carbon. Briquettes produced from the binary combination of *Tectona grandis* with *Daniella oliveri* had higher shatter resistance of 99.52% and heating value of 11297MJ/kg compared with briquettes produced from *Tectona grandis* briquettes with shatter resistance 97.30% and heating value of 10279MJ/kg. The briquettes produced from *Tectona grandis* and *Daniella oliveri* have high shatter resistance and can be transported without many breakage. The briquettes have high heating values and therefore suitable for use as alternative energy sources.

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