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Determination of the Calorific Value of Briquettes Made from *Pinus caribae* and *Eucalyptus citirodora* Sawdust

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AAI, SAA, AOA and JTA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RAJ, EJZ and RS managed the analyses of the study, proof read the article and co-type the manuscript. Authors OEO, MSL and OO managed the literature searches. All authors read and approved the final manuscript

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ABSTRACT

This study determined the calorific value of briquettes made from *Pinus caribaea* and *Eucalyptus citirodora*. Sawdust samples were collected from a sawmill in Buruku, Kaduna State. The briquettes were produced in a manually operated hydraulic briquette machine with binder in percentage mixing ratio (starch: binder) 50:50, 60:40 and 70:30. Three (3) replicates of each mixing proportion were produced making a total number of eighteen products. Calorific tests were carried out on the samples using the Gallenkhamp Calorimeter to determine their energy contents. The results indicated that the addition of starch in various proportion increases the average calorific value when compared to the briquettes produced from 100% pure sawdust material (Control). Also, the result from the Analysis of Variance (ANOVA) showed that the effect of variation of the different proportion of binder on the calorific value is highly significant at $P<0.05$). In the briquettes, the physical properties of materials used for briquette production, also affects the physical properties of briquettes used in this study e.g moisture contents and density.

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1. INTRODUCTION

1.1 Background of the Study

The energy demanded of the entire world is increasing and energy is needed to raise and satisfy the standard of living. Nations consuming more energy per capita always have better standard of living. The world energy consumption is seriously increasing at a critical rate when compared to the world ASpopulation [1]. Traditional, wood in form of fuel wood, twigs and charcoal has been a major source of energy in Nigeria, accounting for 51% of the total energy consumption [2]. Wood fuel is clean when used under controlled condition. It leaves a small amount of ash, which has some value as fertilizer. The other sources of energy include natural gas (5.2%), hydro-electricity (3.1%) and petroleum products (41.3%) [3]. The demand for fuel wood is expected to have risen to about 213.4 X 10^3 metric tons by the year 2030 [2].

The decreasing availability of fuel wood, coupled with fluctuations in prices of kerosene and cooking gas in Nigeria, draw attention to the need to consider alternative sources of energy for domestic and cottage level industrial use in the country. Such energy sources should be accessible to the poor, An energy source that meets such requirement is fuel briquette. Briquetting is a process of converting loose wastes into a dense, compact and consolidated unit through the application to high temperature and pressure with or without a binding agent. This has been found to be a way of turning waste to wealth. Also the fuel in this form when used for cooking burns with a bluish free flame (Aclegoke, 2009). The raw materials of a briquette must bind during compression; otherwise, when the briquette is removed from the mould, it will crumble. Improved cohesion can be obtained with a binder but also without, since under high temperature and pressure, some materials such as wood bind naturally. A binder must not cause smoke or gummy deposits, while the creation of excess dust must also be avoided. Two different sorts of binders may be employed.Combustible binders are prepared from natural or synthetic resins, animals manure or treated, dewasted sewage sludge. Non-combustible binders include clay, cement and other adhesive minerals. There is need to compress sawdust to briquette, a fuel product of any convenient shape that can burn like wood. Its development results in a cleaner environment through the recycling of the wood and agricultural wastes to briquette, which contributes to solving the country's environmental problems and waste disposal [4,5].

1.2 Statement of the Problem

The presence of sawdust in large quantity creates disposal challenges for the wood processing industries [1]. Although electricity, kerosene, coal, charcoal are available in Nigeria and can be alternative to fuel wood, most Nigerians exploit the forest for wood fuel because it is cheaper; but its use is causing serious deforestation problems in the country. Therefore, there is need for research into other alternative high- grade solid fuel for domestic and industrial use.

1.3 Aim and Objectives of the Study

The aim of this study is to determine the caloric value of briquette made from *Pinus caribea* and *Eucalyptus citirodora*. The specific objectives of the study include:

i. To determine the suitability of the wood waste from the two woody species for briquette production.
ii. To determine the effect of binders on the heat energy content of the materials.
iii. To compare the physical properties i.e. moisture content, density and ash contents of the study species.

1.4 Justification of the Study

The idea of producing briquette from timber wastes dates back to the 19th and 20th Centuries [6]. The demand for alternative energy sources for domestic and industrial uses make the utilization of sawdust by converting it into heat economically justified. The calorific value is an essential tool in investigating the suitability of the tree species for briquette production. Therefore, there is need to determine the calorific value of the two study species.

2. MATERIALS AND METHODS

2.1 Raw Materials Preparation

Sawdust *of Pinus caribaea* and *Eucalyptus citriodora* were collected from small scale sawmills in Buruku, Kaduna Sate. The materials were collected immediately after sawing into timber. Caution and appropriate care was taken to obtain clean samples to avoid wrong values during analysis. Cassava starch was obtained in Kawo market, Kaduna and used as a binder in percentage mixing ration at 50:50, 60:40 and 70:30, two (2) replicates of each mixing proportion were produced making a total number of eighteen (18). These briquettes were air-dried for thirty (30) days to reduce their moisture content to five (5) %. The starch was later made into non-viscous gel. The Gallenkhamp bomb calorimeter and oven were used in the course of the experiment.

2.2 Data Collection

The length, width and height of the briquettes were determined by the use of a special constructed device. These measurements were used to compute the volume and density of each of the briquettes produced from the study species. Data collected was on the physical properties of the briquettes produced from *Pinus caribaea* and *Eucalyptus citriodora* sawdust's. These methods were used to determine the selected physical properties of the briquettes made from the study species. The experiment was arranged in a 2 — factors factorial in a Complete Randomized Design (C.R.D). For the caloric value test, a 2x3 factorial experiment was designed. The factor taken into consideration are the types of the species and percentage composition of binder (i.e. Cassava Starch) used in making the briquettes. The effects of these factors on the calorific values of the different briquettes were studied.

2.2.1 Moisture content

5 g of each briquette sample was Weighed into a previously Weighed crucible. The crucible plus sample was put into the oven set at d: 103°C to dry to a constant weight for eight (8) hours. At the end of the eight (8) hours, the crucible plus sample was removed from the oven and transferred to desiccators, cooled for ten minutes and reweighed. The formula used to calculate the moisture content is given below.

$$\%\, Dry\ Matter\ (DM)\ = \frac{W2\ -\ W0}{W1\ -\ W0} \times 100$$

$$\%\, Moisture\ = \frac{W1 — W2}{W1 — W0} \times 100$$

Or % Moisture = 100 - % DM

Where,

W_0 = weight of empty crucible
W_1 = Weight of crucible plus sample
W_2 = weight of crucible plus oven dried sample

2.2.2 Density measurement

The weights of the briquettes were determined on the weighing balance in the laboratory then, the volumes of briquettes were determined by a simple calculation based on the direct measurement of length, width, and thickness of the briquettes.

Formula:

D (kg/m3) = M/V
M = Mass
V = Volume

2.2.3 Heat value

In determining the caloric value of the briquettes, the Gallenkhampbomp calorimeter was first calibrated using a standard sample of Benzoic acid whose known calorific value is 6.32 Kcalgl A known mass of sample of small quantity, 0.5 g of the different composition was placed in the crucibles. Small quantities of the sample material i.e sawdust and starch binder were weighed individually in the stated ratios they were thoroughly mixed before being placed in crucible since they do not form a complete homogenous mixture. The samples were put inside an oven to ensure dryness. One end of a cotton thread of length 50mm was inserted between the coil of ignition wire and the other end dipped into the center of the sample in the crucible. The thread enhances the combustion of the sample inside the crucible. The bomb body was placed and tightly screwed in position. The thermocouple wire was plugged into the hole on top of the bomb body. The pressure release valve was closed oxygen was admitted into the bomb until the pressure rose to 25 bars. The light spot index was set to zero using the galvanometer zero knob ensuring a stable temperature before the firing knob was depressed and released to fire the bomb. Heat is released and the maximum deflections of galvanometer scale was recorded after which the aid of the pressure release from the apparatus with the aid of the pressure release valve. The maximum deflection obtained in the galvanometer was converted to energy value of the sample material by comparing the rise in galvanometer deflection with that obtained when a sample of known calorific value of benzoic acid is combusted. The whole experiment was repeated and for each sample of *Pinus caribea* and *Eucalyptus citriodora* mixing in different rations of binder, five (5) different readings were obtained.

$$G.E.(Kcal/g) = \frac{Galvanometer\ deflection \times Calibration}{Weight\ of\ sample}$$

2.2.4 Ash content

5 g of the briquettes samples was weighed into a crucible. Then, they were transfer into the furnace set at 550°C and left for about 4 hours. About this time, they had turned to White ash. The crucibles and the contents then cooled at room temperature in desiccators and reweighed.

The formula used to determine ash content is thus:

$$Ash\ Content = \frac{Weight\ of\ ash}{Original\ weight\ of\ sample} \times 100$$

3. RESULTS AND DISCUSSION

Descriptive statistic tools such as means and analysis of variance (ANOVA) were used to analyze objectives.

3.1 Results

The following steps were taken in obtaining the calorimeter used, when determine the calorific values of the samples.

Mass of Benzoic acid (S_b) = 0.3 84g
Calorific value of Benzoic acid = 6.32 kcal g '1
Galvanometer deflection without sample (X_1) = I division
Galvanometer deflection with Benzoic acid (X_2) = 6.3 divisions
Calibration constant represented by (Φ)

$$\Phi = 6.32 \times \frac{Sb}{X1 - X2} \tag{3.1}$$

Φ = 0.46.

The calorific values of the various sample was calculated thus:

Let mass of sample = Z g
Galvanometer deflection with sample = X_3 division
Heat releases from sample Z = (X_3 — X_1) Φ
Therefore, calorific value of sample = (X_3 — X_1) Φ / Z kcal'1

$$\Phi = 6.32 \times \frac{Sb}{X1 - X2}$$

Φ = 0.46

Table 1. Moisture content and ash content (dry matter) of sample briquettes made from *Pinus caribea* and *Eucalyptus citirodora*

Sample (%)	Composition Ratio (g)	Weight of Crusible	Weight Crusible + Sample 1	Weight Crusible + Sample 2	Weight Crusible + Sample 3	Weight Crusible + Sample 3	% Moisture
Eucalyptus	50:50	5	20.00	25.00	23.30	66.00	34.00
citirodora	60:40	5	20.15	25.15	24.07	79.02	20.98
	70:30	5	20.00	25.00	24.13	82.60	17.40
Control	100	5	20.12	25.12	23.00	58.54	41.41
Pinus	50:50	5	20.00	25.00	22.70	54.00	41.41
caribea	60:40	5	20.04	25.04	22.80	55.20	44.80
	70:30	5	20.00	25.00	22.40	48.00	52.00
Control	100	5	20.03	25.03	22.06	40.60	59.40

Table 2. Calorific value of samples

Sample	% Composition	X_1(MJ/Kg^{-1})	X_2(MJ/Kg^{-1})	X_3(MJ/Kg^{-1})	Mean
Eucalyptus	50:50	19.18	18.19	20.87	19.41
citriodora	60:40	19.05	19.14	19.34	19.34
	70:30	19.32	18.15	18.53	18.53
Control	100	19.14	14.03	14.03	14.02
Pinus	50:50	17.22	17.77	17.34	17.34
caribaea	60:40	18.83	18.16	18.60	18.60
	70:30	18.32	18.06	18.44	18.44
Control	100	13.05	13.07	13.33	13.33

Table 3. ANOVA table for calorific test

Sources of Variance	Degree of Feedom	Sum of Squares	MeanSum of Squares	F- Cal	F-Tab	Comment
A	1	68.97	33.69	32.42	3.32	**
B	2	13.14	4.08	4.07	2.69	*
AB	2	09.64	1.33	1.33	2.27	*
Error	18	21.74	0.92			

***Highly significant *Insignificant*

Table 2 revealed that the binder at various proportion increases the average calorific values (q) remarkably particularly when compared with the briquettes produced from 100% pure sawdust materials i.e control. The *Eucalyptus citriodora* has the higher calorific value than *Pinus caribaea.*

In Table 3, the effect of the percentage composition of starch binder on the calorific value is significant. There is a significant added variance component on the calorific value at P<0.05 level of significant. Therefore, the addition of starch into the briquettes caused an improvement in their calorific values.

4. CONCLUSION

From the results, the control samples moisture contents percentage showed that *Pinus caribaea* (59.40%) higher than *Eucalyptus citriodara* (4l.41%). The low calorific value of the briquettes is probably as a result of the presence of other materials in the briquette. This indicated that the bind used to control the heat content of the briquettes material. The state of materials used for briquettes production could also affect the density and calorific values. Wood wastes like sawdust are suitable for the production of briquettes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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