Journal of Forestry Research and Management. Vol. 23 (1). 119- 127; 2026, ISSN 0189-8418

www.jfrm.org.ng

Comparative Study of Briquettes Produced from Combined Sawdust of Three Tropical Hardwood Species

*[1]Adebayo, J. O., [2]Elesho, R. O., [2]Aluko, A. K., [2]Majekodunmi, O. A., [2]Yusuf, A. A., [2]Adeniran, T., [2]Aderemi. F. T., and [3]Adetona, A. O

[1] Forestry Research Institute of Nigeria, Derived Savanna Research Station, Al-Hikmah University, Igbaja Campus, Igbaja, Kwara State.
[2]Federal College of Forestry, Jericho, Ibadan.
[3] Department of Forest Production and Products, University of Ibadan
Corresponding author: ologsoljim@gmail.com: 08029545279

ABSTRACT

As a byproduct got from wood industry, sawdust causes great environmental and economic challenges as a result of its disposal. With the increasing rate of deforestation and high demand for energy for domestic and industrial uses, coupled with the climate change menace, technology of briquetting is gaining global support. Therefore, saw dusts of three hardwood species were selected in this study with a view to maximizing their utilization potential for briquette production. Sawdust of three Tropical hardwood species (*Antiaris africana* (A)*, Anogeisus leocarpus* (B) and *Tectona grandis* (C) were air-dried to 12% moisture content and mixed with one another in equal proportion (1:1) to form three different groups of sawdust (AB, AC and BC). Each group was then mixed with cassava-starch binder. Mixture of sawdust and binder was then moved to the compression chamber of the hydraulic press for briquet production.Moisture content (%), Density (g/cm^3), Calorific value (Kcal/Kg), Fixed carbon (%) and Ash content (%) were determined according to Standards. Data were analyzed with descriptive statistics and Analysis of Variance at$\alpha_{0.05}$.Moisture content (%) varied from 3.2 3.2±0.00 % (BC) to 3.43.2±0.00 % % (AB). Density (g/cm^3), varied from 348±1.0 (AB) to 355.6 ±0.55Kg/m^3 (BC). Calorific value ranged from of 28,128.20±2.95Kcal/Kg (AB) to 28,539.20 ±3.42 Kcal/Kg (BC). The fixed carbon ranged from 7.914±1.34% (AB) to 8.554±0.01% (AC and BC). The ash content ranged from 16.836±0.01% (BC) to 17.676±0.01% (AB). Analysis of Variance showed that density, calorific value and ash content were significantly different. Based on the International Standards, moisture content, density, fixed carbon and ash content of briquettes produced from the sawdust of *Antiaris africana*, *Anogeisus leocarpus*, and *Tectona grandis* were below the grade B classification of briquettes. They possessed the grade C combustion characteristics of briquettes which are suitable for small-scale and residential applications.

Keywords: Briquettes, Standards, Calorific value, Fixed Carbon, Ash content

Introduction

Sawdust is generated as a waste product during sawing, milling planning, routing, drilling and sanding woodworking operations (Ghosh *et al*., 2018; Lennox *et al.,* 2019). Sawdust has physical characteristics of high-water retention capacity, low density and high rate of combustion especially when properly dried (Inegbedion 2022). As a byproduct got from wood industry, sawdust causes great environmental and economic challenges as a result of its disposal (Benjeddou, 2025). Proper management and disposal of saw dusts are very important because of the associated

environmental and health hazards. Improper management saw dusts cause pollution to the environment (Deac *et al.,* 2016). Histological and Hematological studies have shown that saw dusts as vegetative-derivative organic matters and also as suspended particulates, contain carcinogenic heavy metals which include lead, arsenic, antimony, cadmium and mercury and can cause lung disease in children and teenagers (Omigie *et al.,* 2024). As a source of high fire hazard or explosion, improper management of saw dusts can endanger the life of employees or damage buildings (Hastings Insurance, 2025).

Sawdust has been found useful in so many ways in agriculture. It is used as a growing medium for seeds, as a compost material and as a poultry bedding material. Apart from fossil oil, several sources of energy are available and can substitute fossil oil. They include solar, biomass, hydro-electric power, thermal and wind. However, the sustainable energy of cardon-source which is used globally is bio-fuel (Onwugbuta *et al.,* 2023). With the increasing rate of deforestation and high demand for energy for domestic and industrial uses, and also coupled with the climate change menace, technology of briquetting is gaining global support. James and Akpete (2023) considered utilization of saw dust in the indoor environment as a remedy for climate change. Briquette is produced by compressing saw dust under high pressure into a solid material using briquetting machine. It is a process of producing a solid block material that involves converting biomass materials which lack plasticity and require addition of a combustible sticking or agglomerating material for solidification (Fikremariam *et al.*2020; Osador, 2006). Production methods of briquette are of two types.

It can be produced mechanically by pressing saw dust under high temperature and pressure. While high temperature melts the lignin content of the wood to serve as a binder, high pressure compacts the saw dust into a solid product. Manual method on the other hand requires a binding material like waste paper (pulp), starch or clay). The efficient utilization of saw dust is the sustainable production of briquettes for heat energy. Studies on suitability of different residues for briquette production have been carried out. Important properties studied by Chin and Sidiqqui (2010); and Demirbas (2014) include binder content, dwell time, briquette durability, handling, strength property, relaxation behavior after brought out of the mold, density and moisture content and were reported to be appropriate for briquette production. However, there is insufficient information on combination of sawdust obtained from different wood species. This study therefore investigates moisture content, density, calorific value and ash content as characteristic properties of briquettes produced from different combination of *Annogesius leocarpus, Antiaris Africana* and *Tectona grandis* with a view to maximizing their utilization potential.

Materials and Method

Sawdust materials of the three Tropical hardwood species (*Antiaris africana* (A)*, Anogeisus leocarpus* (B) and *Tectona grandis* (C) were used in this study. They were collected from Bodija sawmill based on the large size of the sawmill. The cassava binder was purchased at Ojaba market. The hydraulic operated mold briquette machine, weighing balance, a 2mm-sieve, cold water, bomb calorimeter (Isothermal Calorimeter Jacket), muffle furnace, analytical balance, drying oven and a crucible (porcelain) with a tight-fitting

Journal of Forestry Research and Management. Vol. 23 (1). 119- 127; 2026, ISSN 0189-8418
www.jfrm.org.ng

lid. This study was carried out in the Department of Wood Products Engineering, Faculty of Technology, University of Ibadan.

Sawdust raw materials of the three Tropical hardwood species (*Antiaris africana* (A), *Anogeisus leocarpus* (B) and *Tectona grandis* (C) were air-dried to 12% moisture content. They were then mixed with one another in equal proportion (1:1) to form three different groups of sawdust raw materials classified as AB (*Antiaris africana* with *Anogeisus leocarpus*), AC (*Antiaris Africana* with *Tectona grandis*) and BC (*Anogeisus leocarpus* with *Tectona grandis*). Each group was then mixed with cassava starch binder.

The binder (25g cassava starch) was dissolved in 100cm^3 of boiling water and stirred continuously until a paste of the binder was obtained. The mixture of sawdust and binder was then moved to the compression chamber of the hydraulic press. In the compression chamber, the materials were compacted together. This was done by the hydraulic jack which forced a piston into the chamber. The pressure was kept constant for a dwell-time of five minutes for the formed briquettes to stabilized. After stabilization, the hydraulic ram was reversed from the machine and the briquettes were brought out of the machine. Finally, the produced briquettes were air-dried for five days to ensure strength of the briquettes.

The experimental design adopted for this study was Completely Randomized Design (CRD) with five replicates.

Determination of Properties

Moisture Content (%)

Moisture content of the briquette was determined in accordance with the ASTM E871. Gravimetric oven drying method was adopted. Briquettes were weighed before oven-drying and after oven-drying. The percentage moisture content was calculated with the formula:

$$\text{Moisture Content (\%)} = \frac{w1-w2\ x100}{w2} \ldots\ldots\ldots\ldots 2$$

Where w1= wet weight, w2= oven-dried weight.

Density (g/cm^3)

Density (g/cm^3) was performed in accordance with ASTM D2395-17 (2022)Standard Test Methods for Density and Specific Gravity of Wood and Wood-Based Materials

Briquettes were oven-dried to 12% moisture content in an oven. Digital weighing balance was used to weigh the briquettes (45g). A caliper was used to measure the thickness (2.5 cm) diameter (5.0cm) and central hole (1.6cm). The cylindrical geometric volume (V) was calculated using relation:

$$V= \pi\ ^2h \ldots\ldots\ldots\ldots\ldots 3$$

Where V= volume of a cylinder,
$\pi\ ^2$= 3.14
h= height of cylinder

Density was calculated using the formula:

$$D= \frac{m}{v} \ldots\ldots\ldots\ldots\ldots 4$$

Where D= density (g/cm^3)

M= mass (g).

Gross Calorific Value (KJ/kg)

Gross Calorific Value (KJ/kg) was determined in accordance with ASTM E711-23 (reapproved 2023 which employs the use of bomb calorimeter (Isothermal Calorimeter Jacket). The sample was burned in a high-pressure oxygen bomb calorimeter. The rise in temperature was measured. Calculations

Journal of Forestry Research and Management. Vol. 23 (1). 119- 127; 2026, ISSN 0189-8418
www.jfrm.org.ng

usually include thermochemical corrections for Sulphur and Nitrogen acids.

Heat Value (Kj/kg) was calculated using the formula:

Cv= $2326(147.2C + 144v)$…….5

Where Cv= calorific value
c= % fixed carbon
v= % volatile matter.

Fixed Carbon (%)

Fixed carbon was determined through proximate analysis (Residual Moisture, ASTM E790-21; Ash Content, ASTM D1102—84; and Volatile Matter, ASTM E897). It was calculated by subtracting the moisture content (%), ash Content and volatile matter from 100%.

FC (%) = $100 - (\%MC + \%AC + \%VM)$……6

Where:

FC= Fixed carbon
MC= Moisture content
AC= Ash content
VM= Volatile matter

Ash Content (%)

Ash Content which determines the mineral content of wood was expressed as the percentage of the remaining residue after briquettes were oxidized in accordance with the ASTM D1102—84 (2013). Sample was prepared by grinding 2g of briquette to pass No. 40 (425- µm) sieve. Free weight was determined by placing the 2g sample in tared crucible and then weighed. It was then dried in an oven at 100-105^{0}C with the lid removed. After 1hr, the lid was replaced, cooled in a desiccator and then weighed. This process was repeated until a constant weight within 0.1mg was attained to find the weight of oven-dry sample (W_2). The sample was incinerated (oxidation process) by placing the uncovered crucible in the muffle furnace and heated slowly initially to prevent burning. The final temperature was kept between 580-600^{0}C. Finally, the covered crucible was cooled in a desiccator and weighed. Heating cycles of 30-minute were repeated until a constat weight was obtained within 0.2mg so as to get ash weight (W_1).

Ash Content (%) was calculated using the formula:

Ash Content (%) = $\frac{w1\ x100}{w2}$……7

Where w_1= weight of ash,
W_2= weight of oven-dry sample.

Results and Discussion

Moisture Content (%)

The mean moisture content of thebriquettes as shown in Table 1 ranged from of 3.2±0.00 % observed in the briquettes produced with BC. This was closely followed by 3.3±0.00 % observed in AC. The highest moisture content of 3.4±0.00±0.00 was observed in AB. These average values were lower than mean 5.04% reported by Inegbedion (2022) in a study carried out on sawdust briquette production in Benin City (Nigeria). However, the species of the wood used was undisclosed but the observed values in this study were preferred to 5.04% reported by Inegbedion (2022) because low moisture content is required for good combustion of biofuel. These observed results also showed that the values of the moisture content were less than the specified moisture content of ≤15 % (w-w wet weight) by the EN ISO 17225- 3 ISO 17225- 3 (2021) for top quality briquettes. The implication of this result was that these briquettes possessed low-grade moisture content and were only suitable for small-scale and residential uses.

Journal of Forestry Research and Management. Vol. 23 (1). 119- 127; 2026, ISSN 0189-8418
www.jfrm.org.ng

Analysis of variance showed that there was no significant difference in the percentage moisture of the briquettes used in this study (0.05 P≤0.996).

Density

The results of the density of the briquettes were shown in Table 1. The mean density of thebriquettes ranged from of 348±1.0Kg/m^3 observed in the briquettes produced with AB. This was closely followed by 351.2±1.10Kg/m^3 observed in AC. The highest density content of 355.6 ±0.55Kg/m^3 was observed in BC. These results were by far higher than 10.3Kg/m^3reported by Onwugbuta *et al.,* (2023) where mixing ratio of sawdust to starch binder (8:2) was used in an unspecified species of sawdust. However, they were similar to the range of 218.2-322.6Kg/m^3reported by Mengist *et al*., (2020). These values were lower than 1000Kg/m^3 recommended by ISO 17225- 3 ISO 17225- 3 (2021) for top quality briquettes. High wood density is required for high calorific value and long burning period. The implication of this result was that these briquettes possessed density of low-quality suitable for small-scale and residential uses.

Analysis of variance (Table2) showed that there were significant differences in the density values of the briquettes used in this study (0.00 ≤P0.05).

Heat/Calorific Value

The result of the Heat/Calorific was presented in Table 1. The mean Calorific Valueof the briquettes ranged from of 28,128.20±2.95Kcal/Kg as observed in the briquettes produced with AB. This was closely followed by 28,337.40±8.56Kcal/Kg observed in AC. The highest calorific valueof 28,539.20 ±3.42 Kcal/Kg was observed in BC. These average values were higher than the range of 14.5-18.4MJ/Kg (14,500-18,400Kcal/Kg) reported by Mengist*et al*., (2020) in a study carried out on sawdust briquette production with undisclosed wood species using molding cylinders of diameter 6,8, and 10cm in Ethiopia. However, these results were similar to range of 28,494.33, 28,528.33 and 28794 Kcal/Kg in mixed three Tropical hardwood species (*Afzelia africana*, *Terminalia superba* and *Melicia excelsa*) using ash, cow dung and cassava starch binders respectively reported by Emerhi (2011). They were also greater than the 15,500- 16,500 (15.5-16.5MJ/Kg) specification by EN ISO 17225- 3 ISO 17225-3 (2021) for high-quality briquettes. This implied that these briquettes possessed standard calorific values of high-quality suitable for small-scale, residential and industrial applications.

Analysis of variance (Table2) showed that there were significant differences in the percentage calorific values of the briquettes used in this study (0.00 ≤P0.05).

Fixed carbon (%)

The result of the fixed carbonwas presented in Table 1. The mean fixed carbonof the briquettes ranged from 7.914±1.34% which was observed in the briquettes produced with AB. It was closely followed by 8.554±0.01% observed in AC. The mean fixed carbonvalue in BC was similar to AC (8.554±0.01%). Emerhi (2011) reported fixed carbon value of 9.40±0.99, 12.99±1.7 and 9.27±0.61 in three combinations of *Afzelia africana*, *Terminalia superba* and *Melicia excelsa*- AB, BC and AC respectively) similar to the observed values of fixed carbon. Fixed carbon correlates indirectly with burning efficiency and therefore has significant negative effect on the burning efficiency of a combustible material (Onwugbuta *et al*., 2023). A combustible material burns efficiently when its percentage

carbon content is low. Since the percentage ash content and percentage fixed carbon are synonymous in their effects on burning of a combustible material, this implied that these observed values of percentage fixed carbon belong to class C (low-quality grade) briquettes which are suitable for small-scale and residential applications.

Analysis of variance (Table 2) showed that there were no significant differences in the percentage fixed carbon of the briquettes used in this study ($0.05 \leq P \leq 0.31$).

Ash Content (%)

The result of ash content in Table 1 showed that AB had the highest percentage ash content (17.676±0.01%). The percentage ash content of AC was 16.886±0.01% which was lower than AB. In BC, the percentage ash content of was 16.836±0.01%. These values were similar to 19.07± 4.80%, 19.17 ±4.13% and 21, 72± 3.88 reported by Emerhi (2011). The percentage ash content of a combustible material as significant effect on its burning efficiency (Onwugbuta *et al*., 2023). A combustible material burns efficiently when its percentage ash content is low. The observed values of percentage ash content in this study were higher than ISO 17225- 3 (2021) recommendation of ≤3.0% for class B briquettes. The implication is that these observed values of percentage ash content belong to class C (low-quality grade) briquettes which are suitable for small-scale and residential applications. Analysis of variance (Table 2) showed that there were significant differences in the percentage ash content of the briquettes used in this study ($0.00 \leq P 0.05$).

Table 1: Descriptive Statistics of the Species Combination

Properties	*Spp*	N	Mean	Minimum	Maximum	Std. Deviation
Moisture C.	AB	5	3.4	3.4	3.4	0.00
	AC	5	3.3	3.3	3.3	0.00
	BC	5	3.2	3.2	3.2	0.00
Density	AB	5	349	348	350	1.0
	AC	5	351.2	350	352	1.10
	BC	5	355.6	355	356	0.55
Heat Value	AB	5	28128.20	28125	28131	2.95
	AC	5	28337.40	28325	28346	8.56
	BC	5	28539.20	28535	28542	3.42
Fixed Carbon	AB	5	7.914	8.51	8.52	1.34
	AC	5	8.554	8.53	8.54	0.01
	BC	5	8.554	8.55	8.56	0.01
Ash Content	AB	5	17.676	17.67	17.68	0.01
	AC	5	16.886	16.88	16.89	0.01
	BC	5	16.836	16.83	16.84	0.01

Journal of Forestry Research and Management. Vol. 23 (1). 119- 127; 2026, ISSN 0189-8418
www.jfrm.org.ng

Table 2: Analysis of Variance ofMoisture content (%), Density (%), Heat/Calorific value (Kcal/kg), Ash content (%) and Fixed carbon (%)

	SV	Df	SS	MS	F	P
Moisture C.	Spp	2	2.116	1.058	0.004	0.996
	Error	12	3177.468	264.789		
	Total	14	3179.584			
Density	Spp	2	113	56	68	0.00*
	Error	12	10	1		
Total		14	123			
Heat value	Spp	2	4.223481E+05	2.111741E+05	6761	0.00*
	Error	12	3.748000E+02	3.12333E+01		
	Total	14	227229E+05			
Fixed carbon	Spp	2	1.557	0.779	1.293	0.31
	Error	12	7.224	0.602		
	Total	14	8.782			
Ash content	Spp	2	2.220	1.11	37006	0.00*
	Error	12	0.00	0.00		
Total		14	2.221			

Note: *= significant

Conclusion

Briquettes produced from the sawdust raw materials of *Antiaris africana*, *Anogeisus leocarpus*, and *Tectona grandis* exhibited significant variability in density, calorific value and fixed carbon which are principal factors of high-grade refuse derived fuels. Comparison with International Standards showed that moisture content,density fixed carbon and ash content were below the grade B classification of briquettes. Therefore, they felled in grade C classification of briquettes which are suitable for small-scale and residential applications.

References

America Society for Testing and Materials (ASTM D1102-84, 2013). Standard Method for Ash in Woods.

America Society for Testing and Materials (ASTM D2395-17, 2022)Standard Test Methods for Density and Specific Gravity of Wood and Wood-Based Materials.

America Society for Testing and Materials (ASTM E711-23, reapproved 2023). Standard Test Method for Gross Calorific Value (Energy Content) of Solid Refuse - Derived Fuel.

America Society for Testing and Materials (ASTM E790-21). Standard Test Method for Measuring Residual Moisture in Refuse-Derived Fuel (RDF).

America Society for Testing and Materials (ASTM E871- 82, 2006). Standard Method for Determining Moisture content of Biomass Fuels.

America Society for Testing and Materials (ASTM E897, reapproved 2004). Standard Test Method for Measuring Volatile Matter.

Benjeddou, O. (2025). Experimental Investigation of the Impact of the Wood Sawdust Incorporation o the Physical and Thermal Properties of Fired Clay Bricks. *Scientific Report (2025) 15:30855. https://doi.org/10.1038/541598-025-00365-z*

Chin, O and Sidiqqui, K. M. (2010). Characteristics of some Biomass Briquettes Prepared under Modest Dye Pressures. Biomass and Bioenergy, 18: 223-228

Demirbas, A and Sahin, A. (2014). Evaluation of Biomass Residue Briquetting Waste Paper and Wheat Straw Mixtures. *Fuel Processing Technology, 55:175-183.*

Deac, T., Fechte-Tutunaru, L., and Gaspar, F. (2016). Environmental Impact of Briquettes Use- Experimental Approach. *Energy Procedia, 85, 178-183. https://doi.org/10.1016/j.egypro.2025.12.324*

Emerhi, E. A. (2011). Physical and Combustion Properties of Briquette Produced from Sawdust of Three Hardwood Species and Different Organic Binders. *Advances in Applied Science and Research, 2011, 2(6): 236-246. Available online at www.pelagiaresearchlibrary.com*

Fikremariam, H., Gemechu, Y., Mahelete, T., Tegenu,T., Abraham, D., Buzayehu, D., Amsalu, B., Tawabech,A., Yihunie, B., Yonas, B and Degnechew, G. (2020). Production and Characterization of Briquettes from Carbonized *Cupressus lusitanica* Sawdust with Different Organic Binders. *International Journal of Recent Research, 11(12), 2020, pp.40189-40194*

Ghosh, B., Das, B., Sonni, B., and Saurav, A. (2018). Experimental Investigation on Feasibility of Using Sawdust as Partial Replacement of Fine Aggregate in Cement. School of Civil Engineering, Kalinga Institute of Industrial Technology. doi: *https://doi.org/10.13140/RG.2.2.115053.95206*

Hastings Insurance (2025). Woodworking Operations- Fire and Dust Explosion Hazards. *https://hastinginsurance.com/safety-tips/safety-post/safety-thoughts/woodworking-operations-fire-and-dust-explosion-hazards*

Inegbedion, F. (2022). Estimation of Moisture Content, Volatile Matter, Ash Content, Fixed Carbon and Calorific Values of Saw Dust Briquettes. *MANAS Journal of Engineering, Volume 10, Issuse 1 (2022) Pages 17-20. https://doi.org./10.51354/mjen.940760*

International Organization of Standards (ISO 17225-3. 2021 en): Solid Biofuels- Fuel Specifications and Classes- Part 3: Graded.

James and Akpete, A. (2023). Considering Sawdust as a Potential Raw Material for Climate Change Mitigation in Indoor Environment. *Technology Audit and Production Reserves 6 (3/68), S. 24-28. http://journals.uran.ua/tarp/article/download/270479/266576/624974.Doi:1015587/2706-5448.2022.270479.*

Lennox, J. A., Asitok, A., Johnson, G. E., and Etim, B. T. (2019). Characterization of Products from Sawdust Biodegradation using Selected Microbial Culture Isolated from it. African *Journal of Biotechnology, I8 (29), 857-864.*

Mengist, M., Wodeyes, B., and Gabbiye, N. (2020). Advances of Science and Technology 8th EAI International Conferences, ICAST 2020, Bahir, Dar. Ethiopia, October 2-4 Proceedings, Part 11.

Omigie, M. I., Iyawe, V. I and Aihie, E. O. (2024). Effect of Environmental Dust Pollution (Particulate Matter of Sawdust) on Histology of the Lungs Hematological Parameters of Adult Wistar Rats. *Newport International Journal of Research in Medical Sciences (NURMS), Volume 5(2): 34-47. https://doi.org/10.59298/NIJRMS/2024/5.2.03447*

Onwugbuta, G. C., Ononiwu, C. F., and John, G. N. (2023). The Production of Briquette from Sawdust and Waste Paper using Manual Briquetting Machine. *Scholar Journal of Science and Technology Research and Development. ISSN: 2955-0807 Vol. 2, Issue 4 (April, 2023).www.ijaraar.ogr.sjstrd*

Osador, O. O. (2006). Performance Evaluation of Different Briquettes Produced from Wood and Agricultural Wastes. *Journal of Engineering Science and Applications, 4(2), 2006, pp. 90-95.*