FUEL PROPERTIES OF SMOKELESS BRIQUETTE MADE FROM DEAD LEAVES OF *Tectona grandis* (LINN.)

[1]Afolabi, S. O., [1]Oluwadare, A. O., and [2]Areo, O. S.
[1.] *Department of Forest Production and Products University of Ibadan*
[2.] *Forestry Research Institute of Nigeria*

ABSTRACT

As there is a huge demand to find alternatives clean energy that would replace the depleting and non-environmentally friendly fossils fuels for domestic and industrial purposes, biomass briquette shows great potential. Therefore, this study investigated the fuel properties of briquette made from dead leaves of Tectona grandis (Linn.). 500g of the samples of the raw material was pyrolysed at 450˚C and then mixed with cassava flour binder varied at 20%, 25%, 30% and 35% of the weight of biomass sample and briquetted using a mold with hydraulic press at an average pressure of 6 psi. The briquettes produced were subjected to both physical and combustion tests. The pyrolysed samples of the shredded leaves of Tectona grandis gave percentage yield of 56.03%, 1.47%, 4.91% and 37.59% for bio-char, bio-oil, water and gas respectively. The mean percentage value for the elements were: 41.78±0.01, 5.33±0.01, 40.70±0.09, 1.185±0.00 and 0.196±0.00 for Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur respectively. The range of values for the briquette produced were: moisture content (11.33±0.47 - 12.65±0.49%), bulk density (0.50±0.01 - 0.67±0.01g/cm^3), water resistance (71.98±1.35 - 83.24±1.24), Volatile matter (41.40±0.58 - 47.60±0.32%), ash content (18.40±0.51 - 23.20±0.73%), fixed carbon and Heating values (26020.12±256.05 - 27621.15±180.13 KJ/kg). The briquette is ecological friendly because of low content of sulphur and nitrogen. Therefore, based on ultimate, physical and combustion characteristics, the dead leaves of Tectona grandis are recommended for the production of biomass briquette for domestic and industrial use.

Keywords: *Tectona grandis, dead leaves, Briquette, Biomass, smokeless*

INTRODUCTION

In every part of the world, biomass energy remains an integral part of renewable energy. Its importance in nationwide energy blend both for developed counties and in countries that have their economy in transition towards achieving sustainable energy cannot be over emphasized (Hoang *et al.,* 2021). In developing countries, 70% to 90% of the total energy uses are constituted by the energy used for cooking. The increased culture of cooking with solid fuels like traditional biomass and coal can have a negative impact on human health, forest, land as well as climate change (Kumlachew *et al.*, 2014).

In Nigeria, the main sources of domestic energy are fuel wood and charcoal. Statistically, over 50 million metric tons of fuel wood is consumed every year in which 60% of the consumers reside in the rural areas. These account for more than 50% of the total yearly energy usage. Natural gas 5.2%, hydroelectricity 3.1%, and petroleum products 41.3% which accounts for 5%, 3% and 41% are other sources of energy. (Oyelaran *et al.,* 2015). Due to high carbon emission, decreasing availability of fuelwood, deforestation as well as desertification, these sources of energy contributed to global warming. As such, there is a need for alternative sources of energy which is renewable for domestic, low-income society and industrial use.

Babajide *et al.* (2018) reported that this source of energy must be steady, cheap and renewable due to decrease in availability of fuelwood every year. As such, there is a need for an urgent shift into a sustainable source of energy. Aina *et al.,* (2009) opined that fuel briquette is a suitable replacement for fuelwood as fuel briquette is clean, very convenient to use and has a greater heat intensity than fuelwood. The solution to the present and future problems of energy need in developing countries is diversification of energy resources by producing energy from readily available renewable natural resources (Amalinda et al., 2020).

Fuel briquettes are a type of energy derived primarily from biomass. They are made by compacting biomass material into a solid unit using manual or mechanical equipment or other processes, with or without the addition of a binder. Briquettes for fuel can be manufactured from either non-carbonised or carbonised biomass. The objective of this study is to determine the fuel characteristics and suitability of *Tectona grandis* dead leaves for the production of briquette with a view to converting the dead leaves to a useful domestic energy products.

MATERIALS AND METHOD

Procurement of *Tectona grandis* Leaves

The leaf litters from *Tectona grandis* trees was collected at the Department of Forest Production and Products, University of Ibadan. Hammer mill was used to shred the leaves into smaller particles. In order to reduce the moisture content of the milled product,

samples were sundried for 7 days in line with Noah *et al* 2019. The milled and sundried biomass was pyrolysed at the Department of Mechanical Engineering, Faculty of Technology, University of Ibadan by using an electric pyrolyser.
Manual hydraulic press was used to produce briquettes at the laboratory of the Department of Mechanical Engineering, University of Ibadan from the pyrolysed leaf biomass of the tree species. For each of the briquette production set, 500g of the pyrolysed sample was mixed with prepared binder (cassava flour) until mould-condition was achieved with the binder content at 20%, 25%, 30% and 35% variation of the sample based on performance ratio described by Sotannde *et al*. (2010). The mixture of the biomass and binder was then fed into a hydraulic mold which was covered at each of the ends with a lid and compressed at a pressure of 6psi.

Determination of Physical Properties
The following physical properties were assessed on the briquette produced
Bulk Density
Density is the mass of a sample per its unit volume. The mass of the sample was determined by weighing on meter balance. The volume of each briquette sample was estimated from the dimensions measured, using a vernier caliper (Sawadogo *et.al*, 2018).

$$\text{Bulk Density} = \frac{m}{v}\ \text{gcm}^3 \qquad (1)$$

Where.
m = mass of the sample (g)
v = volume of the sample (cm^3)

Water Absorption Capacity
The water resistance capacity of the dry briquettes was determined by submerging five different samples for each of the biomass produced in a container full of distilled water at room temperature for 120 seconds (Davies and Davies 2013). Changes in dimension of each briquette was measured.

$$\%\text{water gained by briquette} = \frac{M2-M1}{M1} \times 100 \qquad (2)$$

Where,
M_1 = Initial weight of briquette before immersion and
M_2 = Final weight of briquette after immersion.

The equation becomes water resistance capacity (%) = 100% − %water absorbed (Davies and Davies 2013).
Proximate Analysis
Water Boiling Test
This test is used to compare the briquettes' cooking efficiency by calculating how long it will take each set of briquettes to boil an equivalent volume of water under the same conditions according to Onuegbu *et al.* (2011). 100g of each briquette sample was combusted to boil 100cm^3 of water in a small stainless pot using a household charcoal stove.

Ignition Time Determination
Ignition time was determined as described by Onuegbu *et al* (2011). In each test a single briquette was placed alone in the center with the Bunsen burner placed directly beneath it. Bunsen burner was adjusted to blue flame and it was also ensuring that the whole of the bottom surface of the briquette was ignited simultaneously. The time taken for the briquette to be ignited was recorded in seconds.

Burning Rates Determination
This is the determination of the degree at which a certain weight of fuel is burnt in the air. The degree of briquettes burning was determined by taking the record of the briquettes weight before ignition and after the briquettes were completely burnt in air, the degree at which briquette samples was burnt was determined using equation 3 (Onuegbu *et al.*, 2011).

$$\text{Burning Rate (gmin}^{-1}) = \frac{\text{total mass of the burnt briquette in air (g)}}{Period\ \text{(min)}} \qquad (3)$$

Percentage Ash Content
2g of oven-dried briquette sample was weighed into a crucible set in a furnace at 550ºC temperature for 4 hours. The ash was weighed after cooling. The percentage of the ash content of the sample was calculated using the equation 4.

$$\text{Ash Content (\%)} = \frac{A}{W} \times 100 \qquad (4)$$

Where:
A = weight of ash (g)
W = weight of oven dried briquette sample (g)

Percentage Volatile Matter

This is the amount of compound that will evolve during a given period of time in the furnace under specified conditions. The volatile matter was gotten by placing 2g of crushed briquette sample in a crucible in the furnace for 10 min at 550ºC temperature. At the expiration of the duration in the furnace, the left over in the crucible was cooled in a desiccator before weighing to get the percentage of the volatile matter.

Volatile matter (%) = $\frac{B-C}{B} \times 100$ (5)

Where:

B= weight of oven-dried briquette sample (g)

C = weight of briquette sample after 10minutes in the furnace at 550^0C

Percentage Fixed Carbon

The fixed carbon percentage was determined by using the equation 6:

Percentage fixed Carbon = 100 – (%VM + %AC) (6)

Where:

%VM = percentage volatile matter

% AC = percentage ash content

Heating Value

This is the calorific value of the heat generated by a given sample. Good material for burning must possess high heating value. This was estimated using the equation 7.

HV = 2.326 (147.6FC + 144VM) KJ/kg (7)

Where,

HV = heating value (kJ/kg); FC = percentage fixed carbon; VM = percentage volatile matter

Moisture Content

Moisture content of a given material, is the percentage of water in that material. The moisture content was calculated according to Noah *et al* (2019). Samples of briquette produced was weighed on a digital weighing balance, placed in the oven at a 103±2ºC temperature and weighed at intermittently for 120 minutes until a uniform weight was obtained. The oven-dry moisture content of the briquette will be calculated as follows.

MC (%) = $\frac{A1-A2}{A2} \times 100$ (8)

Where, MC = percentage moisture content

A1 = initial weight of the sample before oven drying (g)

A2 = final weight of the sample after oven drying (g)

Data Analysis

A 1 x 4 factorial experiment with pyrolyzed biomass materials at 1 and 4 levels of binder was employed in a completely randomized design. The data obtained for the physical and combustion properties from the briquette produced were subjected to Analysis of Variance (ANOVA). Duncan multiple range test would be used as a follow-up technique. All of the investigated properties' means and standard deviations were computed. SPSS was used to conduct all analyses.

RESULTS AND DISCUSSION

Yield of each components of the biomass

Table 1 shows the percentage composition of the pyrolysis product in each of the biomass material. The pyrolysis carried out at 550ºC for the shredded dry leaves of Tectona grandis shows the yield percentage of 56.03%, 1.50%, 4.88% and 41.98% for bio-char, bio-oil, water and gas respectively. According to Shadangi and Mohanty (2014), the yield of each component of the biomass materials has a relationship with the pyrolysis temperature. This means that the yield of the solid and liquid components reduces with increase in temperature used for the pyrolysis. According to Demirbas (2007), char, persistent gases, and vapours that condense to a dark brown viscous liquid at ambient temperature are the three principal products of biomass pyrolysis.

Table 1: Yield of each components of the biomass

Components of *Tectona grandis*	Value (kg)	Yield (%)
Weight of Biomass	11.6	-
Weight of bio-char	6.5	56.03
Weight of bio-oil	0.17	1.47
Weight of water	0.57	4.91

Weight of gas	4.36	37.59

Weight of bio-char, bio-oil and water were measured while weight of gas was estimated.

Ultimate Analysis

The elemental analysis of biomass expresses the mass concentration of the key elements (Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur) present in the biomass. Table 2 shows the mean percentage of the elements analyzed. The mean values are 41.78±0.01, 5.33±0.01, 40.70±0.09, 1.185±0.00 and 0.196±0.00 for Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur respectively. The findings corroborate those of Akowuah et al. (2012), who found that study of biomass utilizing gas analysis methodologies indicated carbon as the primary ingredient, accounting for between 30 and 60 percent of the dry matter and frequently 30 to 40 percent oxygen. Hydrogen, the third most abundant element, accounts for roughly 5% to 6% of dry biomass, whereas nitrogen and sulphur (together with chlorine) account for less than 1%.

Table 2: Mean value of ultimate analysis of the biomass materials

% Carbon	% Hydrogen	% Oxygen	% Nitrogen	% Sulphur
41.78±0.01	5.33±0.01	40.70±0.09	1.185±0.00	0.196±0.00

Bulk Density

Briquette density is a measure of its strength and it is determined by moisture content as well as compaction pressure (Gendek *et al*, 2018). The bulk density (Table 3) increased with increase in binder proportion. The briquette has the highest and lowest density of 0.67±0.01g/cm^3 and 0.50±0.01g/cm^3 respectively. These values are close to the range of 0.63 g/cm^3 and 0.54 g/cm^3 reported by Birwatkar *et al* (2014) in their work on physical and thermal properties of biomass briquetted fuel. Increased density enhances the briquettes' strength, at least in terms of handling characteristics.

Water Resistance Testing

Water resistance testing was conducted to evaluate the rate at which briquettes degrade in high humidity or water exposure. The water resistance (Table 3) range for the briquette was between 71.98±1.35 - 83.24±1.24. The values reported in this study are comparable to those obtained by Rajaseenivasan *et al.* (2016) for sawdust and neem powder briquettes. The hygroscopic property of briquettes at various binder proportions revealed that the amount of binder used increased the water resistance capacity. Briquettes exposed to rain or high humidity conditions during shipping and storage may have a negative impact on their quality.

Volatile Matter

Volatile matter is a mixture of short- and long- chain hydrocarbons that are released during burning, such as combustible or incombustible gases, or a combination of the two. These gases have a considerable impact on the burning of briquettes. The highest and lowest volatile matter (Table 4) was 47.60±0.32% and 41.40±0.58% respectively. The volatile matter of the briquettes produced in this study falls within the range of 43 - 49% obtained by Mulindwa *et al.* (2021) for briquettes made from mixed tropical hardwood species sawdust. However, Adetogun *et al.* (2014) discovered that maize cob briquettes had a higher volatile matter concentration, ranging from 57.82 to 62.91% High volatile matter results in high combustibility at low ash concentration.

Heating Value

The calorific value, often known as the heating value, is a standard measure of the energy content of a fuel. The heating value (Table 4) of the briquette ranges from 26020.12±256.05 - 27621.15±180.13. The heating value recorded in this study is within the range of values (4937 kcal/kg–12,665.67 kcal/kg) reported by (Aina *et al.,* 2009). The amount of energy produced by the briquettes created in this study is sufficient to generate heat for both household cooking and small-scale industrial cottage applications.

Ignition Time

The ignition time (Table 4) obtained in this study increases with increase in binder level. It ranges from 104.40±2.08 sec at 20% binder level to 143.80±2.29 sec at 35% binder level. This could be attributed to an increase in density, as evidenced by the findings of Ige *et al.,* (2020), who discovered that density affects flame propagation in briquettes. Because there are fewer open areas for mass diffusion in low porosity briquettes, drying, devolatilization, and char burning processes are hampered.

Burning Rate

According to the findings of this study, the obtained burning rate values of the briquettes reduced as the binder proportion increased. 0.17±0.002 at 35% binder level and 0.22±0.003 at 20% binder level. The implication of this observation is that cooking with briquettes made from 20% binder may demand more fuel than cooking with briquettes made from 35% binder (Imeh *et al.,* 2017). Briquettes made with a binder content of 35% had the slowest burning rate (Table 5). Onuegbu *et al*. (2011) showed that parameters such as chemical composition and geometry (bulk and packing orientation) of the biomass could be responsible for the burning rate of biomass (briquettes).

Moisture Content

One of the most essential considerations for evaluating briquette durability and igniting propensity is moisture content. Moisture content value of briquette made from *Tectona grandis* leaves ranged from 11.33±0.47% - 12.65±0.49% (Table 5). As seen, moisture content falls in the range of 10-15%, as reported by (Senchi and Kofa, 2020). Also, (Kpalo *et al*, 2019) report an overall, moisture content of 5.55% and 12.33% in their work on briquette produced from paper pulp and *Mesua ferrea* mixtures. The briquettes' low moisture content is capable of influencing the durability and storage, as well as reduce the amount of energy needed for water evaporation during combustion positively (Sotande *et al*, 2017).

Fixed Carbon

Fixed carbon indicates the percentage of char that remains after volatile stuff is distilled away. The fixed carbon of the briquette increased with increase in binder level and ranges from 32.40±0.5% at 20% binder level to 35.40±0.73% at 35% binder level (Table 5). The fixed carbon reported in this study is higher than 5.75 to 8.28 percent stated by Emerhi (2011) and 9.06 to 11.46% obtained by Mulindwa *et al*. (2021), who all worked on briquettes produced from homogeneous particles. In collaboration with the findings of this study, a good quality and efficient fuel briquette is dependent on reduced volatile matter and ash concentration with greater fixed carbon content.

Water Boiling Test

The results of the water boiling test presented in table 5 demonstrate that the time decreases as the binder concentration decreases and ranges from 11.16±0.01 to 14.25±0.05. This was in contrast to the findings of Ige et al., 2020, who found out that increasing the binder proportion decreased the time while increasing the residence time for the briquettes to complete combustion. The water boiling time was governed by two factors: the burning rate (how quickly the fuel burns) and the caloric value (how much heat is emitted) (Onuegbu et al, 2011). This explains why the lower density sample was able to boil water faster than the higher density sample, despite the fact that the former burns faster. This indicates that while the burning rate is significant, the calorific value is also important in determining cooking efficiency.

Table 3: Mean value of the Physical properties of the briquette

Binder Level	Bulk Density (g/cm³)	Water Absorption (%)	Water Resistance Capacity (%)
35%	0.67±0.01[a]	21.35±1.37 [b]	78.65±1.37 [b]
30%	0.63±0.00 [b]	16.76±1.23 [a]	83.24±1.24 [c]
25%	0.58±0.01 [c]	17.25±1.62 [a]	82.78±1.62 [c]
20%	0.50±0.01 [d]	28.02±1.05 [c]	71.98±1.35 [a]

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

Table 4: Mean value of the proximate analysis of the briquette

Binder Level	Ash Content (%)	Volatile Matter (%)	Heating Value (KJ/kg)	Ignition Time (Seconds)
35%	23.20±0.73 [a]	41.40±0.58 [a]	26020.12±256.05 [a]	143.80±2.29 [d]
30%	22.20±1.46 [a]	46.60±0.81 [b]	26319.89±504.36 [a]	135.60±1.93 [c]
25%	19.20±0.37 [b]	47.60±0.32 [b]	27341.47±125.70 [b]	111.60±2.48 [b]
20%	18.40±0.51 [b]	47.00±0.51 [b]	27621.15±180.13 [b]	104.40±2.08 [a]

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

Table 5: Mean value of the proximate analysis of the briquette

Binder Level	Fixed carbon (%)	Water boiling (min)	Moisture Content (%)	Burning rate
35%	35.40±0.73 [a]	14.25±0.05 [a]	12.65±0.49[a]	0.17±0.002 [a]
30%	34.20±1.46 [a]	13.15±0.03 [b]	11.76±1.14[a]	0.19±0.003 [b]
25%	33.20±0.37 [b]	11.24±0.01 [b]	11.73±0.11[a]	0.19±0.004 [b]
20%	32.40±0.51 [b]	11.16±0.01 [b]	11.33±0.47[a]	0.22±0.003 [c]

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

CONCLUSIONS AND RECOMMENDATIONS

The outcome of this study shows that the briquettes produced from *Tectona grandis* dead leaves exhibit great prospect for use as possible and economical domestic fuel. This biomass material can be used because they are readily available. The comparatively high durability index indicates that the briquettes produced will not disintegrate easily during handling and transportation. The level of the moisture content of the briquettes produced is within acceptable limits and has minimal impact on its calorific value that is high enough to generate the needed energy. The low sulfur and nitrogen contents of biomass have a outstanding prospect to reduce emissions formed during combustion. Therefore, the dead leaves of *Tectona grandis* is recommended as a suitable biomass for briquette production.

REFERENCES

Adetogun, A. C., Ogunjobi, K. M. amd Are, D. B. (2014). Combustion properties of briquettes produced from maize cob of different particle sizes. *Journal* of Research in *Forestry*, *Wildlife* and *Environment* 6.1: 28–38.

Aina, O. M., Adetogun, A. C. and Iyiola, K. A. (2009). Heat Energy from Value-Added Sawdust Briquettes of *Albizia zygia.* *Ethiopian Journal of Environmental Studies and Management* 2.1. 42-49

Akowuah, J. O., Kemausuor, F. and Mitchual, S. J. (2012). Physico-chemical characteristics and market potential of sawdust charcoal briquette. *International Journal* of *Energy* and *Environmental Engineering* 3.3: 1-6

Amalinda F., Muliawan A. and Rismawati1 N. (2020). The effectiveness of tabingga briquettes and corncob briquettes as biocoal. *Journal of Physics*. 1434/012008. doi:10.1088/1742-6596/1434/1/012008

Babajide, C. F., Victoria, I. J., Oluwaseyi O. A. and Rivi D. N. (2018). Performance evaluation of the physical and combustion properties of briquettes produced from agro-wastes and wood residues. *Recycling* 3.37: 1-12

Birwatkar, V. R, Khandetod, Y. P. Mohod, A. G. (2014). Physical and thermal properties of biomass briquetted fuel. *Indian Journal* of *Science* and *Technology* 2.4:55–62.

Davies, R.M and Davies O.A. (2013), Physical and Combustion Characteristics of Briquettes Made from Water Hyacinth and Phytoplankton Scum as Binder. *Journal of Combustion* 1:1-7

Demirbas, A. (2007). Production of gasoline and diesel fuels from bio-materials. *Energy Sources 29*.8: 753–760.

Emerhi, E. A. (2011). Physical and combustion properties of briquettes produced from sawdust of three hardwood *Tectona grandis* and different organic binders. *Advances in Applied Science Research* 2. 6: 236–246

Gendek, A., Aniszewska, M. and Malat'_ak J. (2018). Evaluation of selected physical and mechanical properties of briquettes produced from cones of three coniferous tree species. *Biomass and Bioenergy* 117:173–179.

Hoang, A.T.; Nguyen, X.P. (2021). Integrating renewable sources into energy system for smart city as a sagacious strategy towards clean and sustainable process. *J. Clean. Prod. 305*, 127161.

Ige, A. R, Ogala, H., Elinge, C. M. and Abdulrahman H. (2020). The Effect of Binder Ratio on the Physical and Combustion Characteristics of Carbonized Rice Stalk Briquettes. *International Journal of Advanced Academic Research* 6.10: 2488-9849

Imeh, E. O., Ibrahim A. M., Alewo, O. A., Stanley, I. R. O. and Opeoluwa, O. F (2017). Production and Characterization of Biomass Briquettes from Tannery Solid Waste. *Recycling* 2.4: 17

Kpalo, S. Y., Zainuddin, M. F., Halim, H. B. A., Ahmad A. F. and Abbas Z. (2019). Physical characterization of briquettes produced from paper pulp and *Mesua ferrea* mixtures. *Energy and Power* 10.2: 40-47

Kumlachew, G., Molla, G., Zewdu, D., and Dube, J. (2014). Current level and correlates of traditional cooking energy sources utilization in urban settings in the context of climate change and health, northwest Ethiopia: A Case of Debre Markos Town. *BioMed Research International.* Article 572473. Retrieved Oct. 10, 2021, from https://doi.org/10.1155/2014/572473.

Mulindwa, P., Egesa, D., Osinde, A. and Nyanzi, E. (2021). Production of fuel briquettes from bamboo and agricultural residue as an alternative to charcoal. *Journal of Sustainable Bioenergy Systems* 11.3: 105-117.

Noah, A. S., Abiola, J. K. and Olayiwola, Y. B. (2019). Potential Resource of Used Newsprint and Maize Cob as Energy- Giving Biomass Briquette. *International Journal of Applied Research and Technology 8.8*: 86 – 93.

Obi, O.F.; Pecenka, R.; Clifford, M.J. (2022). A Review of Biomass Briquette Binders and Quality Parameters. *Energies*, *15*, 2426. https://doi.org/10.3390/en1507Onuegbu, T. U., Ekpunobi, U. E., Ogbu, I. M., Ekeoma, M. O., and Obumselu, F. O. 2011. Comparative Studies of Ignition Time and Water Boiling Test of Coal and Biomass Briquettes Blend. *International Journal of Recent Research and Applied Studies.* 7.2: 153-159.

Oyelaran, O. A., Bolaji, B. O., Waheed, M. A. and Adekunle, M. F. (2015). Characterization of Briquettes Produced from Groundnut Shell and Wastepaper Admixture. *Iranica Journal of Energy and Environment* 6.1: 34-38.

Rajaseenivasan, T., Srinivasan, V., Syed M., Qadir, G. and Srithar, K. (2016). An investigation on the performance of sawdust briquette blending with neem powder. *Alexandria Engineering Journal* 5.5: 2833–2838.

Sawadogo, M., Kpai, N., Tankoano I., Tanoh, S.T. and Sidibé S. (2018). Cleaner production in Burkina Faso: Case study of fuel briquettes made from cashew industry waste. *Journal of Cleaner Production* 195:1047–1056.

Senchi, D. S. and Kofa, I. D. (2020). Proximate and Ultimate Analysis of Carbonized Rice Husk Briquettes. *International Journal of Advanced Academic Research* (Sciences, Technology and Engineering) 6.10: 2488-9849

Shadangi, K. P. and Mohanty, K. (2014). Production and characterization of pyrolytic oil by catalytic pyrolysis of Niger seed. *Fuel.* 115: 434-442.

Sotannde, O. A., Oluyege, A. O. and Abah, G.B. (2010). Physical and Combustion Properties of Briquettes from Sawdust of *Azadirachta indica*. *Journal of Forestry Research* 21.1: 63-67.