



## Optimization of Some Engineering Characteristics of Agro-Waste Bonded Water Hyacinth (*EICHHNIA CRASSIPES*) Briquettes

Tariebi, Karikarisei<sup>1</sup>

<sup>1</sup>Department of Agricultural and Environmental Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria.

**Corresponding Author:** Karikariseitariebi@ndu.edu.ng

### Abstract

An Eco-friendly and sustainable approach to the aquatic plants menace on our rivers, is their briquetting, bonded by (banana, yam and cassava - peels) whose presence causes environmental concerns. The study dedicate attention to characterize the quantity-based effect of agro-waste binders on water hyacinth briquettes. Feedstock materials were sourced and accordingly pretreated to 1.18mm size particles. 30g of water hyacinth was used for each of the experiments, while respective agro-wastes individually at concentration levels of 20% to 80% in step increments of 20% were mixed with water hyacinth and 200ml of boiled water. The feedstock was compacted in a 14.21cm high and 2.14cm wide cylindrical die, hydraulically at 5 MPa with 20 minutes dwell time before ejected for further experimentation. From the results of the study, calorific value of water hyacinth briquettes ranged from 25.534MJ/kg to 26.965MJ/kg and expressed significance within and among binders in terms of calorific values at ( $p < 0.05$ ).

**Keywords:** Banana peel, cassava peels, yam peels, briquettes. Aquatic weeds.

### Introduction

The impact of greenhouse gas emissions can be significantly decreased by turning agricultural biomass leftovers into sustainable and renewable biofuels with proper management and use (Maninder *et al.*, 2012). Paper and agricultural waste are often used inefficiently and disposed of improperly, which pollutes the environment and puts both human health and the environment at danger. The goal is to reduce the pollution caused by these materials by turning them into briquettes in order to lessen the threat they pose. Because they are primarily loose, low density materials and their burning cannot be adequately regulated, agricultural wastes in their original forms will not produce the intended results (Maninder *et al.*, 2012). Even though there are other ways to turn these leftovers into biomass energy, the briquetting process is one of the more promising methods. Kaur *et al.*, (2017) and Olurunisola, (2004) defined briquette production as a densification procedure, which is also consistent with the definition of Maninder *et al.* (2012) as compaction of residues to produce end product with higher density. Briquette utilization has the potential to

significantly lower the need for wood and, consequently, deforestation. Furthermore, when it comes to heat intensity, cleanliness, usability, and storage space needs, briquettes are more effective than firewood (Oladeji, 2011). Briquetting is a procedure whereby combustible, naturally loose organic materials are compacted into solid fuels of convenient shapes with high-density. Briquetting improves the engineering properties of the raw materials (Olaoye & Kudabo, 2017). It improves volumetric calorific value and material handling characteristics, while reducing transportation costs. The mold has a major role in determining the intended shape and size of the briquettes whereas qualities such as calorific value and appearance is controlled by the compaction pressure and feedstock kind (Olaoye *et al.*, 2003; Bianca *et al.*, 2014). An environmentally beneficial method of addressing the threat posed by aquatic plants to our rivers and creeks as well as the careless disposal of agro-wastes is to transform them into briquettes, using agricultural waste as binding agents. Because of the benefits of densification, a range of biomass resources,

including sawdust, rice husk, peanut shell, coconut fiber, and palm fruit fiber, have been experimentally transformed into densified fuels. (Tariebi & Davies, 2024a). The current study offers useful details on few combustion characteristics of the briquettes made using 1.18 mm water hyacinth residue particles and, respectively, cassava, yam, and banana peels as binders at various binder ratios and a compaction pressure level of 5 MPa.

**Materials and Methods.**

**Water hyacinth samples Harvest**

In Amatolo Village, located in the Southern Ijaw Local Government Area of Bayelsa State, Nigeria, water hyacinth plants were harvested from a creek. This was followed by pretreatments such as washing, drying, chopping with Knife and finally comminuted to enhance surface area by decreasing particle size to improve its densification (Ajit et al., 2017). The comminuted material of size 1.18mm (Plate 1) for the experiment, was determined with the help of tyler sieves. The milling of the materials was achieved with disk mill (Plate 2) and weighing was done with table top digital balance with 0.01g precision (Plate 3)



Plate 1: water lily grinds of size 1.18mm



Plate 2: Disc Mill



Plate 3: Weighing balance

**Agro-waste collection and Briquette production.**

Feedstock materials such as yam peels, banana peels and cassava peels were sourced from table top vendors and the neighborhood and accordingly pretreated by washing, sun-drying, comminution and sieve analysis to 1.18mm size particles. 30g of water hyacinth residues were used for each of the experiments, while respective agro-wastes individually at concentration levels of 20% to 80% in step increments of 20% were mixed with water hyacinth and 200ml of boiled water inline with ((Tariebi & Davies, 2024a). The resultant, homogenous feedstock was compacted in a 14.21cm high and 2.14cm wide cylindrical die, hydraulically at pressure level of 5 MPa with 20 minutes hold time before the briquettes were ejected and taken for further experimentation.

**Burning rate Evaluation:**

This is the rate of combustion of a given volume of fuel in air (Bintu et al., 2015). This was determined in line with the procedure followed by (Tariebi & Davies,

2024b; Onuegbu et al., 2011). A Bunsen burner was ignited and control to attain a blue flame, a tripod stand holder was then carefully used to hold a sample briquette after it has been pre-weighed, and placed over the flame ensuring only the base of the Briquette was in touch with the flame and in a drought free corner. The sample briquette was left over the gas flame until it was thoroughly ignited, after which it was removed and allowed to burn until it went off on its own. The ignition time, burning time and weight loss was recorded and burning rate evaluated by the following expression:

$$B.R = \frac{M_f}{t} \quad 1$$

Where B.R: is burning rate, in (g/s)

$M_f$ : is total weight of burnt briquette in (g),

and

$t$  : is total time taken.in (s).

**Ignition time Evaluation:**

This was calculated in accordance with the methodology used by (Onuegbu et al., 2011). As previously mentioned, a sample of the briquette was lit

at the base in a corner free of drought. using a stopwatch, the average time it took the briquette to produce a continuous glowing flame was determined to be the ignition time.

**Volatile Matter (VM).**

Proximate analysis was done in-line with ASTM standard E711-87 (2004), at the reactions and kinetics laboratory, Department of Chemical Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, to determine the volatile matter and other related

thermal parameters. As indicated in (Plate 4), a muffle furnace was used to heat two grams of crushed, oven-dried briquette sample in a crucible to 600 degrees Celsius for ten minutes. After letting the sample cool in a desiccator as shown in (Plate 5), the proportion of volatile matter was determined by (formula 3):

$$PVM = \frac{B-C}{B} \times 100 \quad 3$$

Where C: represents the weight of the sample after it has been in the furnace for 10 minutes at 6000 degrees Celsius, and

B: represents the weight of the oven-dried sample.



Plate 4: muffle furnace



Plate 5: Desiccator

**Ash content (PAC):**

Ash content was determined in the Reactions and Kinetics laboratory of the department of chemical engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria, by weighing two grams of the pulverized sample briquette using a weighing balance, which was placed in a crucible and heated for four hours at 600 degrees Celsius in a furnace. The sample was then weighed after cooling in a desiccator and PAC calculated as follows:

$$PAC = \frac{D}{B} \times 100 \quad 4$$

In this case, D - represents the weight of ash and B - represents the weight of the oven-dried sample.

**Fixed Carbon (PFC):**

The proportion of fixed carbon (PFC) was gotten by deducting volatile matter (PVM), moisture content

(MC), and ash content (PAC) from 100 as expressed below:

$$FC = 100 \% - (MC + PAC + PVM) \quad 5$$

**The heating value (Calorific value)**

The heating value (HV) was evaluated with the empirical expression below (Bailey & Blankenhorn, 1982).

$$HV = 2.326 (147.6C + 144V) \quad 6$$

Where V: stands for the volatile matter in percentage,

C: for the fixed carbon proportion and

HV: represents the heating value (kJ·kg<sup>-1</sup>)

**Results and Discussion.**

**Combustion Properties of Water hyacinth Briquettes.**

Plate 6 displays samples of Agro-wastes' boned water hyacinth briquettes and the data obtained on combustion parameters are illustrated in corresponding figures in respective sections.



Plate 6: Agro-waste bonded Water hyacinth briquettes

**The impact of binder type and Level on the Ignition time of Water hyacinth Briquettes (WH-B).**

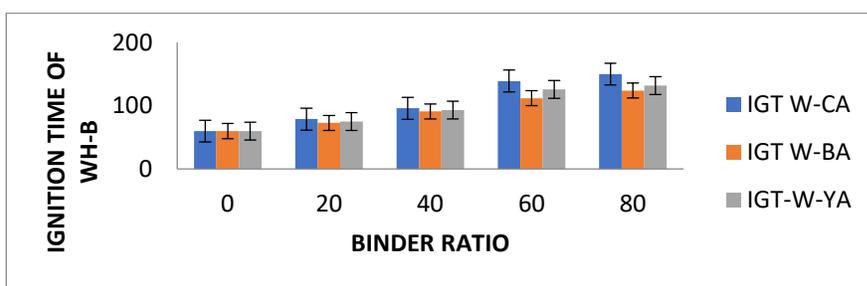


Figure 1: The Effect of binder type and level on Ignition Time of **WH-B**

The findings about ignition time of water hyacinth briquettes bonded by agro-wastes [yam peels(YA), cassava peels(CA) and banana peels(BA)] is displayed graphically in Fig. 1, with varying binder at levels of B1 (20%) to B4 (80%) incorporated with a constant weight of water hyacinth residues. Fig.1 demonstrates a direct correlation between binder concentration and ignition times, across all the agro-waste binders. The ignition time was 60sec. for the controlled briquettes, but increased to 150sec. for Cassava peels’ bonded briquettes, and to 132sec for yam peels’ bonded briquettes, and to 124sec. for banana peels’ bonded

briquettes respectively at B4 (80%) binder level. As seen in Fig.1, the density rose as a result of better bonding, which may have led to low porosity and less oxidant infiltration and combustion product outflow during combustion, which prolonged the ignition time. The findings of (Olugbade & Ojo, 2021) support the theory that the amount of binder lengthens the ignition period because it increases density and showed that this affects the flame propagation in the briquettes. Ignition time indicated statistical significance in relation to binder level and type at ( $p < 0.05$ ).

### The impact of binder type and Level on the Burning Rate of Water hyacinth Briquettes (WH-B).

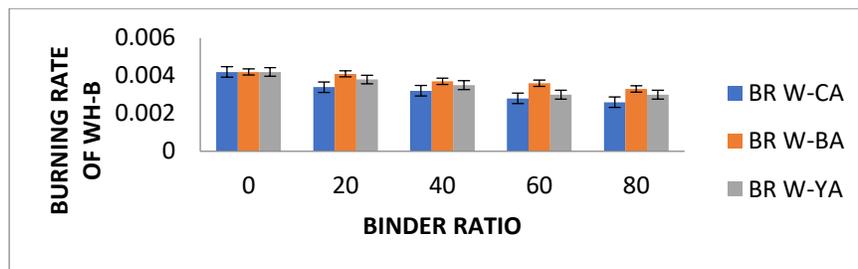


Figure 2: The Effect of binder type and level on Burning Rate of **WH-B**

Burning Rate as reflected in (Fig. 2) for water hyacinth briquettes has an inverse correlation with increment in binder concentration across all binder types, though at different degrees of response. The mean burning rate was 0.00403g/sec at 20% binder level, but reduced to 0.00297g/sec at 80% binder level. An increase in density which could have led to a decrease in porosity may be the cause for burning rate drop as the binder was added. Due to limited heat conductivity, a reduction in

the air gap between neighboring particles may have prevented the spread of the flame. Chaney, (2010) validates the notion that density affects briquette combustion rate because of decreased porosity, which slows the pace at which oxidant infiltrates and combustion products exit the briquette during burning. The Burning rate indicated statistical significance in relation to binder level and type at ( $p < 0.05$ ).

### Ash Content of water hyacinth Sample Briquettes

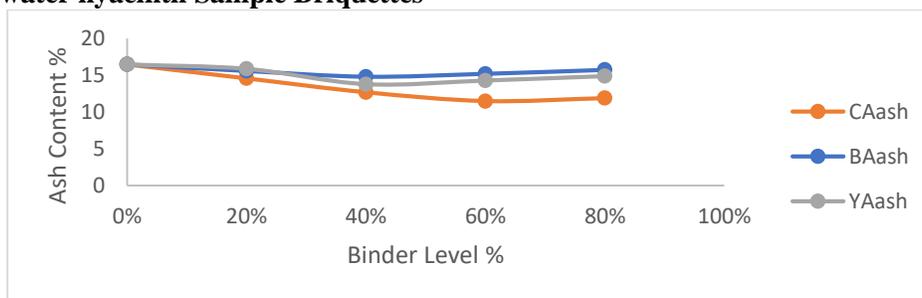


Figure 3: Effect of binder level on Ash content of briquette samples

This study recorded a slight reduction in ash content with increment in binder concentration across the three binders as can be seen in Fig 3. This can be attributed to the agglomeration of particles enhanced by the binder's presence, leading to the formation of more compact structure, resulting in less ash production

during the burning process. However, the ash content values found in this study are larger than the figures mentioned for different agroforestry residues (FAO, 2003). The Ash content values recorded for this study indicated statistical significance across binder levels and types used for this study at ( $p < 0.05$ ).

### Volatiles Content of Water hyacinth Sample Briquettes

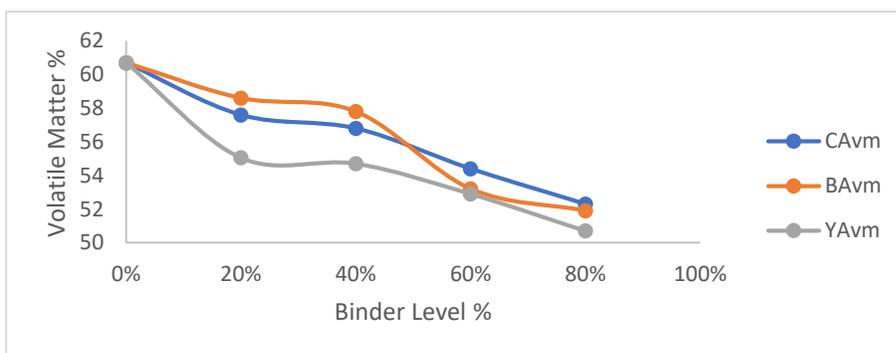


Figure 4: Effect of binder level on Volatile content of WL-Briquette samples.

The study recorded volatile content range of (52.3% to 57.6%) for cassava peel bonded water hyacinth briquettes, while of yam peel and cassava peel bonded briquettes were respectively observed volatile content ranges of (50.7% to 55.05%) and (51.9% to 58.6%), across the binder concentration levels of B1(20%) to B4(80%) of the residue weight of water hyacinth residues. The higher volatile content value of (60.7%) observed for the controlled water hyacinth briquettes reflects the rapidity of combustion of the dried uncompressed water hyacinth plant, during burning. Generally, across binder types and levels, an increment

in binder proportion led to decrease in volatile content of the respective water lily briquettes, though at different pace as can be seen in Fig. 4. This can be attributed to higher degree of bonding provided by the binding agent which could have resulted in reduced pore spaces and enhanced structural integrity, consequently preventing or reducing the escape of volatile matter during combustion. The volatile matter values recorded for this study indicated statistical significance across binder levels, but not across binder types at ( $p < 0.05$ ).

### Fixed Carbon Content of water hyacinth Sample Briquettes

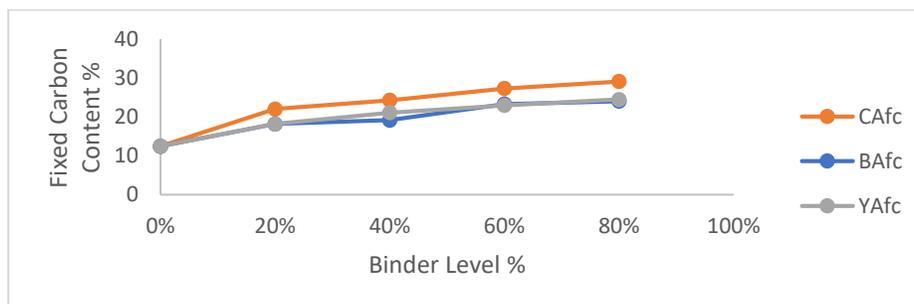


Figure 5: Effect of binder level on fixed carbon content of WH-B samples.

The study recorded Fixed carbon improvement from B0(14.48%) of controlled Samples water hyacinth briquettes with zero binder inclusion to: (29.08%) for cassava peel bonded WH-B, (24.48) for yam peel bonded WH-B and (24.03) for banana peel bonded WH-B with binder level at B4(80%) of the residue weight of water hyacinth as can be inferred from Fig. 5 above. This can be attributed to improved carbonization or char

formation during the burning process, which enhances the stability and combustion efficiency of the fuel. The Findings are consistent with reports of (Emerhi, 2011) concerning starch bonded sawdust briquettes. The study's three binders—cassava, yam, and banana peelings—improved the water lily briquettes' fixed carbon content, notably at ( $p < 0.05$ ).

### Calorific Value of water hyacinth Briquettes (WH-B) Sample.

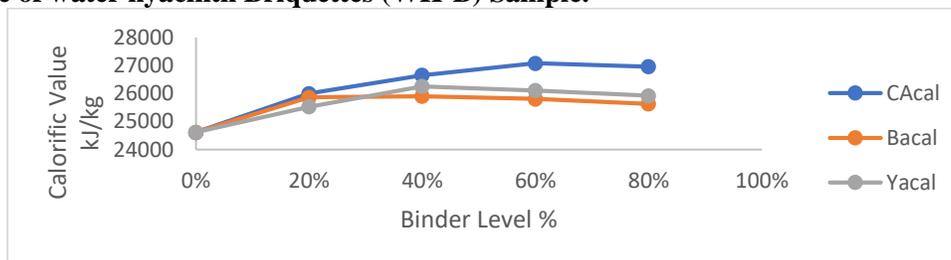


Figure 6: Effect of binder level on calorific value of WH-B samples.

As the binder concentration increased, calorific values of cassava peel bonded water hyacinth briquettes (WH-B) samples improved to a peak value of 27.084 MJ/kg at B4(80% binder level), yam peel and banana peel bonded WH-B samples respectively to peak values of 26.262 MJ/kg and 25.910 MJ/kg respectively both at B3(40% binder level) and slightly declined with further increment up to (80% binder level). This can be attribute to the slight increment in ash content beyond those binder levels due to inherent ash coming into play (Loo & Koppejan, 2008). But generally, the calorific value of the briquette samples improved across the agro-waste binding agents applied for this study with increment in their concentration as can be pictorially observed in Fig. 6. The results of this investigation agree with those found for coconut husk (Jekayinfa & Omisakin, 2005) and also satisfy calorific value requirements outlined by solid fuel standard (DIN 51731:1996-10). The calorific values observed for this study indicated statistical significance across binder levels and types at ( $p < 0.05$ ).

### Conclusion

Cassava peel bonded briquettes performed best in terms of thermal properties, followed by yam peel bonded briquettes and banana peel bonded briquettes being the least performing based on this study's results. They recorded peak values of 27.084 MJ/kg, 26.262 MJ/kg and 25.910 MJ/kg respectively in terms of calorific values. This is because, in comparison to the other two binders, cassava peel has a higher starch content, which gelatinizes at the application of water and heat. This is because Amylose and Amylopectin, the major polysaccharides in starch forms hydrogen bond among themselves with a resultant disruption of its granular structure giving rise to the formation of starch paste or gel which increase in viscosity while cooling. This increase in viscosity that accompanies the conversion of starch from its granular form to paste form, is expressed by significant resistance to deformation and improved

bonding strength (Ai *et al.*, 2018; Zobel, 1984). This improvement in bonding strength leads to better agglomeration among particles, increase in density and structural integrity and consequent improvement in calorific value.

### Recommendations

- ❖ Water hyacinth briquettes bonded by yam peels and banana peels are recommended to produced at 40% binder concentration, to minimize high ash content, based on studies observations.
- ❖ Further studies should be conducted to investigate the physical properties of these varieties of aquatic plant briquettes for their proper handling and storage.
- ❖ The Government should encourage more research in fine tuning the properties of water hyacinth and other aquatic plants' briquettes for their commercialization to mitigate the environmental menace associated with aquatic weeds and agro-wastes.

### References.

Adegoke, C. O. (1999). Preliminary investigation of sawdust as high-grade solid fuel. *Journal of Renewal Energy*. 1-2: 102–107.

Ai, Y. & Jane, J. L. (2024). Understanding starch structure and functionality. In *Starch in food* (pp. 55-77). Woodhead Publishing.

Ajit Kaur, Madhuka Roy & Krishnendu Kundu, (2017). Densification of Biomass by Briquetting: A Review. *International Journal of Recent Scientific Research*. 8(10): 20561-20568.

ASTM standard E711-87, (2004). Standard test method for gross calorific value of refuse –derived fuel by the bomb calorimeter. Annual book of ASTM standard, 11.04. ASTM International, <http://www.astm.info/standard/E711.htm>.



- Emerhi, E. A. (2011). Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders. *Advances in Applied Science Research*. 2 (6): 236-246.
- Nkemdirim, Ogechi Vivian (2014). Effects of Different Binders on the Physical and Combustion Properties of Dried Leaves Briquettes. M.Eng. Thesis, Department of Agricultural and Bio-resources Engineering, Faculty of Engineering University of Nigeria, Nsukka, Nigeria.
- Olugbade, T.O. & Ojo, O.T. (2021). Binder-less briquetting technology for lignite briquettes: A review. *Energy, Ecology and Environment*. 6: 69–79.
- Onuegbu T.U., Ekpunobi U.E., Ogbu I.M., Ekeoma M.O. & Obumselu F.O. (2011). Comparative Studies Of Ignition Time And Water Boiling Test Of Coal And Biomass Briquettes Blend. *IJRRAS*. 7 (2): 153 – 159.
- Jekayinfa, S.O. & Omisakin O.S. (2005). The energy production of some agricultural wastes as local fuel materials in Nigeria. *Agricultural Engineering International the CIGR E-Journal of Scientific Research and Development* Vol. VII, Manuscript EE 05 003: 10-19.
- Chaney J. O. (2010). Combustion Characteristics of Biomass Briquettes. Ph.D. Thesis Submitted to University of Nottingham, UK.
- Chin O. C. & Siddiqui, K. M. (2000). Characteristics of some biomass briquettes prepared under modest die pressures. *Biomass and Bioenergy*. 18: 223–228.
- Borman, G. L. & Ragland K. W. (1998). Combustion Engineering. McGraw-Hill Science/Engineering/Math.
- Loo, S. V & Koppejan, J. (2008). A Handbook of Biomass Combustion and Co-firing: Earthscan.
- Demibas, A. (2001). Yield of hydrogen-rich gaseous products via pyrolysis from selected biomass samples. *Fuel*, 80(13), 1885-1891.
- Zobel, H. F. (1984). Gelatinization of starch and mechanical properties of starch pastes. In *Starch: chemistry and technology* (pp. 285-309). Academic Press.
- Bailey, R.T. & Blankenhorn, P.R. (1982). Charcoal production, improvement for rural development. First Edition, Vol 1. Page 61-70.
- Tariebi, Karikarisei & Davies, Rotimi Moses (2024a). Some handling characteristics of cassava peels bonded water hyacinth briquettes. *International Journal of Innovative Mathematics, Statistics and Energy Policies*. 12(2): 72 -80.
- Tariebi, Karikarisei & Davies Moses Rotimi (2024b). Some thermal characteristics of Yam Peels bonded Water lily (*Nymphaea Odorata*) briquettes. *RSU Journal of Biology and Applied Sciences*. 4(1): 24-32.
- FAO, (2003). The briquetting of Agricultural waste for fuel. *FAO corporate document repository*: [www.fao.org/docre/T0275E/T0275E03htm](http://www.fao.org/docre/T0275E/T0275E03htm).
- Olaoye, J. O., Alonge, A. F. & Adams, B. A. (2003). Effects of die diameter, mix ratio and compressive force on briquetting of oil palm mush. *Nigerian Journal of Technological Development*, 3, 27 – 37.
- Olurunnisola, O. A. (2004). Briquetting of Rattan Furniture Waste. *Journal of Bamboo and Rattans*, 3(2), 133-149.
- Olaoye, J. O. & Kudabo, E. A. (2017). Evaluation of Constitutive Conditions for Production of Sorghum Stovers Briquette. *Arid Zone Journal of Engineering, Technology and Environment*, 13(3), 400 – 412.
- Kaur, A., Roy, M., & Kundu, K. (2017). Densification of Biomass by Briquetting: A Review. *International Journal of Recent Scientific Research*, 8(10), 20561 - 20568.
- Bianca, G. d. O. M., Souza, O., Marangoni, C., Hotza, D., Oliveira, A. & Sellin, N. (2014). Production and Characterization of Fuel Briquettes from Banana Leaves Waste. *Chemical Engineering Transactions*, 37, 439-444.
- Maninder, K., Kathuria, P. S. & Grover, S. (2012). Using Agricultural Residues as a Biomass Briquetting: An Alternative Source of Energy. *Journal of Electrical and Electronics Engineering*, 1(5), 11 – 15.
- Oladeji, J. T. (2011). The effects of some processing parameters on physical and combustion characteristics of corncob briquettes. (Ph.D), Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
- Bintu, Grema Mustafa, Ali, L. Yaumi., Mohammed, Modu Aji. et al., (2015). Comparative Studies On The Combustion Performance Of Briquettes Produced From Selected Biomass Residues In Maiduguri. *World Journal of Energy Sciences & Engineering*. 1(1): 1 – 8.