SOME THERMAL CHARACTERISTICS OF YAM PEELS BONDED WATER LILY (*Nymphaea Odorata*) BRIQUETTES.

Tariebi Karikarisei[1]
Department of Agricultural and Environmental Engineering,
Faculty of Engineering, Niger Delta University,
Wilberforce Island, Amassoma, Bayelsa State, Nigeria
Email: Karikariseitaribi@gmail.com, **Tel:** +2348063289501

Davies Rotimi Moses[2]
Department of Agricultural and Environmental Engineering,
Niger Delta University, Wilberforce Island,
Amassoma, Bayelsa State, Nigeria.

ABSTRACT

The hike in price of cooking gas, kerosene, electricity, and related firewood scarcity is a clarion call for the development of alternative affordable energy source, to the rescue of the low-income earners in Nigeria and abroad. Water lily, which falls into the invasive category of aquatic plants, blooms heavily in the Niger Delta region, all year round due to its endowment with network of rivers and streams. The study investigated the effect of binder concentration on the combustion properties of water lily briquettes. For this study, yam peels were gotten from table top vendors, which were then cleaned, sun-dried and milled to particle sizes 1.18 mm using Disk mill and Tyler sieves. The water lily plants were harvested manually, and treated similar to the yam peels to arrive at particle size of 1.18 mm. Yam peels' grinds at concentration levels of (B1) 20% to (B4) 80% of a constant weight of water lily grinds at steps of 20% were blended together with addition of 200ml of boiled water. The resulting homogenous feedstock was then fed into a steel cylindrical die of dimension 14.21cm height and 2.14cm diameter, and compressed by hydraulic press at pressure level of 5 MPas with dwell time of 20 second before the resulting briquettes were ejected for further studies. From the results of the study, Fixed Carbon ranged from 15.98 to 26.38, volatile matter from 49.7 to 57.9, Ash from 15.7 to 17.8 and calorific value from 24880kj/kg to 25981 kj/kg. The values obtained in this study are above 17000kj/kg threshold minimum calorific value by standard (DIN 51731) for fuel sources, hence they are suitable for household and for small industrial heating applications. Though the combustion properties, generally improved with increase in binder concentration, it could be inferred that the optimum amount of binder recommended for the production of water lily yam peels' bonded briquettes is at 60% and below, because beyond 60% the ash content increased and the calorific value declined.

Keywords: Agro-waste, yam peels, energy, briquette, Biomass.

1.0 INTRODUCTION

Numerous developing nations generate enormous amounts of agricultural wastes, yet they are often handled inefficiently, severely polluting the environment (Grover and Mishra, 2009). Agro-waste must be turned into energy due to the rising costs of obtaining cooking gas, electricity, kerosene, and other fuels, as well as the issue of greenhouse gas emissions from the burning of fossil fuels. Energy is regarded as the foundation for a country's and society's development and prosperity (Tariebi and Davies, 2024).

The utilization of briquetting technology presents a viable resolution to the issues associated with underutilized agricultural residues (Ribeiro and Junior, 2023). The method can be characterized as a densification procedure that enhances the volumetric calorific value of biomass and improves the handling qualities of raw materials (Oladeji, 2010). In fact, when agricultural leftovers are burned, they sometimes burn quickly and produce smoke, and when they are fresh, they are often bulky and difficult to manage (Rodriguesa *et al.*, 2017). Primarily used for cooking and heating in rural families in poor nations, biomass is the world's fourth-largest source of energy (Felix and Gheewala**,** 2011).

In Nigeria, Niger Delta is known for its extensive network of rivers and creeks. Aquatic weeds such as water lily, water lettuce, water hyacinth, etc. blooms heavily in the Niger Delta Creeks, causing obstruction: in drainage systems, rivers and creeks, preventing normal operation of hydropower plants, fishing and navigation along rivers etc. Physical, chemical, or biological methods have not been successful in controlling these aquatic weeds. Its quick growth rate in comparison to other agricultural plants may be the cause of this. However, this rapidity of growth of water hyacinth can be capitalize on to ensure sustainable production of fuel briquettes, which will open up employment opportunities to those mostly affected by them, and absorb the shock from hike in price of energy accessibility and firewood scarcity for heating applications on the low income earners (Patomsok, 2008).

The briquetting of water hyacinth weeds with cassava peels as binding agent is a sustainable way of tackling both the aquatic plants' menace on our rivers and creeks as well indiscriminate disposal of cassava peels on the environment. A number of biomass resources, including sawdust, rice husk, peanut shells, coconut fiber, and palm fruit fiber, have been experimentally investigated to be converted into densified fuels due to the benefits of densification (Davies and Davies, 2014).The current work offers important insights into a few thermal properties of briquettes made from 1.18 mm water lily particles with yam peel binder at various binder ratios and 5 MPa compaction pressure.

2.0 MATERIALS AND METHODS.

2.1 Water Lily Harvest and Preparation

For this investigation, samples of water Lily (*Nymphaea odorata*) plants, commonly found in slow moving streams, were collected from a creek in Azikoro Town, Yenagoa Local Government Area of Bayelsa State, Nigeria, which were then transported to the Farm Structure laboratory in the Department of Agricultural and Environmental, Faculty of Engineering, Niger Delta University Wilberforce Island Bayelsa State, Nigeria. They were thoroughly washed for them to be void of foreign matter before sun drying to reduce moisture, after the water hyacinth had dried, it was chopped into pieces and then milled to 1.18mm size particles as shown in Plate 2.1 with the intent to enhance surface area and promote densification as recommendations by (Ajit *et al.*, 2017).

Plate 2.1: Milled water lily (size: 1.18mm)

Plate 2.2: Milled Yam peels (size: 1.18mm)

2.2 Yam Peels collection and preparation.

Samples of yam peels were collected from table top vendors, which are normally disposed indiscriminately. After giving them a thorough washing to get rid of any dirt or stone, they were sun-dried and ground into smaller pieces to enhance the densification process. Tyler sieves were used to isolate size particles of 1.18mm see plate 2.2 which were used for the experiment. In line with procedures followed by (Nkemdirim, 2014; Davies and Davies, 2014). The chosen particle sizes at concentration levels of B1(20%), B2(40%), B3(60%), and B4(80%) of the residue weight of the aquatic plant were hydrated by addition of predetermined amount of hot water. The resulting mixture was stirred constantly together with the weighed bulk of aquatic plant powder until a homogeneous mixture is produced before it was fed into a die (Plate 2.3) for densification on a hydraulic Press as shown in Plate 2.4. The briquette was expelled and taken for additional research after a 20-minute dwell period.

Plate 2.3: Hydraulic press Plate 2.4: Mould for Briquette Production

2.3 Ignition time and Burning rate:

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 (Onuegbu *et al*., 2011; Davies and Davies, 2013). 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:

$$B.R = M_f/t \quad (1)$$

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).

2.5 Proximate Analysis:

This analysis was done in-line with ASTM Standard E711-87, (2004), to determine: volatile matter, ash content and fixed carbon content of the sample briquettes. Variety of techniques are then used to calculate the relative amounts of each of these constituents.

2.6 Moisture content (MC)

A fixed mass of briquette sample was employed to evaluate the moisture composition, by oven drying it at 105°C to achieve mass uniformity. Consequently, the moisture content was then computed on dry basis, as follows:

$$(MC)\% = \frac{M_{i-M_f}}{M_f} * 100 \quad \text{(Borman and Ragland 1998)}, \quad (2)$$

Where M_i – initial mass briquette sample, M_f – final mass of briquette sample after drying.

2.7 Volatile Matter (VM).

As indicated in (Plate 2.4), 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 2:5), the proportion of volatile matter was determined using equation 3

$$PVM = \frac{B-C}{B} x\ 100 \quad (3)$$

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 2.4: muffle furnace for proximate analysis

Plate2.5 Desiccator

2.8 Ash content (AC): In order to quantify ash content, two grams of the pulverized sample briquettes were measured with weighing balance into crucible and heated in a furnace for four hours at 600 degrees Celsius. The sample was then weighed after cooling in a desiccator and PAC calculated as follows:

$$PAC = \frac{D}{B} x100 \qquad 4$$

In this case, D - represents the weight of ash and

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

2.9 Fixed Carbon (FC): By deducting the total of the moisture content (MC), percentage of volatile matter (PVM), and percentage of ash content (PAC) from 100, the percentage fixed (PFC) was calculated as follows:

$$PFC = 100\ \% - (MC + PAC + PVM) \qquad 5$$

2.10 Calorific value

The calorific value was computed with the empirical expression below (Bailey and Blankenhorn, 1982).

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

Where V: stands for the volatile matter in percentage,

C: for the fixed carbon proportion and

HV: represents the heating value ($kJ \cdot kg^{-1}$)

3.0 Results and Discussion.

3.1 Thermal Properties of Water Lily Briquettes.

Plate 3.1 displays samples of yam peels bonded water Lily briquettes and the data pertaining to the combustion parameters are summarized in tables 3.1

Plate 3.1: Water Lily briquette samples

Tables 3.1: Summary of Thermal Properties of Yam Peel Bonded Water Lily Briquettes

Mean of Combustion Properties	Sample Replication Value	0% of YA	20% of YA	40%of YA	60% of YA	80% of YA
Ash Content (%)	3	19.4	17.8	15.3	14.7	15.7
Volatile Matter (%)	3	59.2	57.9	55.4	53.5	49.7
Fixed Carbon Content (%)	3	13.08	15.98	20.98	23.48	26.28
Calorific Value (Kj/Kg)	3	24319	24880	25759	25981	25669
Burning Rate (G/S)	3	0.00433	0.00352	0.00333	0.00316	0.00314
Ignition Time (S)	3	123	140	174	248	253

3.1.1 The impact of binder Level on the Burning Rate and Ignition time of Water Lily Briquettes (WL-B):

Ignition time gives a picture of how easily a fuel source can be activated to start burning, while burning rate indicate how a given mass of fuel will last. This section clarifies the impact of binder inclusion in the feedstock on these afore mentioned parameters as highlighted in Figure 1 and Figure 2.

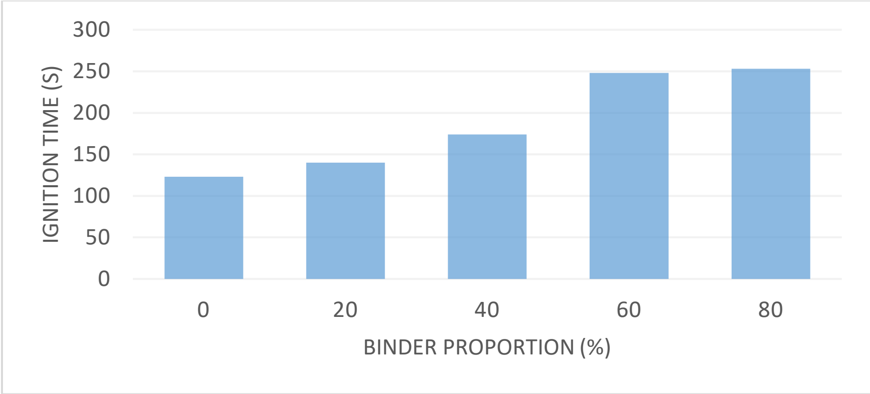

Figure 1: The Effect of binder type and level on Ignition Time of water Lily Briquettes

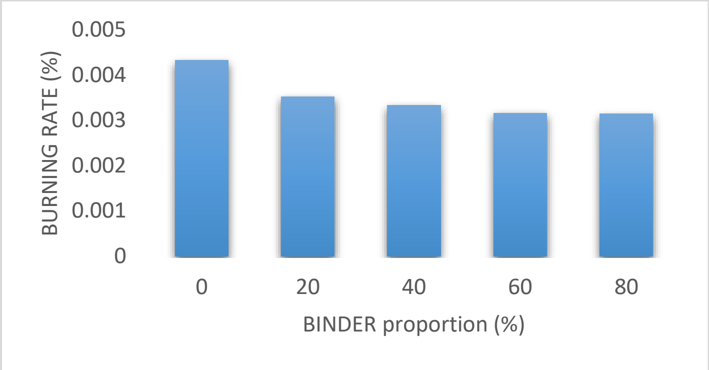

Figure 2: The Effect of binder type and level on Burning Rate of water Lily Briquettes

The results of thermal properties of briquettes made of water lily, with binders at levels of B1 (20%) to B4 (80%) of water Lily grinds' residue weight, at steps of 20% is shown in Table 3.1. Based on Table 3.1 and figure 1, it can be seen that the ignition time increased gradually from 123seconds for control briquettes at B0(0%) to 253sec. at B4(80%) of cassava peelings binder concentration, which depicts that higher binder concentration resulted in longer ignition time. This could be due to improved bonding, resulting in increased density, low porosity and decreased oxidant infiltration and combustion product outflow during combustion. The findings of (Olugbade and Ojo, 2021) support the theory that the amount of binder lengthens the ignition period due to increases density. The outcomes of this investigation are comparable to those for bio-coal briquettes produced by combining components at different coal concentrations of 10 to 50%, which range from 19 to 186 seconds (Onuegbu *et al.*, 2011).

Burning Rate as shown in (Tables 3.1) and figure 2, indicates an inverse correlation with binder concentration. The mean burning rate was 0.00357g/sec at 20% binder level, but reduced to 0.00329g/sec at 80% binder level. 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, according to (Chaney, 2010). Parallel to this, poor volatile matter in briquettes is linked to sluggish burning and difficulty in ignition (Sotannde *et al*., 2010). This validates greater combustion rates that are achieved with lower binder concentrations. The Burning rate as well as ignition time indicated statistical significance across binder level at ($p<0.05$.

3.1.2 Moisture content of water Lily Sample Briquettes

Moisture content significantly influences the burning characteristics of biomass fuel, the briquette samples were dried to a moisture level of 8.32% on a dried basis prior to performing proximate analysis on them. Chin and Siddiqui (2000) suggested a lower moisture content of between 5% and 12% for better combustion and briquette stability (Nkemdirim, 2014).

3.1.3 Ash Content of water Lily Sample Briquettes

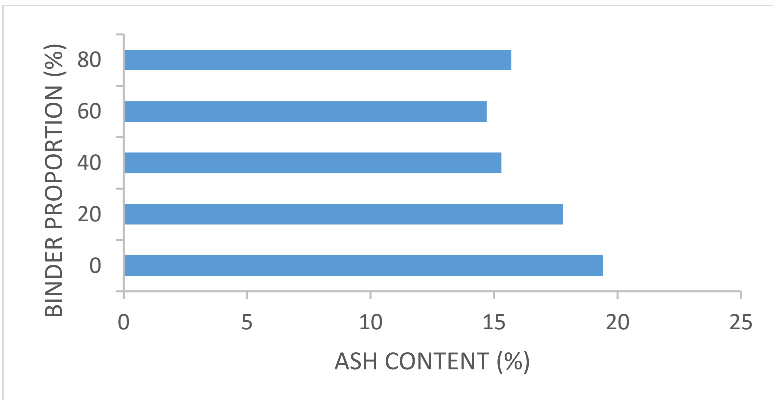

Figure 3: Effect of binder level on Ash content of briquette samples

The content of ash as can be seen in Table3.1 and Figure 3, took a slightly downward trend with increment in the binder level for this study. This can be attributed to the agglomeration of particles enhanced by the binder, leading to the formation of more compact structure, resulting in less ash production during the burning process. Yam peels bonded water lily briquettes recorded steady decline of ash content to 14.7% at binder level of B4 (60%), but increased slightly thereafter. This phenomenon may be explained by the effect of mineral matter that was bound into the carbon structure of the binders and of water lily (inherent ash). The values found in this study are comparable to those found in studies by Emerhi (2011) on briquettes made from sawdust from three hard wood species (19.07 ±4.80 – 21.72 ±3.99%), and Onuegbu *et al*., (2010) on coal briquettes (18.27%), but higher compare to the recommendation of 0.7% ash content for fuel briquettes (DIN 51731, 1996). The Ash content values recorded for this study is statistical significance across binder levels at ($p<0.05$).

3.1.4 Volatile Content of Water Lily Sample Briquettes

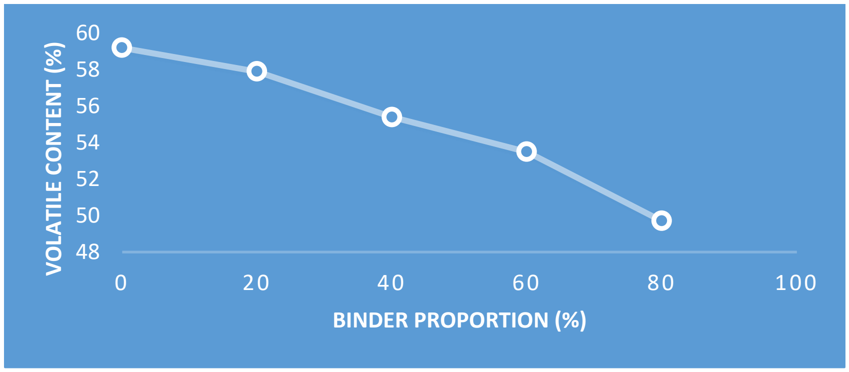

Figure 4: Effect of binder level on Volatile content of WL-Briquette samples.

The volatile content of a fuel source hints us on how it can be easily ignited especially at lower temperature. A high value of the volatile content of a fuel source implies easy ignitability and rapidity in combustion during burning, which is not very desirable because the fuel apparently will not last long. A mean value of volatile content of (54.13%) was observed for yam peels' bonded briquettes across binder inclusion level of B1(20%) to B4(80%) of the residue weight of water lily grinds in steps of 20%. The higher volatile content value of (59.2%) observed for the controlled water lily briquettes is a reflection of the rapidity of combustion of the dried uncompressed water lily plant, during, burning. It can be inferred from figure 4, higher binder proportions led to decrease in volatile content of yam peels' bonded water lily briquettes. 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. Volatile content values obtained from this study compete favorably with 89.47±0.22% reported by (Emerhi, 2011) for starch bonded sawdust briquettes from three hard wood species, and 70.810% reported by (Nkemdirim, 2014) concerning gum bonded dried leave briquettes.

The volatile matter values recorded for this study indicated statistical significance across binder level at ($p<0.05$).

3.1.5 Fixed Carbon Content of water lily Sample Briquettes

A fuel's fixed carbon is essentially the portion of carbon that can be burned to produce char. This is not equivalent to the ultimate carbon, or the entire quantity of carbon in the fuel, because a sizable portion is also emitted as hydrocarbons in the volatiles. The amount of char that is left over after the devolatization step is indicated as fixed carbon (Chaney, 2010). This section introduces the findings of binder's influence on the volatile matter of the feedstock and it is illustrated in Figure 5.

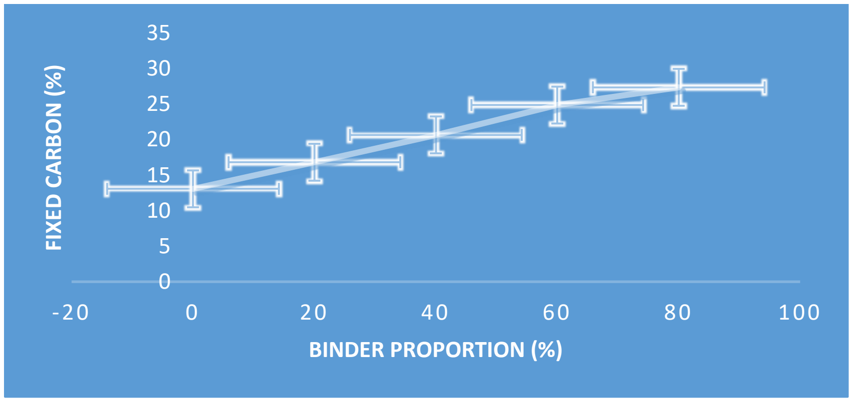

Figure 5: Effect of binder level on fixed carbon content of Water Lily briquette samples.

The fixed carbon content of yam peels bonded water lily briquettes in this study, recorded improvement from 13.08% to 26.38% with increment in binder concentration as can be inferred from Figure 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. This result is consisting with that given by (Nkemdirim, 2014) over starch bonded dried leave briquettes. Yam peels' binder improved the water lily briquettes' fixed carbon content, notably at ($p<0.05$), and performed favourably with others binders registered in literature for briquettes production (Dirmibas, 2001).

3.1.6 Calorific Value of water Lily Sample Briquettes.

The influence of concentration of yam peel binder on the calorific value of water lily briquettes is illustrated below in Figure 6 below:

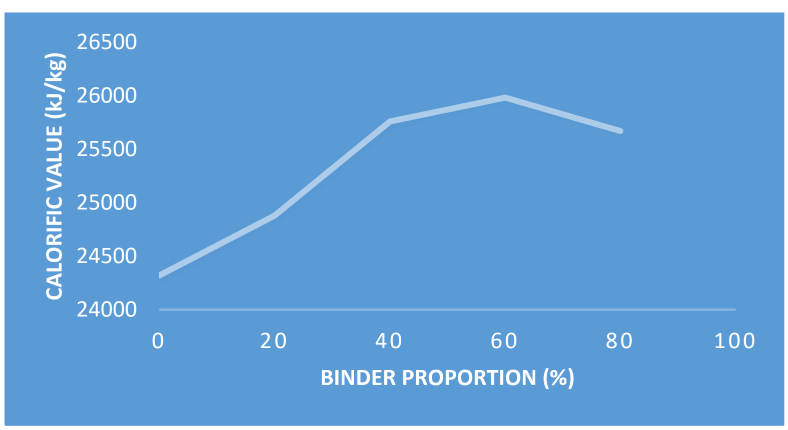

Figure 6: Effect of binder level on calorific value of water lily briquette samples.

The calorific values of yam peel bonded water lily briquette samples increased with increment in binder concentration to a peak value of 25981kj/kg at B3(60% binder level) and slightly declined with further increment. This decline in calorific value beyond 60% of binder concentration is attributed to inherent ash impact (Loo and Koppejan, 2008). Study of Sawdust- and palm kernel shell-mixed briquettes by (Adegoke, 1999) also validates increment of calorific value from 19.91MJ/kg to 20.54MJ/kg with binder increment. The heating values gotten from this investigation agree with those found for coconut husk (Jekayinfa and Omisakin, 2005). It was also more than the 17,500 Kj/Kg threshold that is suggested in order for a material to be considered to have an adequate calorific value (DIN 51731, 1996). The calorific values observed for this study indicated statistical significance across binder levels at ($p<0.05$).

4.0 CONCLUSION AND RECOMMENDATION

According to the study's findings, the amount of yam peels used as a binder in the water lily briquette feedstock had a big impact on how well it burned. Their low carbon content and other features of combustion make them extremely safe for users and environmentally benign. Calorific value of yam peels' bonded water lily briquettes ranged from 24319kj/kg to 25981kj/kg for this study. These values are above 17000kj/kg threshold minimum calorific value required by standard (DIN 51731) for fuel sources, hence they are suitable for household and for small industrial heating applications. This variant of water lily briquettes is recommended to be produced at 60% binder level and below, as calorific value was observed to reduce beyond 60% binder level, due to ash increment. Handling properties should also be investigated, for proper handling of this briquette variants.

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