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Some Thermal Properties of Banana (Musa acuminata) Peels Bonded Waterlily (Nymphaea lotus Linn.) Briquettes

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ABSTRACT

The purpose of the study was to determine how the amount of binder affected the ignition time and rate of burning of fuel briquettes made from a blend of banana (Musa acuminata) and waterlily (Nymphaea lotus Linn.) peels at varying binder ratios (0, 20, 40, 60, and 80% by weight of each feedstock). Before the briquettes were expelled for additional research, the homogenous feedstock was compressed by a hydraulic press at a pressure level of 5 MPas and a dwell period of 20 seconds. The steel cylindrical die had dimensions of 14.21 cm in height and 2.14 cm in diameter. Fixed carbon ranged from 16.68 to 25.38, volatile matter from 50.5 to 56.8, ash from 15.4 to 18.2, and calorific value from 24751 kJ/kg to 25737 kJ/kg, according to the study's findings. The results of this study are appropriate for domestic and small-scale industrial heating applications since they exceed the standard minimum calorific value of 17000 kj/kg for fuel sources (DIN 51731:1996-10). Because the ash content increased and the calorific value decreased beyond 60%, it can be concluded that the ideal amount of binder recommended for the production of waterlily banana peels' bonded briquettes is at 60% and below, even though the combustion properties generally improved with an increase in binder concentration. Increasing the binder ratio and decreasing the particle size resulted in a decrease in the burning rate, but it also prolonged the briquettes' ignition period.

Keywords: Agricultural waste, binder levels, biomass compression, handling characteristics, homogenous feedstock,

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 rock of development and prosperity of Nations (Davies and Tawari, 2010 and Tariebi and Davies, 2024). [6, 21] The utilization of briquetting technology presents a viable resolution to the issues associated with underutilized agricultural residues (Davies and Abolude, 2013 and Ribeiro and Junior, 2023). [5, 8, 20] 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). [17] 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). [22] 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). [26]

Nigeria's Niger Delta is known for its extensive network of rivers and creeks. Aquatic weeds such as waterlily, 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 lily 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). [10]

The briquetting of waterlily (*Nymphaea lotus* Linn.) weeds with banana (*Musa acuminata*) 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 banana 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). [4]The current work offers important insights into a few thermal properties of briquettes made from 1.18 mm water lily particles with banana peel binder at various binder ratios and 5 MPa compaction pressure level.

2.0 Materials and Methods

2.1 Waterlily (*Nymphaea lotus* Linn.) Harvest and Pretreatment

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 (mud,stone etc.) 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 (Ajit *et al*, 2017).[2]

2.2 Banana (*Musa acuminata*) Peels collection and Pretreatment

Banana **(*Musa acuminata*)** peels were collected from 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. Banana peels was processed into binder according to Davies and Davies (2014).[4] 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 for densification on a hydraulic compression machine. The briquette was extruded and taken for additional research after a 20-minute dwell period.

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). [23] This was determined in line with the procedure followed by (Davies and Davies, 2013; Onuegbu *et al.*, 2011).[5, 13] 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:

$B.R = M_f/t$ 2.1

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),[3] to determine: volatile matter, ash content and fixed carbon content of the sample briquettes, at the Reactions and Kinetics laboratory of the department of chemical Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Wilberforce Island, Amassoma, Bayelsa State, Nigeria. Variety of techniques were then used to calculate the relative amounts of each of these constituents.

2.6 Moisture content (MC)

The fuel's moisture content serves as a gauge for its water content. According to Borman and Ragland (1998), there are two types of moisture that can be found in solid fuels: bound water that is a component of the material's chemical structure, and free water that is present in the fuel's pores and interstices. 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:

$$(MC)\% = \frac{M_{i-M_f}}{M_f} * 100 \qquad 2.2$$

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 by by (formula 2:3):

$$PVM = \frac{B-C}{B} x100 \qquad 2.3$$

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.

2.8 Ash content (AC)

In order to quantify ash content, two grams of the pulverized sample briquettes were measure with weighing balance into crucible and heated in a furnace for four hours at 600 degrees Celsius in the Reactions and Kinetics laboratory of the department of chemical Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Wilberforce Island, Amassoma, Bayelsa State, Nigeria. The sample was then weighed after cooling in a desiccator and PAC calculated as follows:

$$PAC = \frac{D}{B} x100 \qquad 2.4$$

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:

$$PFC = 100\,\% - (MC + PAC + PVM) \qquad 2.5$$

2.10 Calorific value

The calorific value was computed with the empirical expression below (Bailey and Blankenhorn, 1982). [24]

$$HV = 2.326\,(147.6C + 144V) \qquad 2.6$$

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 Waterlily Briquettes

Figure 1 displays samples of yam peels bonded waterlily briquettes and the data pertaining to the combustion parameters are summarized.

Figure 1: Waterlily briquette samples

3.1.1 The influence of binder Level on the Burning Rate and Ignition time of Waterlily 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 2 and Figure 3.

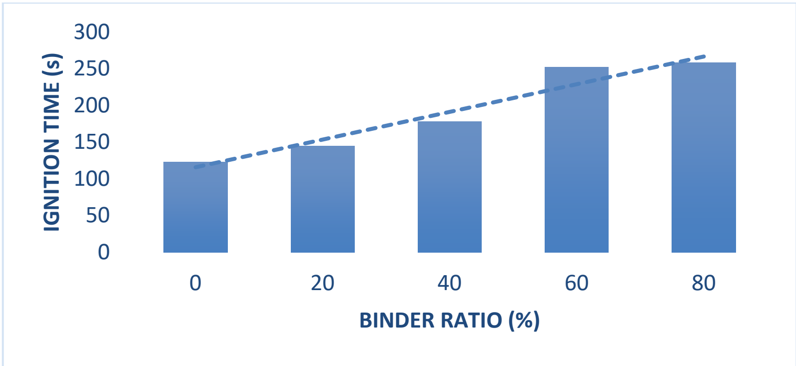

Figure 2: The Effect of binder level on Ignition Time of waterlily briquettes

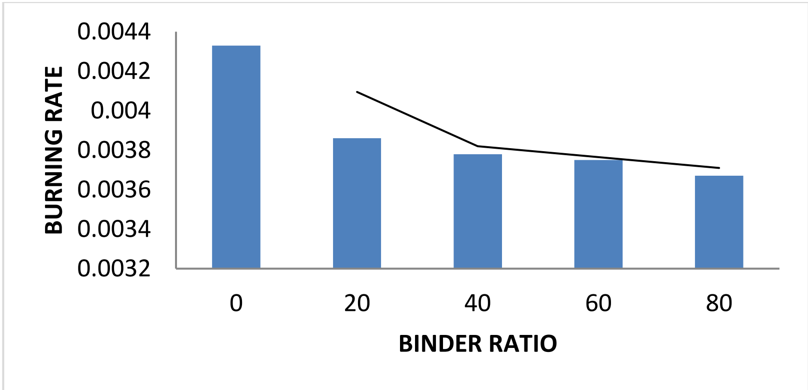

Figure 3: The effect of binder level on burning rate of waterlily briquettes

The end-point of ignition is arbitrary and determined by personal opinion. The average amount of time needed to produce a stable, brilliant flame was used as the ignition time in this investigation. The results of thermal properties of briquettes made of water lily, with banana peel binder at levels of B1 (20%) to B4 (80%) of waterlily grinds' residue weight, at steps of 20% is shown in Figure

2. From Figure 2, it can be inferred that the ignition time is directly proportional to binder concentration. 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) [12] support the theory that the amount of binder lengthens the ignition period due to increases density. The outcomes of this investigation is 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). [13]

Burning Rate as shown in Figure 3, indicates an inverse correlation with binder concentration. The mean burning rate was 0.00386g/sec at 20% binder level, but reduced to 0.00367g/sec at 80% binder level. Density affects briquette's 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). [15] Parallel to this, poor volatile matter in briquettes is linked to sluggish burning and difficulty in ignition (Sotannde *et al*., 2010). [27] 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 waterlily Sample Briquettes

Because 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) [16] and Davies and Abolude (2013) [5,8] suggested a lower moisture content of between 5% and 12% for better combustion and briquette stability (Nkemdirim, 2014).[11]

3.1.3 Ash Content (AC) of waterlily Sample Briquettes

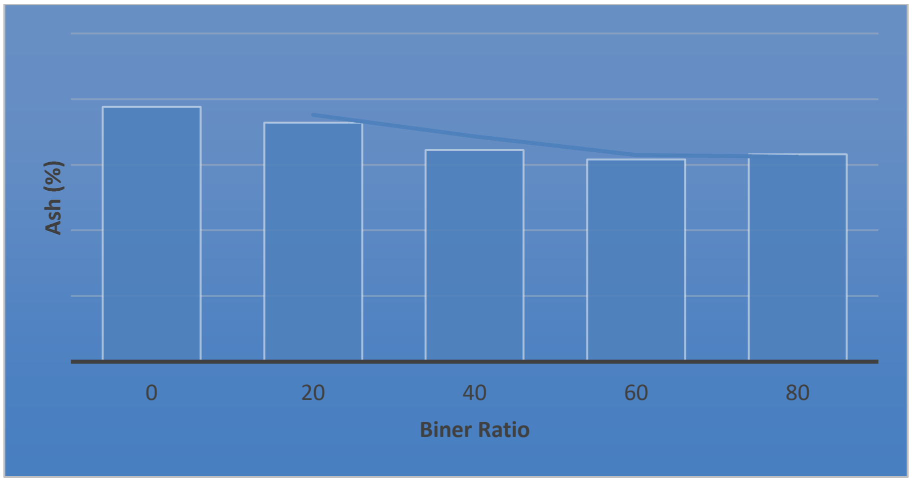

Figure 4: Effect of binder level on (AC) of briquette samples

The content of ash as can be seen in Figure 4, 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. Banana peels bonded water lily briquettes recorded steady decline of ash content to 15.4% 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) [9] on briquettes made from sawdust from three hard wood species (19.07 ±4.80 – 21.72 ±3.99%), and Onuegbu *et al*. (2010) [25]

on coal briquettes (18.27%), but higher compare to the recommendation of 0.7% ash content for fuel briquettes (DIN 51731:1996-10). The Ash content values recorded for this study is statistical significant across binder levels at ($p<0.05$).

3.1.4 Volatile Content (VC) of Waterlily Sample Briquettes

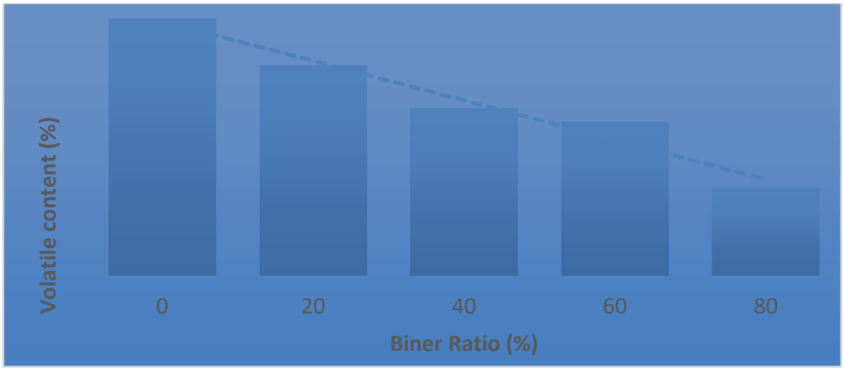

Figure 5: Effect of binder level on (VC) of WL-Briquette samples

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. The results of proximate analysis for banana peel bonded water lily briquettes, as shown in Figure 5 , reveals volatile content range of 50.5% to 56.8% across binder concentration level of B1(20%) to B4(80%) of a constant weight of water Lily grinds, in steps of 20%. It can be inferred from Figure 5, that volatile content of banana peels' bonded water lily briquettes portrays an inverse correlation with binder concentration. 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 findings from this study comparable to 89.47±0.22% reported by (Emerhi, 2011) [9] for starch bonded sawdust briquettes from three hard wood species, and 70.810% reported by (Nkemdirim, 2014)[11] 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 (FC) 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). [15] This section introduces the findings of binder's influence on the volatile matter of the feedstock and it is illustrated in Figure 6.

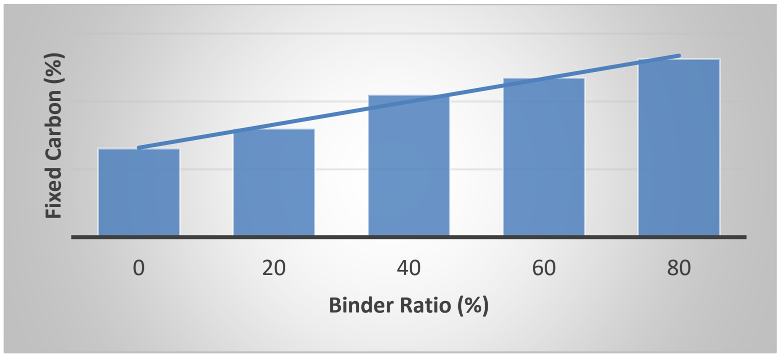

Figure 6: Effect of binder level on (FC) of waterlily briquette samples

The fixed carbon content of Banana peels bonded water lily briquettes in this study, recorded improvement from 13.08% to 25.38% with increment in binder concentration as can be inferred from Figure 6 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 consist with that given by (Nkemdirim, 2014)[11] over starch bonded dried leave briquettes. Banana 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 (Demirbas, 2001). [19]

3.1.6 Calorific Value of waterlily Sample Briquettes

The influence of concentration of yam peel binder on the calorific value of waterlily briquettes is illustrated below in Figure 7 below:

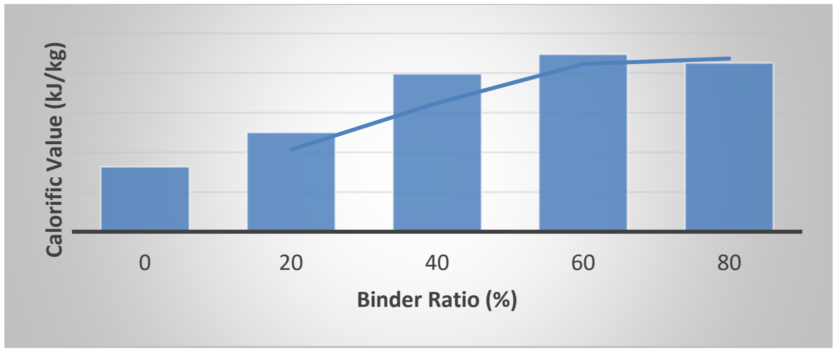

Figure 7: Effect of binder level on (CV) of waterlily briquette samples

The calorific values of banana peel bonded waterlily briquette samples increased with increment in binder concentration to a peak value of 25737kJ/kg at B3(60% binder level) and slightly declined with further increment due to influence of inherent ash (Loo and Koppejan, 2008). [18] The outcome of this study is consistent with Sawdust- and palm kernel shell-mixed briquettes by (Adegoke, 1999) [1] which also recorded increment of calorific value from 19.91MJ/kg to 20.54MJ/kg with binder increment, and coconut husk briquettes by (Jekayinfa and Omisakin, 2005). [14] The average calorific value obtained in this study is above the 17,000 KJ/Kg threshold minimum that is suggested in order for a material to be considered to have an adequate calorific value (DIN 51731: 1996-10). The calorific values observed for this study indicated statistical significance across binder levels at ($p<0.05$).

4.1. Conclusions

According to the study's findings, the amount of banana peels used as a binder in the waterlily 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 banana peels' bonded waterlily briquettes ranged from 24751kJ/kg to 25737kJkg for this study. This values are above 17000kj/kg threshold minimum calorific value required by standard

(DIN 51731:1996-10) for fuel sources, hence they are suitable for household and for small industrial heating applications. This variant of waterlily briquettes are recommended to be produced at 60% binder level and below, as further increment of binder inclusion, recorded reduction in calorific value and increment in ash content. Handling properties should also be investigated, for proper handling of this briquette variants.

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