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THE CHARACTERIZATION OF WATER LILY BRIQUETTES WITH BANANA PEEL BINDER

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ABSTRACT

The study assessed the interaction of binder proportion with burning characteristics of banana peel blended water Lily fuel briquettes. For this study, a constant mass (30g) of water lily powder was used across all mixtures, while a varying mass of banana peel, i.e. (0%, 20%, 40%, 60%, and 80% of the 30g mass of water lily was correspondingly used for the respective mixtures). The resultant homogenous feedstock, hydrated with 200ml of hot water, was compacted in a steel cylindrical die with 14.21 cm as height and 2.14 cm as diameter, applying pressure of5 MPa, and observing a hold time of 20 minutes. The briquettes were then expelled for additional research. 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 24751kJ/kg to 25737 kJ/kg. These calorific value range recommend this briquette variants, suitable for small scale heating application, in line with solid fuel standard (DIN 51731:1996-10), which stipulate among other requirements, 17000 kJ/kg as the threshold minimum calorific value for solid fuels. Based on the experimental results, it was observed that the binder increment in the feedstock composition, lengthened the briquettes' igniting period, but decreased their burning rate.

Keywords: Calorific Value, Binder Levels, Biomass Compression, Handling Characteristics, Banana Peel

1.0 INTRODUCTION

Significant quantity of agro-industrial wastes is produced in many developing countries, hence creating environmental concerns, due to inefficiently treatment and their transformation into useful products (Grover and Mishra, 2009). Transformation of agro-waste into briquettes will check mate the rise in the costs of cooking gas and other fuels, and also mitigate the problems of waste disposal and harmful emissions associated with the combustion of fossil fuel. Energy is considered the foundation for a nation's growth and prosperity (Tariebi and Davies, 2024 and Davies and Tawari, 2010). The utilization of briquetting technology presents a viable ~~re~~solution to the issues associated with underutilized agricultural residues (Davies and Abolude, 2013 and Ribeiro and Junior, 2023). The process can be described as a densification process that increases biomass's volumetric calorific value and enhances raw materials' handling capabilities (Oladeji, 2010). Agricultural leftovers in their untreated state is characterized by bulkiness and uncontrollable burning (Rodriguesa et al., 2017). Biomass is the most accessible fuel in the rural setting for heating applications and rates fourth in usage worldwide (Felix and Gheewala**,** 2011). Nigeria's Niger Delta is known for its extensive network of rivers and creeks. Aquatic weeds such as waterlily, water lettuce, water hyacinth, etc. bloom~~s~~ 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 of weed control, have not been successful in addressing 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).

The briquetting of waterlily (*Nymphaea lotus* Linn.) weeds with banana (*Musa Acuminata*) peel as binder, is an environmentally friendly approach in addressing both the occlusion of our rivers by aquatic plants and the indiscriminate disposal of banana peels on the surroundings. Banana peel contains some measure of starch which gelatinizes in the presence of heat and water**,** hence the choice of its application as a binder (Ai and Jane, 2024). A number of biomass resources, among which is palm fruit fiber, rice husk, peanut shells, sawdust and coconut fiber have been experimentally investigated to be converted into densified fuels due to the benefits of densification (Elinge et. al., 2020; Davies and Davies, 2014). The current investigation offers insight on thermal characterization of banana peel particles bended water lily briquettes with feedstock particle at level of 1.18 mm and applying 5 MPa compaction pressure level.

2.0 MATERIALS AND METHODOLOGY

2.1 MATERIALS

2.1.1 Waterlily Harvest and Pretreatment

Samples for this study were gotten from a canal in Amassoma Town of Sothern-Ijaw Local Government Area of Bayelsa State in Nigeria. The samples were taken to the Department of Agricultural and Environmental Engineering, Niger Delta University Wilberforce Island, Bayelsa State, Nigeria, for the experiment after requisite treatment such as manual washing, sun drying, milling with disc mill and sieving with tyler sieves to obtain particle sizes of 1.18 mm to promote densification (Ajit et al., 2017).

2.1.2 Banana Peels collection and Pretreatment

Banana peel samples for this experiment were collected from banana traders, subsequently given pretreatments such as washing, drying, comminution and sieve analysis to isolate size particles of 1.18 mm, in accordance with (Tariebi and Davies, 2024).

2.2 METHODS

2.2.1 Production of water lily briquettes with Banana peel binder

Thirty grams (30 g) of water lily particles (WL) was consistently used each experimental feedstock mixture, while banana peel (BA), as binder was added in a spectrum, varied as a percentage of the 30g mass of water lily, i.e. B0(0% of 30 g), B1 (20% of 30 g), B2 (40% of 30 g), B3(60% of 30 g), and B4(80% of 30 g) respectively for the corresponding experiments. These percentage masses of banana peel, precisely 0 g, 6 g, 12 g, 18 g, 24 g, respectively were mixed with 30 g of water lily in a plastic plate, The resultant mixture was hydrated with 200 ml of boiled water and stirred constantly to ensure homogeneity, before it was fed into a die for densification on a hydraulic Press. The briquette was expelled and taken for additional research after a 20 minutes hold time.

2.2.2 Design of the experiment

The experiment was carried out as 5x3 randomized complete block design (5x3 RCBD) i.e.

i. Five (5) binder treatment levels, replicated (blocked) thrice, for each parameter investigated.
ii. Computation of means of blocks (corresponding binder treatment level replicates), to minimize associated errors and obtain a representative value for each binder treatment level for, all parametres investigated.
iii. Plotting of graph for each parameter against representative binder treatment levels and generation of associated regression equations, using Microsoft excel software.
iv. Analysis of parameter values, using ONE-WAY-ANOVA, to conclude if the different binder treatment level had significant influence on them.

2.2.3 Characterization parameters

2.2.3.1 Ignition time and Burning rate

This is the rate at which a certain amount of fuel is combusted in air (Bintu et al., 2015). This was determined following the method adopted by (Tariebi and Davies 2024; Onuegbu et al., 2011) which is in line with ASTM E1321-13. A Bunsen burner was ignited and controlled 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 that only the base of the briquette is contacting the flame, in a wind free area. The briquette was removed from the Bunsen burner after observing a brilliant flame as signal of ignition, 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 equation 1:

$$C.R = M_f/t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Where

C.R: = rate of burning expressed, (g/s)

$M_{f:}$ = overall mass of burnt briquette expressed, (g),

t = total time taken (s).

2.2.2.2 Proximate Analysis

This analysis was conducted at the laboratory of the department of chemical engineering, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria, in accordance with ASTM Standard E711-87, (2004), to ascertain the volatile matter, ash content, and fixed carbon content of the sample briquettes. Variety of techniques were then used to calculate the relative amounts of each of these constituents.

2.2.2.3 Moisture content (MC)

Borman and Ragland, (1998) reported that moisture can exist in solid fuels in two distinct forms, namely as bound water – which exist as constituent of the material's chemical structure, and free water – which is resident in the interstices and pores of the fuel. A constant mass of sample briquette, was oven dried at 105°C until mass consistency was observed, then moisture content on dry basis was evaluated using equation 2 (ASTM E871; Francis and Emmanuel, 2022).

$$MC\% = \frac{M_{i-M_f}}{M_f} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

Where,

M_i – sample mass before drying,

M_f – sample mass after drying.

2.2.2.4 Volatile Matter (VM)

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 in line with ASTM E711-87. After letting the sample cool in a desiccator, the proportion of volatile matter was determined by (equation 3):

$$\text{PVM \%} = \frac{B-C}{B} x\ 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

Where

C = briquette sample mass after it has been in the furnace for 10 minutes at 600 degrees Celsius,

B = briquette sample mass after oven-drying.

2.2.2.5 Ash content (AC)

Two grams of pulvervised briquette sample were weighed into a crucible, and heated for four hours at 600 degrees Celsius in accordance with ASTM E711-87, in a vecstar brand of furnace at the laboratory of the Department of Chemical Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. The by-product of the sample after four-hours' resident time in the furnace, was removed and allowed for temperature decrement to room temperature in a desiccator, and then final weighing done to evaluate the ash content (PAC) as shown in equation 4.

$$\text{PAC \%} = \frac{D}{B} \text{x}100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 4$$

Where,

PAC = Percentage ash content,

D = mass of ash derived at the 4hours maintained at 600^{o}C,

B = oven-dried mass of pulverized sample briquette.

2.2. 2.6 Fixed Carbon (FC)

The summation of percentage of moisture (MC), the percentage of volatile matter (VM), and the percentage of ash content (AC) was deducted from 100 in order to obtain the percentage of fixed carbon as shown in equation 5.

$$\text{FC} = 100\ \% - (\text{MC}+\text{AC}+\text{VM}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 5$$

2.2.2.7 Calorific value

The Heat value was empirically computed by using the results from the proximate analysis as given in equation 6 (Sotannde et al., 2010):

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

Where

V= volatile matter in percentage,

C= fixed carbon proportion and

HV= heating value ($kJ\cdot kg^{-1}$)

3.0 RESULTS AND DISCUSSION

The Waterlily briquette samples produced for this experiment as presented in Plate 1 have average height of 3.03 cm, average diameter of 4.21 cm and average compressed density of 0.61 g/cm^3.

Plate 1: Banana peel bonded Waterlily briquette samples.

3.1 The graph of binder Level against-Ignition time of Waterlily Briquettes (WL-B)

Fig. 1 illustrates the impact of binder (banana peel powder) inclusion in the feedstock for the production of water lily briquettes, as portrayed in the ignition characteristics of the fuel.

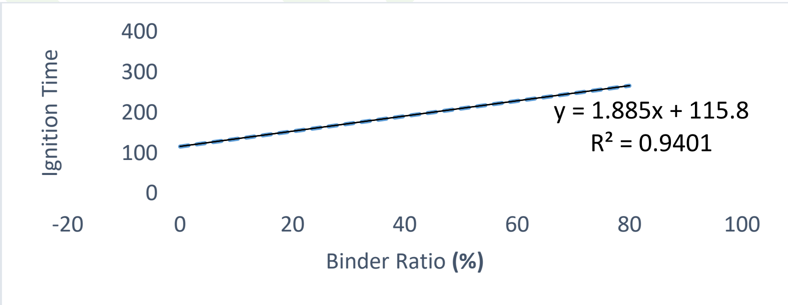

Fig. 1: Graph of Binder Level Against Ignition Time of WL-B

The regression equation linked with the Figure exemplifies a directly proportionate relationship between ignition time and the binder amount in the feedstock composition for the production of the briquettes. The ignition time for the control briquettes B0 [(0% 0f 30 g) Banana peel: (30 g of water lily)] was 123 seconds, but gradually increased with binder intensification in the feedstock to 233 seconds at B4 [(80% of 30 g) Banana peel: 30 g of water lily). This is likely 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 duration due to increases density. The results of this study are similar to those of bio-coal briquettes made by mixing ingredients at varying coal concentrations of 10 to 50%, which range from 19 to 186 seconds (Onuegbu et al., 2011). The ignition time indicated statistical significance across binder level at ($p<0.05$).

3.2 The graph of binder Level against Burning Rate of Waterlily Briquettes (WL-B)

Fig. 2. illustrates the effect of the intensity of the binder (banana peel powder) in the feedstock for the production of water lily briquettes, as reflected in the burning rate of the resultant composite fuel.

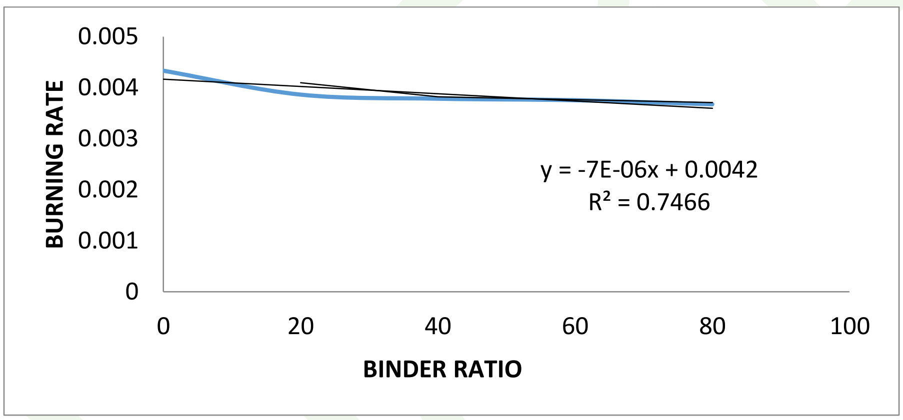

Fig. 2: The Effect of Binder Level On Burning Rate of Waterlily Briquettes

Fig. 2 along with the corresponding regression equation, suggests a decaying relationship between the burning rate and binder concentration level. 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 (Chaney, 2010). This validates greater combustion rates that are achieved with lower binder concentrations. The burning rate indicated statistical significance across binder level at ($p<0.05$).

3.3 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. (Nkemdirim, 2014) suggested a lower moisture content between 5% and 12% for better combustion and briquette stability.

3.4 Ash Content (AC) of waterlily Sample Briquettes (WL-B)

The amount of ash form from the burning of the briquettes, as reflected by the regression line equation of Fig. 3, record a gently decaying relationship with binder intensification level.

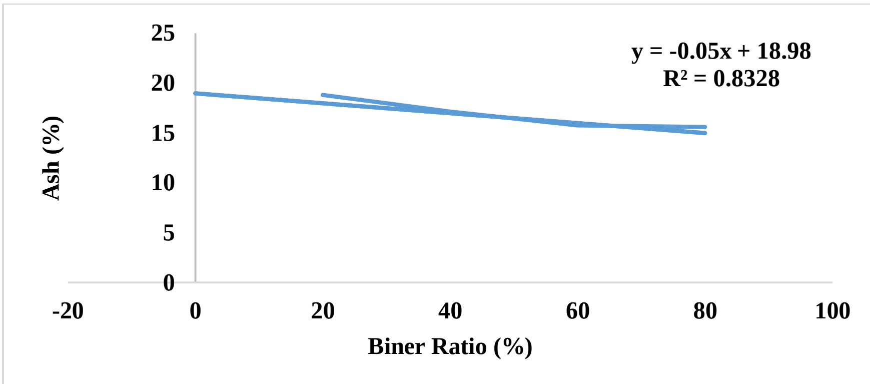

Fig. 3: The graph of binder level against (AC) of WL-B

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 peel 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) 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 significantly high 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 statistically significant across binder levels at ($p<0.05$).

3.5 Volatile Content (VC) of Waterlily Sample Briquettes

The results of proximate analysis for banana peel bonded water lily briquettes, as exemplify in Fig. 4.

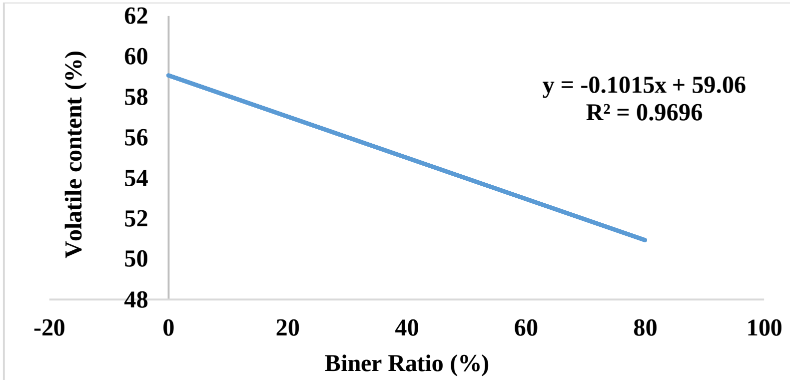

Fig. 4: Effect of binder level on (VC) of WL-Briquette samples

The corresponding regression line equation, reveals a gradually decaying relation between volatile content and the the binder intensity level, which range from 50.5% to 56.8% across binder concentration level. 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) 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 ($p<0.05$).

3.6 Fixed Carbon Content (FC) of water lily Sample Briquettes

The effect of the binder's intensity in the feedstock for the production of water lily briquettes, as reflected in the amount of fixed carbon derivable from the combustion of the resultant briquettes is illustrated in Fig. 5.

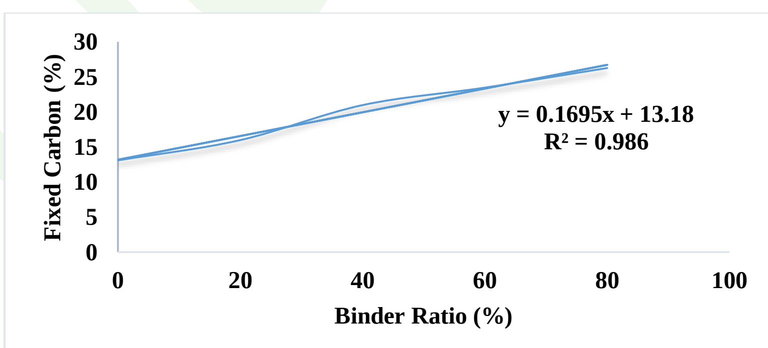

Fig. 5: Effect of binder level on (FC) of waterlily briquette samples

The fixed carbon content of banana peel bonded water lily briquettes in this study, recorded improvement from 13.08% to 25.38% with increment in binder concentration as can be explained from the regression line equation (Figure 5). 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 consistent with that given by (Nkemdirim, 2014) over starch bonded dried leave briquettes. Banana peel binder improved the water lily briquettes' fixed carbon content, notably at ($p<0.05$).

3.7 Calorific Value of waterlily Sample Briquettes

The impact of banana peel binder intensity, in the feedstock for production of water lily briquettes, on the calorific value of resultant waterlily briquettes is illustrated in Fig. 6:

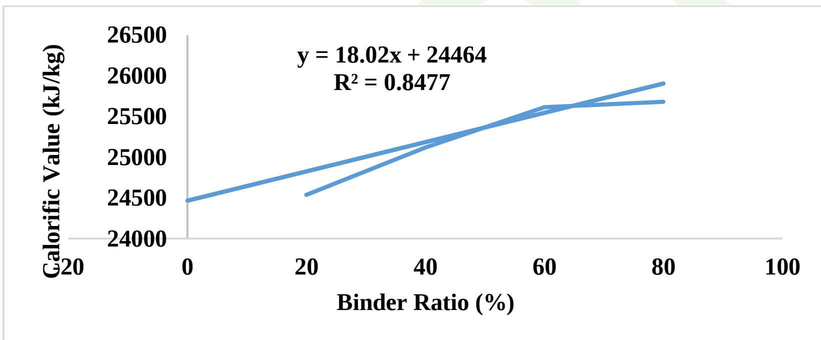

Fig. 6: Effect of binder level on (CV) of waterlily briquette samples

The calorific values of banana peel bonded waterlily briquette samples as seen from the regression line equation in Fig. 6, increased with increment in binder concentration to a peak value of 25737kJ/kg at B3(60% binder level) and gently declined with further increment owing to the inherent ash influence (Loo and Koppejan, 2008). The outcome of this study is consistent with Sawdust- and palm kernel shell-mixed briquettes by (Ayebani et. al., 2021) which also recorded an increment of calorific value from 19.91 MJ/kg to 20.54MJ/kg with binder increment, and coconut husk briquettes (Jekayinfa and Omisakin, 2005). The average calorific value obtained in this study is above the 17,000 kJ/kg threshold minimum that is suggested 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 ($p<0.05$).

4.0 CONCLUSION

Based on the experimental results from this study, the amount of banana peel content, in the waterlily briquette feedstock, had a pronounce effect on how well it burned. Their moderate carbon content and improved burning rate in relation to the controlled briquettes without binder treatment, make them durable and safe for users. The burning rate ranged from 123 sec. to 233 sec., ignition time range from 0,00433 g/sec. to 0.00367 g/sec. and calorific value range from 24751 kJ/kg to 25737 kJ/kg for this study, hence the briquette variant recommendation as suitable for small scale heating application, because the average calorific value is above the threshold minimum requirement for solid fuels, which is 17000kj/kg as stipulated in standard (DIN 51731:1996-10). This variant of waterlily briquettes is recommended to be produced at 60% binder level or below, as further increment of binder inclusion, recorded reduction in calorific value and with a corresponding increase in ash content. Handling properties should also be investigated, for proper handling of these briquette variants.

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