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A Study Into Some Engineering Properties Of Selected Agro-Wastes Bonded Water Hyacinth Briquettes

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ABSTRACT

Water hyacinth, 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. Water hyacinth weeds from literatures records have defied biological, chemical and mechanical means of control and their presence encourages flooding, disrupt: fishing, navigation and recreational activities on streams and normal hydropower operation. Water hyacinth briquette handling qualities were examined in relation to binder type and concentration. Agro-wastes binders, namely - Cassava peels (CA), yam peels (YA) and banana (BA)) were used for this experiment. The Agro-wastes as well as water hyacinth plants were sourced, pretreated by cleaning, sun-drying, milling and finally sieve analyzed to arrive at particle sizes of 1.18 mm ratified for this study. 30g of water hyacinth particles' constant weight was used across all the experiments, while respective agro-wastes particles were added from 20% (B1) to 80% (B4) of the constant (30g) weight of water hyacinth particles in steps of 20% increment. Each of the independent combinations were evenly mixed together, after addition of 200ml of boiled water, before it was 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. The resultant briquettes were ejected for further experimentation after observation of 20 minutes dwell time. From the results of the study, all the physical parameters investigated showed improvement with increment in binder concentration. The Durability of water hyacinth briquettes ranged from 81.58 to 98.12% with mean value of 93.12%, while cassava peel bonded water hyacinth briquettes and yam peel bonded briquettes recorded durability values that ranged from 91.79% to 99.93% with 97.01% as mean and from 86.90% to 99.28% with 95.29% as mean respectively, across the binder concentration levels applied for this study. Briquettes below the binder concentration level of B2 (40%) are not recommended for production as they do not meet the threshold minimum strength for handling, transportation and storage as stipulated by standard (DIN 51731:1996-10) for fuel briquettes. This work provides valuable insight on the handling characteristics of agro-waste bonded water hyacinth briquettes, and highlighted the need to investigate their suitability for sustainable energy generation in rural communities.

Keywords: Biomass, cassava peels, energy, briquette.

1.0 INTRODUCTION

The development of any nation is closely linked with his energy sector progress. Nigeria with its epileptic power supply has made the country to develop at a very slow pace. But Nigeria as a nation is endowed with several network of rivers and creeks especially in the Niger Delta region of the country. Water hyacinth, which clogs ditches and drainage systems and shades out other aquatic vegetation, is a concern for this river and its creeks. It also causes issues for commercial activities including fishing, recreation, and water transportation. 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 might be the most effective way to collect and manage water hyacinth when it comes to using it to produce biofuel. Additionally, this will improve the growth of rural economies in relation to production, harvesting, and consumption and as well mitigate the adverse environmental effects of this weed (Tariebi & Davies, 2024).

The briquetting of water hyacinth weeds with agro-waste 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 & Davies, 2014).The current work offers important insights into a few handling characteristics of the briquettes made from 1.18 mm water hyacinth waste particles with cassava peel binder at various binder ratios and 5 MPa compaction pressure.

2.0 Materials and Methods.

2.1 Water Harvest and Pretreament

For this investigation, samples of water hyacinth (*Eichornia crassipes*) plants were harvested from Amassoma river, Southern Ijaw Local Government Area of Bayelsa State which were transported to the farm structural laboratory of the Department of Agricultural and Environmental Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island Bayelsa State, Nigeria. They were pretreated to remove the interference of foreign matter, sun dried to reduce moisture, chopped into pieces and then comminuted to 1.18 mm shown in Plate 2.1 to increase surface area and promote densification (Kaliyan & Morey, 2009).

Plate 2.1: Water Hyacinth grinds of size 1.18mm. Plate 2.2: Cassava peelings grinds of size 1.18mm

Plate 2.3: Yam peel grinds of size 1.18mm Plate 2.4: Banana peel grinds of size 1.18mm

2.2 Agro-wastes collection and pretreatment

Samples of Agro-wastes were collected from the neighborhood, where they 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 speed up the densification process. Tyler sieves were used to isolate size particles of 1.18mm see Plate 2.2 to Plate 2.4 which were used for the experiment. In line with procedures followed by (Tariebi & Davies, 2024; Nkemdirim, 2014). The chosen particle sizes at concentration levels of B1 (20%) to B4(80%) in step increment of 20% of the residue weight of the aquatic plant were hydrated by addition of 200ml of boiled 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 the die (Plate 2.5) for densification on a hydraulic as shown in Plate 2.6. The briquette was expelled and taken for additional research after a 20-minute dwell period.

Plate 2.5: Die

Plate 2.6: Hydraulic compression machine

2.3 Physical properties of sample briquettes

In relation to briquetting the indices such as compressed density, relaxed density, compaction and relaxation ratios are useful in the investigating the physical properties of briquettes (Sotande & Alandele, 2010).

2.4 Compressed density.

As soon as the briquette was ejected from the die, as a ratio of the observed mass in grams to the volume in cubic centimeters. The mass was gotten with help of the weighing balance given above while the volume was calculated after the dimensions of the briquette was obtained. It was then calculated as follows (Olorunnisola, 2007)

$$\text{Compressed Density} = \frac{MEASURED\ MASS\ (g)}{CALCULATED\ VOLUME\ (cm^3)} \qquad 1$$

2.5 Relaxed density.

Relaxed density was determined after ensuring that the briquette produced has been dried and has reached a stable state, as the ratio of the mass (g) of the dried briquette over the calculated new volume based on the dimension of the sun dried stable briquette measured in line with the procedure adopted by (Olorunnisola, 2007)

$$\text{Relaxed Density} = \frac{MASS\ OF\ DRIEDBRIQUETTE\ (g)}{NEW\ VOLUME\ OF\ DRIED\ BRIQUETTE\ (cm^3)} \qquad 2$$

2.6 Relaxation ratio.

This was calculated as the ratio of compressed density to relaxed density after the briquette had been sun dried to a stable state. (Bolufawi & Bamgboye, 2014).

$$\text{Relaxation Ratio} = \frac{COMPRESSED\ DENSITY}{RELAXED\ DENSITY} \qquad 3$$

2.7 Shattering Index of Briquettes .

Durability gives a picture of the briquette's interaction with material handling equipment and was evaluated based on ASTM D440-86 (ASTM 2002) Standard. The relaxed briquette was pre-weighed and then allowed to fall gravitationally from a height of 1.5meter onto a concrete base. After that, a sieve with a 2.36 mm aperture was used to filter the material, taking record of the mass that was retained on the sieve .This was done in triplicate and the mean recorded using equation 4 (Kpalo et al. 2020; Suprin, 2008).

$$D = (M_a / M_b)x100 \qquad 4$$

Where, M_a – mass of briquette after dropping and that was retained on sieve, M_b – mass of briquette before dropping and D – durability in percentage.

3.0 RESULT AND DISCUSSION

Plate 3.1 Displays Samples agro-wastes' bonded water hyacinth briquettes while the figures that follows shows the dynamic of physical properties with binder concentration level.

Plate 3.1: Water hyacinth briquettes

3.1: Effect of binder level on Relaxed and compressed densities of water hyacinth briquettes.

Figure 1: The effect of binder level on compressed density

Figure 2: The effect of binder level on relaxed density

Relaxed as well as compressed density displayed a positive correlation with binder concentration level across all binder type, drawing inference from Figure 1 and Figure 2. Based on the outcome of study, cassava peel bonded briquettes recorded relaxed density ranged of 0.310 g•m–3 to 0.327 g•m–3, while yam peel bonded briquettes and banana peel boned briquettes recorded relaxed density ranged of 0.302 g•m–3 to 0.325 g•m–3 and 0.296 g•m–3 to 0.315 g•m–3 respectively. But compressed density of cassava peel bonded briquettes range from 0.554 g•m–3 to 0.640 g•m–3, while yam peel bonded briquettes and banana peel boned briquettes recorded value ranges of 0.525 g•m–3 to 0.569 g•m–3 and 0.517 g•m–3 to 0.565 g•m–3 . Across all binder types and binder concentration levels ratified in this investigation compressed density was observed to be consistently higher compare to the relaxed density. This can be explained by significant elastic recovery and stress relaxation processes that takes place after the briquette is taken out of the die in order for it to reach its stable state. Figure 1 and Figure 2 shows an increase in the binder ratio led to an increase in the compressed and relaxed densities of the briquettes, which is consistent with briquettes made from municipal waste (Park et al., 2014; Davies and Davies, 2014; Thabuot et al., 2015 and Rajaseenivasan et al., 2016). When compared to other organic and inorganic binders reported in the literature, the cassava peel three binder utilized in this work performed considerably well in briquette formation (Rajaseenivasan et al., 2016). Cassava peel as binder recorded the highest density range, due to higher starch content which gelatinizes in the presence of water and heat leading to significant bonding strength, better agglomeration among feedstock particle with a consequent improvement in overall density of the briquettes.

3.2 The effect of binder level on the Relaxation Ratios of Water Hyacinth Briquettes.

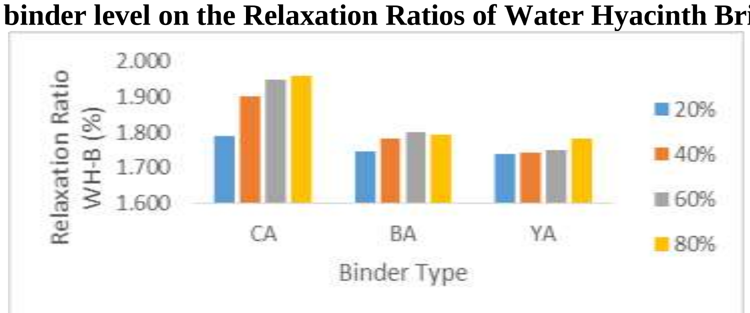

Figure 3: Effect of binder level on Relaxation Ratio

According to Figure 3, the relaxation ratio for cassava peel (CA) bonded briquettes varied from 1.79 to 1.96 depending on the binder level, with a mean value of 1.9, while banana peel bonded briquettes and yam peel bonded briquettes recorded relaxation value range of 1.747 – 1.801 with a mean of 1.781 and 1.739 – 1.782 with 1.753 as mean respectively, for binder levels of B1 (20%) to B2 (80%) of the residue weight of water hyacinth. Figure 3 demonstrates a positive correlation between Relaxation ratio and the binder level across all the three binder types used, i.e., an increasing trend of Relaxation ratio with increment in the binder level, this is in conformity with a researched works that was previously reported by (Bolufawi, 2011) for coconut husk briquettes and by (Oladeji et al., 2009) for groundnut and melon shell briquettes. Given that lower relaxation ratio values indicated a lower tendency of elastic property and more stability and higher relaxation ratio values indicated a higher tendency of elastic property and less stability, the observed relaxation ratio values obtained for this study across all binder levels suggest that the briquettes have good packaging, storage, and transportation qualities with cassava peeling bonded briquettes leading.

3.3 The effect of binder level on the Durability of water Hyacinth briquettes

The shattering index or durability of the banana peel bonded water hyacinth briquettes ranged from 81.58 to 98.12% with a mean value of 93.12, while cassava peel bonded briquettes and yam peel bonded briquettes recorded durability value ranges of 91.79 – 99.93 with 97.01 as mean and 86.90 – 99.28 with 95.29 as mean respectively, for binder levels of 20% to 80% of the residue weight of water hyacinth grinds. These values showed that the briquettes were able to maintain their shape after being subjected to an impact force, as they are higher than the recommended value of 90% same as investigated by these researchers (Borowski 2007; Borowski & Hycnar 2013; Gwenzi et al., 2020) on sawdust briquette mixed with neem powder and (Rajaseenivasan et al., 2016 and Kpalo et al. 2020) on a maize cob and oil palm trunk bark briquette.

Figure 5 Effect of binder level on the **Shattering Index** of water hyacinth briquettes

As illustrated in Figure 4, the briquettes' shattering index exhibits an increasing trend as the binder is added. A possible explanation for the increase in the shattering index with higher binder concentration could be the amalgamation of the constituent components, leading to a strong bonding of particles with more binding agent present. Briquettes made by mixing lignite with leftover paper had an equivalent outcome (Yaman et al., 2001).

4.0 CONCLUSIONS

The agro-waste bonded water hyacinth briquettes is an ecofriendly fuel that has the potential of contributing to environmental sustainability, waste management and local economies, when produced. The percentage of binder added to the feedstock had a substantial impact on the handling properties of the water hyacinth briquettes, according to this study. According to the study's findings, every physical property examined showed improvement as the binder level increased; however, because briquettes below B2 (40%) binder level do not satisfy the minimal requirements for handling by standard (DIN 51731-1996-10), production of such briquettes is not advised. The handling characteristics of this variant of water hyacinth briquettes competed favorably with those of other biomaterials based on reports. Thermal characteristics of agro-waste bonded water hyacinth briquettes should also be studied to know their suitability for household and small-scale industrial heating applications. Cassava peel bonded briquettes exhibited the highest, in respect to mechanical handling characteristics, followed by yam peel bonded briquettes and banana peel bonded briquettes. This can be attributed to fact that cassava peel is richest in starch content among the three binders, which gelatinizes in presence of water and heat, resulting paste that increases in viscosity while cooling, hence recording a significant bond strength among the feedstock particles.

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