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EFFECT OF PROCESS VARIABLES ON CALORIFIC VALUE OF WATER HYACINTH BRIQUETTES

R. M. Davies[1]†, D. S. Abolude[2] and A. M. I. El –Okene[3]

ABSTRACT

The experiment on the effect of compaction pressure, binder and particle sizes on calorific values of water hyacinth briquettes and the proximate analysis of raw material were investigated at 5.6% w.b. The obtained values were statistically analyzed using mean, Analysis of Variance (ANOVA) and Duncan Multiply Range Tests (DMRT). The percentage fixed carbon varied from 23.0 to 26.8%. The obtained result showed reduction in ash content as binder concentration is being increased. With respect to volatile matter, Sample 100:0 (100% water hyacinth) recorded the lowest value (56.1%) while Sample 0:100 (100% plantain peels) had the highest volatile matter (65.5%). The result of calorific values of briquettes produced from mixture of water hyacinth and binder at different levels varied from 3443.03±59.42 to 4533.56±40.43kcal/kg. The effect of binder on calorific value was significant (P< 0.05). The effect of compaction pressure on calorific value was not significant (P>0.05). This proved that the gross calorific value is not influenced by the compaction pressure but mainly by the chemical composition of briquette. The effect of particle size on calorific was significant at 5% probability level. Briquette $D_1P_4B_5$ obtained the highest calorific value (4533.56kcal/kg) among the produced briquettes from water hyacinth and binder. It was found out that all the briquettes produced fulfilled the minimum requirement of calorific value for making commercial briquette (>17500 J/g) as stated by DIN 51731.

KEYWORDS: Water hyacinth, briquettes, plantain, pressure, fuel wood.

INTRODUCTION

Energy is a necessary requirement for everyday life. Its utilization ranges from cooking, local industrial and food processes, warming of the body and other complex industrial and commercial applications. Hydroelectric power is used in the industry primarily and non-renewable fossil fuels are used in commercial transportation and domestic sectors of the economy [1, 2]. The Niger Delta of Nigeria is characterized by extensive network of rivers and creeks which discharge their waters into the Atlantic Ocean. One of the most invasive and prolific aquatic weed that devastate lakes, canals, rivers and pond in the Niger Delta is water hyacinth (*Eichhornia crassipes*). This aquatic weed blooms heavily in Niger Delta due to favourable climatic condition [3]. The harvest frequency for aquatic plants tends to be in the order of days, whereas the frequency for trees and crops are the order of years and months. The abundance, availability, low cost, and rapid growth of water hyacinth make them an ideal candidate for biofuel, particularly in the developing countries [4]. Water hyacinth is found globally in the tropics and subtropics, and is considered as one of the worst weeds in the world-aquatic or terrestrial [3].

This prolific aquatic weed smoothers water bodies, chokes other aquatic lives, prevent navigation, favour mosquitoes breeding and fosters water borne diseases, environmental nuisance and threat to ecodiversity. .Water hyacinth was reported to be difficult to control by physical, chemical and biological means and substantial amount of money have been spent on their control annually throughout the world. However, when water hyacinth is used for biofuel production, this will be perhaps the best method to both control and harvest. This will also enhance: rural economic development, farm income, and market diversification, reduction in agricultural surplus, international competitiveness, reduced negative environmental impact and creation of employment opportunities in the area of production, harvesting and utilization.

The uncontrolled level of cutting of wood for firewood and charcoal for combustion, and for other domestic and industrial uses, is now a serious problem in Nigeria. Akinbami [5] estimated the total annual consumption of wood in Nigeria at about 50-55 million cubic meters of which 90% is firewood, while estimated shortfall of fuelwood in the Northern part of country is about 5-8 million cubic meters. While the annual deforestation of the wood lands in the Northern part of Nigeria run to about 92, 000 hectare a year. The fuel wood extraction rate in the country is estimated to be about 3.85times the rate of re-growth or afforestation. The deforestation rate will continue to increase if nothing is done to discourage the use of fuelwood and promote the use of alternatives and replenish through deliberate afforestation and fuel lots. Sophie [6] reviewed the potential level of application and limitation of biomass resources as a form of alternative source of energy in Nigeria. The author concluded that availability of this resource is a reality but the required technology to harness this resources or its variant is a missing link in the production and utilization of biomass resources in Nigeria.

[1]Department of Agricultural and Environmental Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria
[2]Department of Biological Sciences, Ahmadu Bello University, Samaru, Zaria, Kaduna State Nigeria.[3]Department of Agricultural Engineering. Ahmadu Bello University, Samaru, Zaria, Kaduna State Nigeria
† Corresponding: rotimidavies@yahoo.com

MATERIALS AND METHODS

This study involved collection of samples in Port- Harcourt, Niger Delta and is located between latitudes 4^0 2" and 6^0 2" North of the equator and longitudes 5^0 1" and 7^0 2" East of the Greenwich meridian Tawari [3]. The samples (water hyacinth) were harvested manually. Water hyacinth samples were cleaned to devoid of foreign matters (stone, dust and plant materials) prior drying.

The samples were sundried and finally milled to desire particle sizes using hammer mill. The particle size distribution was achieved by using Particle Size Analysis Equipment consisting of sieve shaker and Tylers sieves of various diameter or particles size openings. The percentages of binder used in the mixture were 10, 20, 30, 40 and 50%. The agitating process was done in a mixer to enhance proper blending prior compaction. The experiments were conducted in the moisture of 5.6% (w.b.).

The pre-treatment processing of briquette sample for this study comprised of drying, size reduction and compaction operations. The raw materials were sundried for 5-7days. The dried raw materials were ground using hammer mill. The particle size distribution was achieved by using Particle Size Analysis Equipment consisting of sieve shaker and Tylers sieves of various diameter or particles size openings 0.5, 1.6 and 4mm (Table1). The percentages of binder used in the mixture were 10, 20, 30, 40 and 50% (Table 1). The agitating process was done in a mixer to enhance proper blending prior compaction. A steel cylindrical die of dimension 14.3mm height and 4.7mm in diameter was used for this study. The die was freely filled with known amount of weight (charge) of each sample mixture and be positioned in the hydraulic powered press machine for compression into briquettes. The piston was actuated through hydraulic pump at the speed of 30mm/min of piston movement to compress the sample.

Compacted pressure ranged from 3.0 – 9.0MPa (Table 1). A known pressure was applied at a time to the material in the die and allowed to stay for 45 seconds (dwell time) before released and the briquette formed was extruded. Stop watch was used for purpose of timing. Prior the release of applied pressure the maximum depth of piston movement was measured for the purpose of calculating the volume displacement to enable the determination of compressive density of the briquette.

Each briquette was replicated three times according to the level of process variables. The moisture content of the ground material before and after compaction was determined using ASABE [7] standard. The calorific value of the sample was determined using Gallenkamp Ballistic Bomb Calorimeter according to ASTM. E440-86 [8]. Proximate analysis carried out on the briquette samples to determine the percentage volatile matter content, % ash content, % content of fixed carbon and heating value of the samples. The procedure of ASTM. E711-87 [9] was adopted.

Table 1. Process variables

Process variable	Different levels
Compaction pressure	P_1 (3MPa), P_2(5MPa), P_3(7MPa) and P_4 (9MPa).
Binder proportion	B_1(10%), B_2 (20%), B_3 (30%), B_4 (40%) and B_5 (50%).
Particle size	D_1 (0.5mm), D_2 (1.6mm) and D_3 (4.0mm).

The data was analysis using Analysis of variance, Duncan Multiply Range Tests and descriptive statistics. All the analyses were carried out with SPSS statistical software.

RESULTS AND DISCUSSION

The experimental results of the proximate analysis of raw materials such as moisture content, ash content, percentage volatile matter and fixed carbon are presented in **Figure 1**.

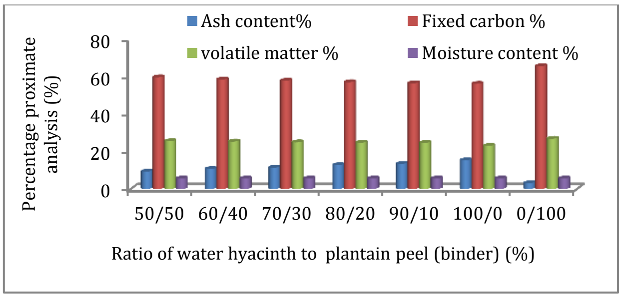

Figure 1. Proximate analysis for mixture of water hyacinth and plantain peel

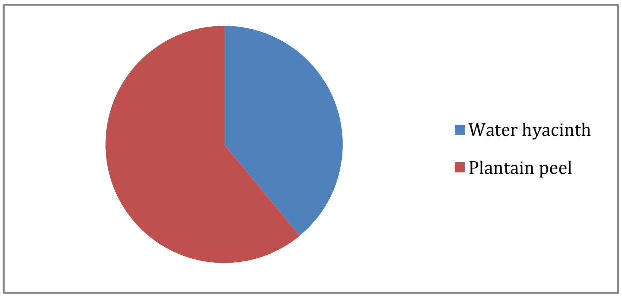

Figure 2. Calorific value of water hyacinth and plantain ground

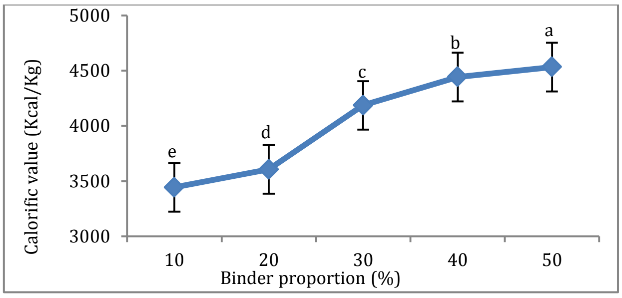

Figure 3. Calorific value and binder proportion (Means of different letter are significantly different (P<0.05))

Moisture content of 5.6% was chosen because of its importance in affecting the burning characteristic of the biomass. During combustion, moisture in the biomass absorbs heat by vaporization and heating of the resulting vapour, significantly reduces the heating value of a given fuel.

The percentage ash content of the raw materials ranged between 3.1% for binder concentration of 50% (Sample 50:50) and 15.3% for (Sample 100:0). The present ash content of samples except Sample 100:0 and Sample 0:100 increased as binder concentration decreased. The ash content of the biomass should be low to enhance combustion of the fuel [10]. Jekayinfa and Omisakin [10] reported ash content values for some agricultural wastes namely palm oil effluent (10.97%), corn cob (4.85%), yam peels (4.56%), mango peels (4.33%), black walnut hull (4.10%), cherry (3.80%), coconut shell (3.47%) and orange peels (2.66%) and these values competed favourably with the present observation. Ash content values for rice husks (23%), pine wood (1%) and groundnut shell (0.8%) were reported by Demirbas and Sahin [11]. The percentage ash content as reported Onuegbu *et al.* [12] varied from 5.16% for *pennisetum purpureum* to 18.23% for coal. The lowest ash content (5.1%) was recorded for Sample 0:100 (only plantain peels) and followed by Samples 50:50 (5.3%) and 60:40 (6.1%). This indicated that higher heating values could be obtained at those binder concentrations. Sotannde *et al.* [13] reported similar trend of lower ash content for briquettes of lignite with biobinder, briquette from oil palm biomass and briquettes from charcoal and gum arabic and starch. The highest ash content (9.0%) was recorded for Sample 100: 0 (100% water hyacinth).

It could be inferred therefore, that water hyacinth contains more mineral (non-combustible) matters than plantain peels and its high concentration might negatively impair on the quality of fuel that will be produced. The volatile matter (56.1%) for Sample 100:0 (100% water hyacinth) was the lowest value while the highest value (65.5%) was recorded for Sample 0:100 (100% plantain peels). The lowest volatile matter recorded by Sample 100:0 implied that the briquettes produce from this biomass might have its ignition time prolonged but once ignited, it might burn smoothly with clean flame without smoke.

The lower the volatile matter of the biomass the better the quality of the fuel in terms of ignition time, burning rate and specific fuel consumption. Conversely, briquette produced from high volatile matter such as 65.5% might readily ignite and equally have higher burning rate compared to low volatile matter. Volatile matter content of the biomass has great influence on the thermal characteristic of solid fuel [13]. This indicated that the study biomass could be a more reactive fuel than coal giving a much faster combustion rate during the devolatisation phase. The study of Onuegbu *et al.* [12] reported the volatile matter values of coal (43.44%), *pennisetum purpureum* (70.10%) and *imperata cylindrical* (69.10%). Furthermore, the volatile matter content of charcoal briquettes from neem wood residue ranged from 10.63 to 13% as reported by Sotannde *et al.,* [13]

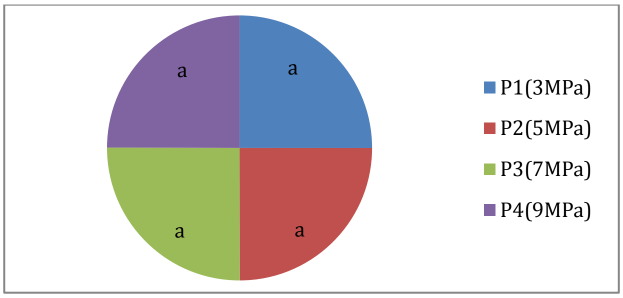

Figure 4. Effect of compaction pressure on Calorific value (Means of same letter are not significantly different (P>0.05))

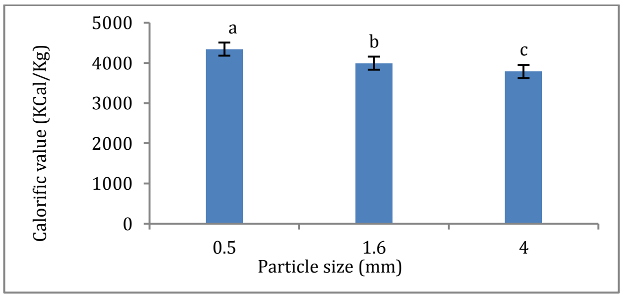

Figure 5. Calorific value and particle size (mm) (Means of different letter are significantly different (P<0.05))

Fixed carbon varied from 23% for Sample 100:0 (100% water hyacinth) to 26.8% for Sample 0:100 (100% plantain peels). A high quality fuel is expected to have high fixed carbon value that improves burning and inflammability qualities [13]. Therefore, the briquettes that will be produced from mixture of water hyacinth at higher binder level are expected to have higher values of fixed carbon than briquettes made from only water hyacinth alone. The fixed carbon content decreased with reduction in binder concentration. The inclusion of plantain peels as binder improves the fixed carbon content of the biomass thus the quality of its fuel is enhanced. The present obtained values of fixed carbon were much higher than the corresponding values reported by Jekayinfa and Omisakin [10] for groundnut (15.50%), yam peels (14.50%), coconut shell (8.78%), mango peels (9.59%) and corn cob (8.75%). It is recorded reported the percentage fixed carbon values for coal (30.65%), *pennisetum purpureum* (elephant grass) (15.11%) and *imperated cylindrica* (spear grass) (14.49%) and these values except coal were lower than the obtained for water hyacinth and plantain peels and their mixture Onuegbu *et al.* [12]. This indicated that the present raw materials might produce higher quality briquette than these biomass.

The calorific value of 100% water hyacinth and 100% plantain peel were investigated. The result showed that water hyacinth had 3190kcal/kg and plantain peel had 4986kcal/kg **Figure 2**. The calorific values of briquettes produced from mixture of water hyacinth and binder at different levels are presented in Figure 3. The calorific values of the briquettes ranged between 3443.03±59.42kcal/kg (B_1) and 4533.56±40.43kcal/kg (B_5).

This indicated that plantain peels as binder improved the calorific value of water hyacinth from 3190 kcal/kg (Sample 100:0) (**Figure 2**) to 4533.56±22.44kcal/kg (B_5) (water hyacinth briquettes). The calorific value of whole water hyacinth (3190 kcal/kg) was lower than the obtained calorific values of water hyacinth briquettes at the different binder proportions. The high calorific value of plantain peels (4986kcal/kg) (**Figure 2**) could be the possible reason for the recorded higher calorific values of the water hyacinth briquettes. This observation might be a positive development in combating the menace created by water hyacinth by using it for bio-energy. The recorded values of calorific values were significant at the different binder levels (P<0.001).

The addition of plantain peels as binder resulted in improved calorific values for all the binder proportions for all the particle sizes. Adegoke [14] reported improved in calorific value of briquettes of palm kernel shell mixed with sawdust from 19.91 MJ/kg to 20.54MJ/kg. Similar observation was reported by Kuti [15] on effect of particle size on the calorific value palm kernel shell. It was also mentioned that the finer the grade (1.18mm) of palm kernel shell in the briquette, the higher is the calorific value. The calorific value of biomass of deciduous wood was improved from 19000 (kJ/kg) to 24000 (kJ/kg) by blending 20% of this wood to 80% of pit coal. The addition of binder to waste wood improved the thermal properties of biomass. The coal plays a stabilizing role in the burning process and equally enhances the thermal property of the biomass [16]. The value is sufficient as a source of warming energy in electric generating plants. Such briquettes, moreover, as an environmental friendly fuel complying with regulations for protecting the environment, limitations of SO_2 emissions into the atmosphere, this process require no desulphurization of fumes [17].

The present study briquettes fulfilled the minimum requirement of calorific value for making commercial briquettes (>17500 J/g) as stated Deutsches Institut für Normung e.V [18]. The properties of the produced briquettes obtained from the study were compared to the commercial sawdust briquettes properties and to the minimum requirements of DIN 51731[18]. The produced fuel briquettes complied with the standard regulations for the protection of the environment, especially in area of low emissions of harmful substances such as SO_2 and NO_2 to the atmosphere.

Densification improves the volumetric calorific value of a fuel, reduces the cost of transport and can help in improving the fuel situation in rural areas Olorunnisola [19]. The obtained values of calorific values of the briquettes gave a clear picture of the importance of densification through using pressure. The compaction pressure ranged between 3437±82.80 (P_4) and 3445.96± 79.97kcal/kg (P_3) (**Figure 4**). The obtained values were mathematically different but statistically not significant (P>0.05). This proved that the gross calorific value is not influenced by the compaction pressure but mainly by the chemical composition of briquettes. The results of calorific value of briquettes as shown in **Figure 5** varied between 3789.92±69.45kcal/kg (D_3) and 4343.45±46.76kcal/kg (D_1) and the observed variations of the calorific values at the three particle sizes depicted significant difference at P<0.001.

The relationship between particle size and calorific value of the briquettes showed inverse correlation. This showed that particle sizes influenced the calorific values of fuel briquettes made from mixture of water hyacinth and plantain peels. The present observation could be attributed to variation in the chemical composition of the roots, stem and roots. In addition, the chemical composition of the water body, where the water hyacinth plant is grown could be attributed to this observation. The highest calorific value of briquettes produced from water hyacinth and plantain peels was 4533.56kcal/kg and the briquette is tagged $D_IP_3B_5$.

CONCLUSION AND RECOMMENDATION

This work was conducted to investigate the proximate and calorific value of water hyacinth of briquettes produced from water hyacinth and plantain peels at different levels of binder and compaction pressure. The quality of the briquettes was enhanced by plantain peel used as binder. The compaction pressure had no significant effect on the calorific value of the briquettes. The effect of binder inclusion on the calorific value of the sample showed significant different (P<0.05).

The optimum binder level, compaction pressure and particle size required to produce the highest calorific value of briquettes from water hyacinth and plantain peels are B_5, P_1 and D_I. Thus, its utilization as briquettes for fuel will be environmental friendly, release lesser carbon to the atmosphere, reduce health hazard associated with the use of fuel wood and reduce desertification and its environmental implication. Therefore, combination of water hyacinth and plantain peels are very suitable for briquette production for domestic and industrial uses.

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