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Some Engineering Characteristics of Carbonized Palm kernel Shell and Plantain Peels Briquettes

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ABSTRACT

Briquetting of biomass as alternative source of energy engender better wastes management and create employment opportunities. The study investigated the physical and mechanical properties of briquettes made from carbonized palm kernel shell of different binder ratios of plantain peels at different compaction pressure. The palm kernel shell samples were manually cleaned, oven-dried and carbonized and milled and sieved. The briquettes were produced at 4 pressure levels of 3MPa (P1), 5MPa (P2), 7 MPa (P3) and 9MPa (P4) and 5 binder levels of 10% (B1), 20% (B2), 30% (B3), 40% (B4) and 50% (B5) by weight of each feedstock. A steel cylindrical die of dimension 14.3mm height and 4.7mm diameter was used to produce briquettes using hydraulic press with dwell time of 90 seconds. The effect of binder ratios and pressure levels on the density, relaxation and compaction ratio, shattering index, compressive strength and water resistance capacity of briquettes were significant ($P<0.05$).

It could be concluded that the production of carbonized palm kernel shell and plantain peels water hyacinth briquettes is feasible and are environmentally friendliness as compared to firewood, mangrove wood and charcoal.

Keywords: *Pressure, Binder Concentration, Biomass, Agricultural Wastes, Biofuel.*

INTRODUCTION

There is over dependent on fuelwood, twigs and charcoal as the major source of renewable energy and this consequently led to serious deforestation which has destroyed the ecosystem and mangrove. Forest have been over-depleted and fuelwood price have gone up considerably and leaving women and children to travel long distance for its collection. This has eventually led to increase in prices of kerosene and cooking gas in Nigeria. Many researchers have shifted focus on other forms of renewable energy sources such as biomass for domestic and cottage level industrial use. The current changes in global environmental conditions and the increase in atmospheric concentration of carbon and sulphur compounds are motivating studies towards finding alternatives solution since use of fossil fuels have a limited potential and serious detrimental consequences on the environment due to pollution induced by greenhouse gases (Jaan *et al.*, 2010).

Densification of biomass to produce briquettes can be described as an ideal energy source that meets sustainability requirements of energy source (Yaman *et al.* 2000 and Olorunnisola, 2004; Tumuluru, 2010 and Wagner and Buscher, 2005).

Traditionally, agricultural waste and residue are disposed off either through burning or leaving them to decompose causing serious nuisance to the environment. With the recent technology advancement in the production of upgraded fuel products such as briquettes and biodiesel have offered unique qualities products that provides better environmental benefits. Some distinctive characteristics of the upgraded biomass products includes; better handling characteristics of raw materials, improving the volumetric calorific values, reduction in cost transportation and production of uniform, clean, stable fuel, or an input for advance refining processes of biomass. Also, greater heat intensity, handiness and relatively smaller space requirement for storage (Bamigboye and Bolufawi, 2008). Huge investment into reforest will help to mitigate climate change, reduces acid rain, soil erosion, water pollution, provides wildlife habitat and helps to maintain forest health (Hamelinck and Faaji, 2006 and Jekayinfa and Omisakin, 2005). Introduction and utilization of biomass energy in form of briquettes in commercial level could contribute immensely to sustainable development. Chin and Siddique (2000) described a briquette as block of compressed coal, biomass or charcoal dust that is used as biofuel.

Briquettes can be produced under high pressure and elevated temperature or at ambient temperature based on the technology. Sometimes, in briquetting techniques the materials are compressed with or without adhesive. Recently, researchers have shown that combination of coal and biomass enhances briquette combustion properties and environment friendly (Chin and Siddique, 2000). The production of briquettes create employment opportunities through engendering many micro enterprise opportunities that include the manufacturing of the hydraulic presses from locally available materials, utilization of materials such as agricultural waste and sawdust, briquette production enterprise, packaging and selling of the briquettes.

Agricultural and industrial wastes are potentially huge source of energy-giving materials, and large quantities of these wastes are produced annually and are greatly under-utilized in Nigeria, (Emerhi, 2011).

Some engineering characteristics of briquettes have been investigated by some scientists for various agricultural wastes for example water hyacinth and plantain peels briquettes (Davies and Davies, 2014), waste paper and coco nut shell (Olorunnisola, 2010), water hyacinth and water lettuce briquettes (Davies and Davies, 2015), maize cob (Wilaipon, 2007), alfalfa products (Sokhansanj and Crerar, 2005), rattan furniture waste (Olorunnisola, (2004), Corncob (Oladeji, 2012) rice straw (Ndiema et al., 2002).

Akinbami (2001) reported that socio-economic development of a country greatly anchors on the availability and consumption of energy. Continuous depletion of the natural resources by an increased consumption of fossil based energy and the growing awareness of the negative environmental consequences due to Greenhouse Gas emissions have entrenched the importance of biomass as an energy resource in the developing countries such as Nigeria.

Thus, alternative to fossil fuels has to be searched out. Its selection as an alternative source of energy is an important way of managing the wastes problem and contributing to environment management. The objective of the study was to investigate and establish a database for engineering properties of carbonized palm and plantain peels briquettes.

MATERIALS AND METHODS

Palm kernel shell was collected from oil palm processing firm, Elele, Rivers State, Nigeria. Prior the drying of palm kernel shell, the samples were cleaned to devoid of foreign matters (stone, dust and plant materials). Palm kernel shell was put in dryer with temperature 125 ^{o}C for twelve hours to achieved moisture content of 7.94% dry basis.

Locally produced carbonized kiln of dimension 1.0 meter in height and 0.75 meter in diameter was used for carbonization of palm kernel shell. Carbonized palm kernel shell was ground using hammer mill powered by diesel engine. The desire particle size of 0.750 mm of achieved using Tylers sieves of various diameter or particles size openings (ASAE 424.1, 2003).

One hundred grams (100g) of ground plantain peel was hydrated with 120 ml of distilled water and stirred constantly to form colloidal solution of the binder. The colloidal solution was heated in a boiling water bath at 100^{0}C for 10 min with continuous stirring until smooth and homogeneous paste was produced.

The consistency of the binder was maintained at a preset level with its concentration in the sample mixture ranged from 10, 20, 30, 40 and 50% level of the residue by weight (Bamigboye and Bolufawi, 2008). A dwell time of 120 seconds was observed for the briquettes formation. The relaxed density of the briquettes was determined according to ASAE standard method of determining densities.

Determination of Relaxed Density of Briquette

The height and diameter of the briquette was consistently measured until it was stabled. The stable height and diameter was used to calculate the new volume of the briquette since the charge was known initially (Olorunnisola, 2007 and Bamigboye and Bolufawi, 2008).

Relaxation Ratio

Relaxation ratio was calculated as the ratio of compressive density to relaxed density according to Bamigboye and Bolufawi, (2008)

$$\text{Relaxation Ratio} = \frac{\text{Compressive Density}}{\text{Relaxed density}} \qquad (1)$$

Moisture Content Determination

The moisture content of the ground material before and after compaction was determined using ASABE (2003) standard use of oven-drying method.

Compressive Strength

The compressive strength of the briquette was estimated by means of Universal Testing Machine in accordance with ASTM 1037-93 (1998). Compressive strength was calculated by dividing the load at the fracture point by cross sectional area of plane of fracture.

Compression Ratio

Compression ratio can be described as the ratio of the compressed density of the briquettes to initial bulk density of residue. The compaction was determined according to ASABE (2003) standard.

Shattering Index Test

Briquettes shattering index (durability index) was determined according to ASTM. D440-86 (1998) of drop shatter developed for coal.

$$\text{Shattering index} = \frac{\text{Weight of briquettes retained on the screen after dropping}}{\text{Weight of briquettes before dropping}} \quad \ldots\ldots\ldots \quad (2)$$

Results and Discussion

The effect of binder ratios and compaction pressure on the relaxed density of briquettes varied from 423.25 ±5.76 kg/m^3 (B_1) to 619.05 ± 8..64 kg/m^3 (B_5)was shown in Fig. 1. The relaxed density of the briquettes increases with increase in binder proportion. The relaxed density increased with increase in compaction pressure. Briquettes produced at B_5P_4 had the highest relaxed density. It could be inferred that the optimum amount of binder required for densification was 50% (B_5). At this level of binder and pressure, the briquettes produced have the required strength to withstand handling, transportation and storage.

Similar trend were reported by some researchers on the increased in binder proportion and compaction pressure led to increase in relaxed density Enngellectner (2001), Oladeji (2011) and Chin and Siddiqui (2000). On the contrary, the corresponding report by Sotannde *et al.* (2010) discovered that the binder types and blending ratio had no significant influence on the relaxed density (P>0.05). This parameter is one of the most important properties that influence handling characteristics, transportation, storage, hygroscopic characteristics, and combustion characteristics such as ignition, specific fuel consumption, thermal fuel efficiency and burning rate behavior of briquettes. Most desirable ideal fuel briquettes should have high density due to their high energy content per unit volume and slow burning rate property (Kumar *et al.* 2009 and Saptoadi, 2008).

Increased in relaxed density with increased in compaction pressure could be attributed to the possible compactness of the material as pressure increases and the reduction in elastic recovery during relaxation of the formed briquette. The increased in relaxed density with compaction pressure could be due to the possible compactness of the material as pressure increases and reduction in elastic recovery during relaxation of the formed briquette.

This could be attributed to the possible compactness of the material as pressure increases and the reduction in elastic recovery during relaxation of the formed briquette. Based on European Standard for commercial briquettes CEN\TS14961 (2004), the acceptable relaxed density ≥ 500kg\m^3. This is an indication that all the briquettes met the standard requirements except briquettes produced with compaction pressure 3 MPa.

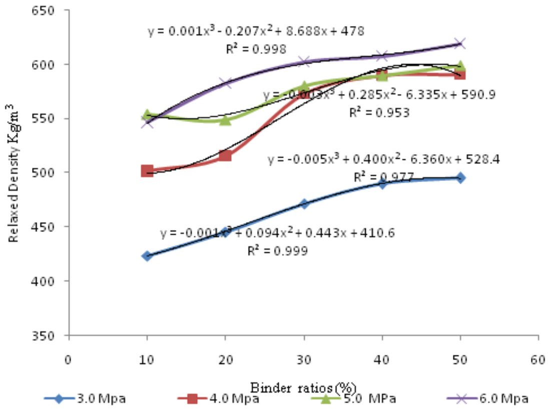

Figure1. *Effect of binder ratios and compaction pressure on density of briquettes*

The values of relaxation ratio of the briquettes ranged between 1.54 and 1.99. These values are low but produced briquettes exhibited low elastic property and more stabled compared with briquettes of higher relaxation ratio that exhibited high tendency of elastic property and less stable. Similar trend was observed by Olorunnisola (2007) with values of relaxation ratio of 1.8 to 2.5 for briquettes from wastes paper and coconut shell.

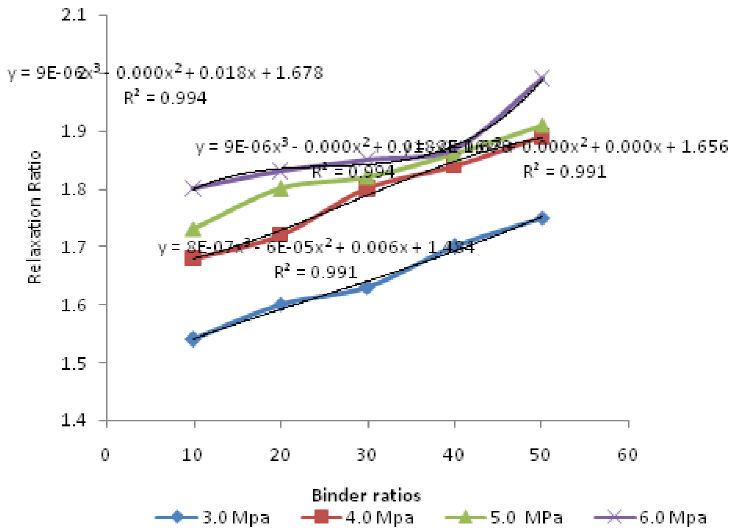

Figure2. *Effect of binder ratios and compaction pressure on relaxation ratio of briquettes*

Other studies on the effect of binder types, binder levels, compaction pressure and particle sizes on relaxation ratio were reported by Sotannde *et al*. (2010) and Davies and Davies (2015). The obtained range of relaxation ratio in this study is still within the reported range of 1.8 to 2.5 and 1.65 to 1.8 by O'Dogherty (1989) and Olorunnisola (2007). Sotannde *et al*. (2010) reported relaxation ratio values between 1.11 and 1.32 for briquettes made from charcoal and Arabic gum respectively but briquettes produced from charcoal and cassava starch had relaxation ratio values of 1.17 and 1.34. Oladeji (2011) reported relaxation ratios values between 1.33 and 2.68 for briquettes produced from corncob from white maize. Compaction ratio ranged between 2.67 and 6.42. The obtained higher values recorded for compaction ratio showed more volume displacement which is positive development for packaging, storage and transportation and above all, it is a signal of good quality briquettes. Bamigboye and Bolufawi, (2008) obseved compaction ratio between 3.179 and 9.730 for briquettes made from guinea corn residue and starch. Compaction ratio of 3.80 was obtained during briquetting of rice husk (Oladeji, 2010). Compaction ratios of 3.5 and 4.2 were observed during production of briquettes of groundnut and melon shells (Oladeji *et al*., 2009). It was found that compaction ratio for briquettes produced from corncob from white maize varied from 2.23 to 6.50 for pressure levels 2.1, 4.2 and 6.4 N/m^2 (Oladeji, 2012).

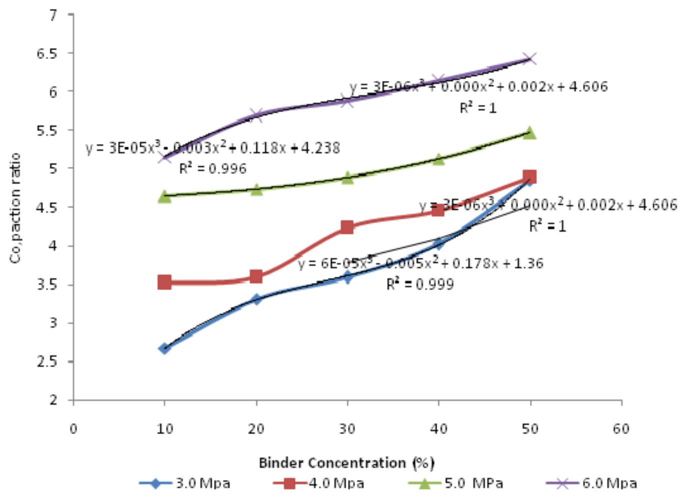

Figure3. *Effect of binder ratios and compaction pressure on compaction ratio of briquettes*

The effect of binder proportion on the durability of the briquettes was investigated as revealed in Fig.4. The mean shattering index ranged between 0.47±0.01 (B_1) to 0.98 ±0.03 (B_5) and variation of the values were significant ($P<0.05$). The obtained values indicated that increase pressure caused increase durability of the briquettes. The effect of pressure on the durability is significant. Based on the observation is that binder 50:50 is the optimum binder level requirement to produce durable, reliable and stable briquettes that stands mechanical handling and transportation, economical feasible and environmentally friendliness. The strength and durability values of briquettes produced using binder ratio 50:50 matched with the quality requirement for transportation (Sotannde *et al.*, 2010, Altun *et al.*, 2001, Borowski and Kuczmaszewski, 2005 and Borowski, 2007). According to European Standard on commercial briquettes CEN\TS14961 (2004), the acceptable shattering index is ≥ 0.95.

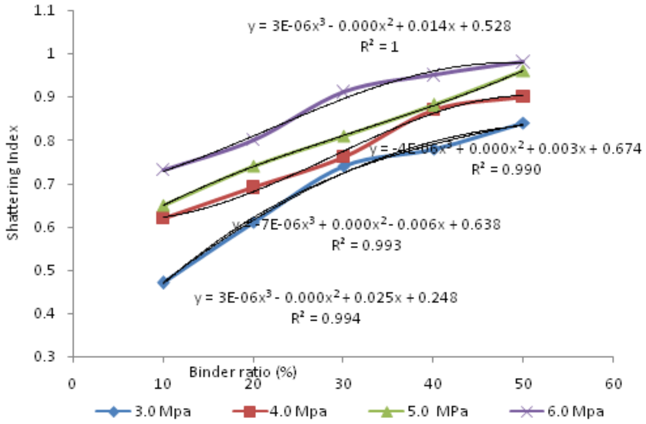

Figure4. *Effect of binder ratios and compaction pressure on shattering index of briquettes*

The compressive strength (compressibility) of briquettes increased with increased binder proportions and compaction pressure. Based on the obtained result the plantain peels as binder could be regarded as good binder for the briquetting of water hyacinth. For briquette quality control, the physical parameters such as density and compressive strength were found to be the best indicators of additive quality. It was found that increased binder content increased the compressive strength of the briquettes. This parameter is important in determining the stability and durability of a briquette (Kaliyan and Morey, 2009 and Bisana and Laxamana, 2008)). It is also the major quality index for fuel briquettes. The obtained values of compressive strength at different compaction pressure were in strong agreement with those reported by Chin and Siddiqui, (2000) on the effect of compaction pressure on the compressive strength of some biomass namely sawdust, rice husk, peanut shell, coconut and palm fibre. The strength and durability values of briquettes made by using the binder were within the recommendation specified for transportation. Sotannde *et al.* (2010), Altun *et al.* (2001), Borowski and Kuczmaszewski (2005) and Borowski (2007) reported the effect of binder on the durability of briquettes.

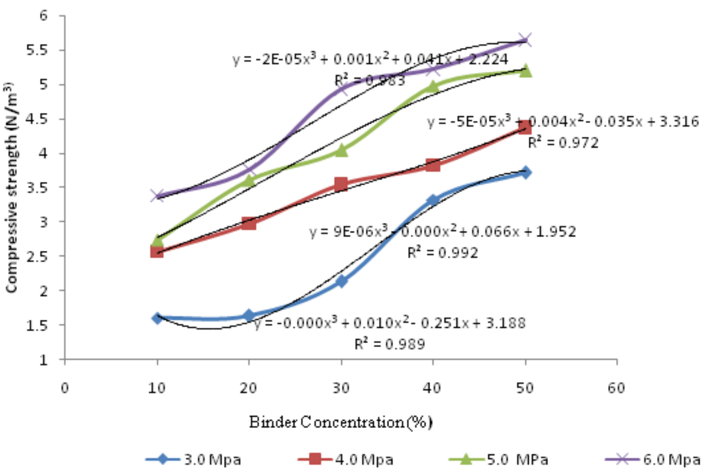

Figure5. *Effect of binder ratios and compaction pressure on compressive strength of briquettes*

Kaliyan and Morey, 2009 reported that fuel briquettes produced under different conditions such as compaction pressure, binder ratio and particle sizes to have different handling characteristics. Besides, these characteristics were also found to be strongly affected by raw material properties. The relationship between binder ratios, compaction pressure and relative change in height ranged between 6.86±0.13 mm and 9.97± 0.84 mm and there was significant variation of the values ($P<0.05$) (Fig.4). The water resistance capacity of the briquettes at different binder proportions and particle size showed increased in water resistance capacity with increased quantity of binder and compaction pressure. The water absorption capacity of briquettes decreased with increased in compaction pressure levels and increased in binder proportion thereby enhanced its hygroscopic property. This is an indication that voids between particles inside the briquettes might have been sealed up, thereby disallowed water infiltration and passage. The briquettes produced at 6MPa and 50% had the highest water resistance capacity of the briquette. Compaction pressure and binder ratio at 6 MPa and 50% might have brought the particles sizes closer so that the forces acting between them became stronger. At this process variable briquettes made provided more strength to the densified bulk material so that the product would have sufficient strength to withstand rough handling and humid condition.

Thus, in a highly humid environment pressure at least 6MPa and 50% is recommended.

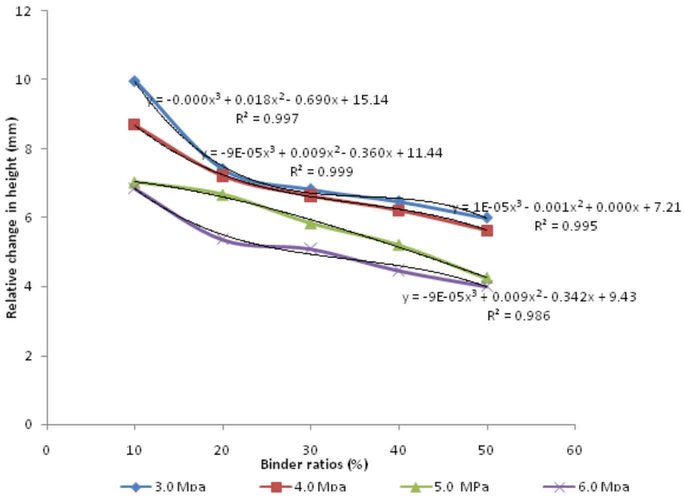

Figure7. *Effect of binder ratios and compaction pressure on relative change in height of briquettes*

CONCLUSION

The production of briquettes from water hyacinth and plantain peels is feasible and its physical and combustion characteristics compare favorably with briquettes from other agricultural wastes.

This study found that processing parameters such as % binder ratio and compaction pressure significantly affected the physical characteristics of palm kernel shell briquettes. For the two processing parameters examined in this study, variables with binder ratio 50% and compaction pressure (9 MPa) exhibited the most positive attributes than the other variables.

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