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Original Research Article

Characterization and Performance Evaluation of Bush Mango Shell and Palm Pressed Fibre Briquettes

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ABSTRACT

In this study, five different samples of briquettes were produced by varying the compositions of BMS and PPF in the ratios (BMS: PPF) of 100:0, 75:25, 50:50, 25:75, and 0:100 and labeled sample A, B, C D and E respectively and completely characterized. The results of the properties tested were compared among the mixture of the biomasses proportions. The TGA result revealed that palm pressed fibre had the least rate of decomposition of 3.84% at 375 °C, while bush mango shell had the highest rate of decomposition of 5.48% at almost 400 °C. It was observed from the produced briquette samples that the maximum density, compression pressure, shattering index and calorific value increased as bush mango shell composition increased. Ignition time decreased with increase in bush mango shell concentrations in the mixture. The briquette sample (B) produced more heat (higher calorific value) during combustion than the others, while sample (E) ignite more readily and burn faster than other formulations because of its higher volatile matter but low in heating value (due to its low and coarse density). Therefore, Sample B briquettes showed good physical, mechanical and combustion properties with density of 1280 g/cm^3, shatter index of 98%, calorific value of 18.65 kJ/kg; ignition and burning rate of 0.472 g/min and 38.17 g/min at optimum compression time of 40 minutes and pressure of 25 MPa thus suitable for biofuel production.

1. INTRODUCTION

Energy is crucial to the wellness of humans and in boosting any country's economic development. Unfortunately, developing countries like Nigeria are faced with epileptic and unstable electricity supply with

incessant shortfalls both in rural and urban centers (Batidzirai, 2012). Energy from biomass can potentially be an alternative approach to solving the country's electricity problems as it constitutes over 84% of Nigerian energy consumptions as shown in Figure 1 (EIA, 2011). Nigeria is capable of producing 47.97 MTOE from 168.49 million tonnes of agricultural residues and wastes that can potentially be generated every year (Simonyan and Fasina, 2013). However, there has been gross underutilization of such potentials.

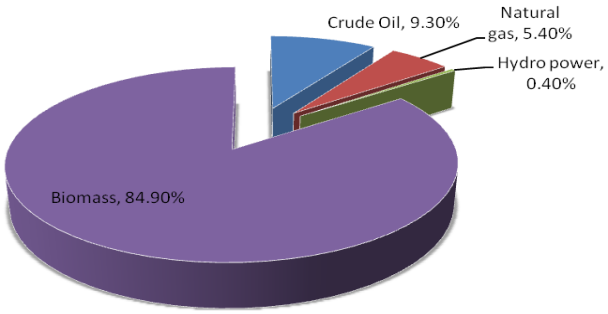

Figure 1: Energy consumption in Nigeria (EIA, 2011)

Biomass as organic and a renewable energy source contain energy in a chemical form which can be converted to fuel. It includes the residues from agricultural operations, food processing, forest residues, municipal solid wastes and energy plantations (Ezealigo *et al.*, 2021). It is one of humanity's earliest sources of energy particularly in rural areas where it is often the only accessible and affordable source (Demirbas *et al.*, 2004). Generation of energy from biomass materials offers the potential to reduce the greenhouse gas emissions from fossil fuels (Trubetskaya *et al.*, 2019). It can also guarantee energy security, tackle environmental problems (Sawadogo and Tankoano, 2018); contributes to efficient biomass energy management and economic development of rural areas (Duca *et al.*, 2014). The prospects of biomass wastes usages in the production of densified solid fuel briquettes with high energy content have been on focus by researchers (Ndindeng *et al.*, 2015; Lubwama and Yiga, 2017; Zhenkun *et al.*, 2020).

Biomass wastes usually of plant origin or product of processing operation such as rice husks, cassava peels, groundnut shells, sugar cane bagasse, corn cobs, coconut shells and husks sawdust, bush mango shell, kernel shells, palm fibres have been exploited in remote areas in form of direct fuel and disposed in open burning system or left to decompose naturally in farmlands constituting environmental pollutions and degradations (Jekayinfa and Omisakin, 2005; Okot *et al.*, 2018; Zhenkun *et al.*, 2020). Biomass exhibit low energy characteristics when exploited in their crude state (Felfli *et al.*, 2011). In addition, they are characterized by low bulk densities owing to their porous structure resulting in processing, storage, transport, and combustion challenges (Miranda *et al.*, 2018). Even their disposal options have been grossly ineffective with huge environmental consequences (Da Silva *et al.*, 2018). As a result, biomass conversion to a more usable, energy condensed state becomes important for its consideration as viable fuel (Mendoza-Martinez et al., 2019). Densification presents an important opportunity for transforming biomass wastes with low heating value into condensed solid fuel energy. It also offers necessary homogeneity and improves their bulk densities for haulage and transport optimization. Such briquetting technology remains the most available option for producing energy as solid fuel usually for cooking at rural household level where energy shortfalls prevail (Oladeji, 2010; Sotannde *et al.*, 2019). Densification and briquetting of several combinations of different biomasses, showed evidence of high energy content potentials (Musa, 2007; Oyelaran *et al.*, 2014; Olugbade and Mohammed, 2015; Amadi and Ikhazuangbe, 2020).

Bush mango shell and Palm pressed fibre are among the biomasses whose underutilization of energy potentials in their crude state has resulted in huge energy and economic waste (Batidzirai *et al.*, 2012). In addition, inefficient disposal management mechanism of these abundant biomasses has constituted daunting environmental challenges manifesting in land, air and water pollutions (Amadi and Ikhazuangbe, 2020). Hence, there is need to exploit the energy potentials of these biomass wastes through a technologically articulated process of conversion to a ready-to-use, high-energy resource, haulage-able and environmentally-

friendly. Such form is largely dependent on the types of biomass, mix ratio, additives (binders) and processing methods and conditions. Investigation of these controlling factors and process parameters will guarantee the best products (briquettes). Therefore, in the present study, bush mango shell and palm pressed fibre were used as the biomass feedstocks for the production of briquettes with the aim of characterizing and evaluating the briquettes performance for the best physical, mechanical and combustion properties.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in the production of the biomass briquettes includes bush mango shells and palm pressed fibre (collected from a refuse site in Nsude, Udi local government area of Enugu State in South-Eastern Nigeria), and cassava starch (binding agent accessed from a local cassava processing plant at Emene, Enugu State). Laboratory and other equipment used include: a set of sieves (0.5 – 1.5 mm mesh size), steel spatula, stirrer, bowls, hand gloves, metal files, mobile hardness tester, furnace, milling machine, Bunsen burner, bomb calorimeter (PARR 6200), tripod stand, water, stop watch, die, heater and digital weighing machine (DWM of 0.1 g accuracy). A hydraulic press briquetting machine (KENNEDY Model HBP020, UK) was employed in the sample productions. The briquettes were produced at TOAN Engineering and services limited workshop, Enugu State College of Education Technical (ESCET) and analyzed at Project Development Institute (PRODA), all in Enugu State, Nigeria according to the standard methods.

2.2. Methods

Bush mango shell and palm pressed fibre were processed and characterized using proximate and thermogravimetric analysis (TGA). The combustion properties of the biomasses were improved upon by densification of the biomasses through briquettes formation. Briquettes production was done using various proportions of the two biomasses. Performance evaluations of the briquettes formed was carried out and energy analyses of the briquettes were studied.

2.2.1. Sample preparation

The biomass samples of bush mango shells and palm pressed fibers were sun dried for one week to about 12% moisture content, then milled separately using an electric milling machine and sieved with a sieve shaker of 0.5 mm mesh size to obtain the required particle size. The characterization methods used include: proximate or elemental analysis of the biomasses, thermogravimetric analysis.

2.2.2. Proximate and combustion analyses of the biomasses

The proximate analysis of the biomasses studied includes density, moisture content, calorific value, ash content and flash point. A clean empty specific gravity bottle was weighed on an electronic balance and the mass (W_1) noted. It was then filled with each milled biomass, in turn, at the room temperature and its mass (W_2) and volume noted. The mass of each milled biomass (W_s) was the difference between W_2 and W_1. The bulk density of the biomass material, (ρ) was calculated using Equation (1).

$$\rho = \frac{m}{v} \tag{1}$$

where ρ = bulk density of biomass (g/cm³), m = $mass\ of\ biomass\ (g)$, v = $volume\ of\ biomass$ (cm^3)

The dry oven method was employed in determination of moisture content. A clean glass petri dish was weighed (w_i). Two grams of the test sample was weighed into the weighed petri dish (w_T). The petri dish containing the sample was introduced into a hot air oven and left for an hour at 105 °C. After this, the sample was immediately transferred into a desiccator and allowed to cool. It was weighed again to obtain the final weight (w_f). The moisture content (MC) was then determined using Equation (2).

$$\%\ MC = \frac{W_T - W_f}{W_T - W_i} \times 100 \tag{2}$$

The ash content was determined from the total loss in weight that occurred during the incineration of the sample in the presence of oxygen at temperature high enough to allow all organic matter to be burnt off without allowing appreciable decomposition of the ash content or loss by volatilization. It was the inorganic residue remaining after the organic matter has been burnt away. An empty clean porcelain crucible (W_c) was weighed. Two grams of sample (W_i) was weighed into the crucible and heated in a Bunsen burner at 600 ºC for three hours. It was allowed to cool in desiccators and weighed (W_f). The ash content (A_C) was determined using Equation (3).

$$\% A_C = \frac{W_i - W_f}{W_i} \times 100 \quad (3)$$

where W_i = Initial weight of un-burnt sample, W_f = Final weight of ash

Volatile matter was determined using the ASTM D-3175 method (ASTM, 2004). Here, the residual dry sample from moisture content determination was heated to drive off the volatiles (just before it ashes). Percentage volatile matter (VM) was calculated using Equation (4).

$$\% VM = \frac{W_4 - W_5}{W_4} \times 100 \quad (4)$$

where W_4 is the weight of oven dried sample and W_5 is the weight of sample after 7 minutes in the furnace at 950 ± 20 ˚C.

The fixed carbon, (FC) is the solid combustible residue that remains after moisture, volatiles and ash have been expelled from a sample. This was calculated on percentage basis using Equation 5.

$$\% FC = 100\% - (MC + VM + A_C) \quad (5)$$

In determining the calorific value of each of the biomass, a bomb calorimeter was used. The weight of the biomass sample was measured in grams, put into a crucible and standard method prescribed by ASTM (2004) was adopted. Oxygen in the bomb was kept at a pressure of 2.8 -3.0 MPa while the experiment was conducted, then the calorific value (CV) was calculated using Equation 6.

$$CV = \frac{E\Delta T - \emptyset - V}{w} \quad (6)$$

Where $w =$ weight of sample, $E =$ energy equivalent of the calorimeter per degree Celsius, $\Delta T =$ change in temperature, $\emptyset =$ correction for heat of combustion of firing wire, (2.3l) and $V =$ volume of titre used during titration

Heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel. This was calculated using the expression in Equation 7 (Bailey and Blankenhorn, 1982).

$$\text{Heating value, } HV = 2.326\,(147.6FC + 144VM) \quad (7)$$

The flash point temperature of biomass fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. It is a determinant for flammability classification of materials. To determine the flash point of the biomass, a sample of the biomass was put into the test cup up to the specified level. The cover was then fitted into position on the cup and the sample was heated and stirred at a slow and constant rate. At every 2 ºC temperature rise, a flame was introduced over the test cup at a very slow rate for a moment with the help of a shutter. The temperature at which a flash appeared in the form of sound and light was recorded as the flash point.

2.2.3. Thermal characterization

Thermogravimetric analysis is a thermal analysis technique that was used to determine changes in the weight of the respective samples as a function of temperature. It depicts the thermal decomposition and thermal stability of the bush mango shell. For this study, samples of biomass (BMS and PPF), were subjected to thermogravimetric analysis. The TGA test procedures were performed on a single sample during the course of a single experiment. The weights (10 mg) of the samples were monitored as a function of temperature.

All of the samples were tested over the temperature range of 30 - 1000 °C. Nitrogen was used as the inert gas during the experiments.

2.3. Briquette Production

The biomass samples as prepared in section 2.2.1 were mixed in the ratio of bush mango shell to palm pressed fibre as 100:0, 75:25, 50:50, 25:75, 0:100 and labeled Sample A, B, C, D and E respectively. Starch (10 % by weight) was added to each composition as a binder. Thereafter, the mixtures were introduced to the briquetting machine for briquette samples production. The briquettes were produced in a cylindrical mold of 56.6 mm inner diameter and height of 74 mm. The mold was filled with the mixtures and densification of the mixture in the mold was done under constant operating conditions (temperature and pressure) with manually operated air hydraulic piston press briquetting machine of 20 tonne capacity. Five briquettes of each sample were produced while their initial densities were noted at the point of ejection from the mold. The resultant briquettes (Figures 2 and 3) were exposed on a flat surface to air dry at room temperature (28 ˚C) and condition for a period of seven days prior to testing. The dried briquettes were taken to the laboratory for further analysis.

Figure 2: Briquettes (wet) immediately after extrusion from machine

Figure 3: Briquettes (dried at temperature 28 ºC) after ten days

2.4. Characterization of briquette

2.4.1. Physical properties

Among the physical parameters determined for the produced briquettes were length, diameter, weight, volume and density (maximum and relaxed). The Length and diameter of the briquettes were measured with the aid of a meter rule and Vernier caliper respectively. Density was determined with Equation 1 (where m and v are the mass and volume of briquette respectively. The maximum density (ρ_M) also referred as the compressed density was determined as the density of a briquette immediately after ejection from the briquetting machine. The relaxed density (ρ_R) of the briquettes also known as spring back density was determined in dry conditions after nineteen days when the briquette has remained stable (Olugbade and Mohammed, 2015). It is calculated as the ratio of the new weight to the new volume. Also, density ratio could be determined using Equation 8 to give the shrinkage factor for packaging and storage optimization. Density ratio (D.R) was calculated as thus:

$$D.R = \frac{\rho_R}{\rho_M} \quad (8)$$

2.4.2. Shattering index

According to ASTM D440-87 (ASTM, 2004), shattering or durability index is measured after two weeks of briquette samples formation. This is done by placing five briquette samples of known weight in a polythene

bag and dropping the bag from a height of 2 m onto concrete floor for three times. The briquettes and fractions are placed on top of square mesh screen and sieved The amount of dust generated is then measured. The shattering index (durability) was calculated using Equation 9.

$$S_I = \frac{W_A}{W_B} \tag{9}$$

where S_I = shattering/durability index, W_A = weight of briquette after dropping and W_B = weight of briquette before dropping

2.4.3. Proximate analysis and combustion property of briquettes

Proximate analyses as well as determination of combustion properties were carried out on produced briquettes as was done on biomass constituents. The time (ignition time) taken to raise the briquette to its ignition point (determined as the average time taken to achieve steady glowing flame) was noted while specific fuel consumption was calculated in grams per litre. Water boiling test in which 100 g of each briquette samples were put in a stove, ignited and used to boil 100 ml of water was performed. The total times taken for each of the briquette sample to boil 100 ml of water were noted to indicate which briquette sample boiled faster. Burning rate was determined as mass of briquette burned divided by the burning time. Thermal efficiency was also determined as the ratio of the work done by heating and evaporating water to the energy of the fuel consumed, as suggested by Olatunde *et al*. (2015).

2.4.4 Determination of the effect of process parameters on briquette properties

The effect of compression time on the briquettes properties was studied by varying the compression period of each briquette compositions (samples A, B, C, D, and E) from 30, 60 90 120 and 150 min. Furthermore, the effect of compression pressure on the briquettes properties was studied by varying the compression pressure applied on each briquette composition from; 15, 30, 45, 60 and 75 kPa.

3. RESULTS AND DISCUSSION

3.1. Proximate Analysis of the Biomass and Briquette

The results of proximate analysis of the biomass materials and briquettes are shown in Tables 1 and 2 respectively. From the results in Table 1, it is clearly shown that the bush mango shell sample has higher calorific value (16.85kJ/kg) and fixed carbon (27.5%) with low ash content (6%) while palm pressed fibre has the higher volatile matter (72%). The calorific value of bush mango shell indicates that it will release more heat during combustion than the other biomass sample while the palm pressed fibre biomass will ignite more readily and burn faster than the bush mango shell because of its high volatile matter (Amadi and Ikhazuangbe, 2020). Also, the high ash content of the palm pressed fibre is an indication that it contains more mineral (noncombustible) matters than the other biomass material and its concentration will have great influence on the amount of ash that will be generated by biomass briquettes. When the results of the briquette samples were compared (Table 2), sample B (with bush mango shell to palm pressed fibre mix ratio of 75:25) showed the highest calorific value of 18.65 kJ/kg with low ash content (7 %), moderate volatile matter (60.36 %) and low burning rate of 38.7 g/min hence the optimum mix ratio. This is an indication that briquettes of the composite biomasses are of high energy value.

Table 1: The results of proximate analysis of various raw materials

Sample	Moisture content (%)	Ash content (%)	Volatile matter (%)	Fixed carbon (%)	Calorific value (kJ/kg)
Bush mango shell	10	6	56.5	27.5	16.85
Palm pressed fibre	8	8	72	12	14.95

Table 2: The results of proximate analysis of BMS-PPF briquette samples

Sample	MC (%)	AC (%)	VM (%)	FC (%)	CV (kJ/kg)	Burning rate (g/min)
A	12.80	6.50	58.00	22.70	16.81	46.60
B	12.00	7.00	60.36	20.64	18.65	38.17
C	11.70	7.20	65.19	15.91	14.85	41. 64
D	10.80	7.50	68.42	13.28	12.90	48.02
E	7.91	8.10	72.00	11.99	12.40	54.20

3.2. Thermogravimetric Analysis

Figures 4 and 5 show the TGA curves for bush mango shell BMS and palm pressed fibre PPF. The TGA curves show that there was a minor decrease in weight for both samples at about 100 °C, which is caused by the evaporation of water and partial volatilization of volatile materials (Chaney, 2010). The second and third stages occurred due to the dehydration of the carbohydrate and protein polymer chains and a complete decomposition of sample residues, respectively as suggested by Norström *et al.*, (2014). Derivative thermogravimetry (DTG) (curves shown with blue line), as displayed in Figures 4 and 5, are used to determine the maximum rate of decomposition for all samples. According to the DTG curves, palm pressed fibre had the least rate of decomposition of 3.84% at 375 °C, while bush mango shell had the highest rate of decomposition of 5.48% at almost 400 °C.

3.3. Physical, Mechanical and Combustion Properties of Briquettes

Maximum (compressed) densities of briquettes at different biomass concentrations are presented in Figure 6. The recorded values showed that an increase in BMS biomass concentration (25–100%) in the briquettes caused an increase in maximum density of the briquette. Thus, sample A briquette with biomass ratio of 100:0 (100 % BMS) had the highest density. The increase observed in the compressed density with increase in BMS biomass concentration could be attributed to the high bulk density of BMS and its ability to occupy pores in-between the particles of biomass samples. It is clearly shown that maximum density is directly proportional to bulk density of the raw biomass. This trend was in agreement with the values reported in the production of fuel briquettes from waste paper and coconut husk by Olorunnisola (2007). The increased maximum density characteristics of briquettes also help in handling, storage and transportation optimization (Amadi and Ikhazuangbe, 2020). Figure 7 depicts the graph of density at the different biomass concentrations on compression time of briquettes. The recorded values showed that as the briquettes compression time increases the density also increases, but at varying rate with different concentration of BMS and PPF biomasses in the samples considered, with sample A briquette made of 100% BMS having highest density. This means that more time allows compaction of biomass. During briquetting, prolonged compression time causes particles to rearrange to form closely packed mass and then to elastically and plastically deform thereby allowing particles move and fill void spaces and consequently increasing both density and strength (Okot *et al.*, 2018).

Figure 8 presents the graph of compression pressure of briquettes at the different biomass concentration on maximum density. The recorded values showed that as the compression pressure increased, the compressed density increased for the different biomass samples considered. Sample A with biomass proportion of 100:0 (100 % BMS) has the highest density. The increase observed in density with increased pressure could be attributed to the lower ash content of the biomass with BMS concentration as shown in Table 2. It could be also observed that the density of the briquette biomass decreases as the proportion of palm pressed fibre (PPF) increases. This could be attributed to higher ash content of PPF biomass (Amadi and Ikhazuangbe, 2020).

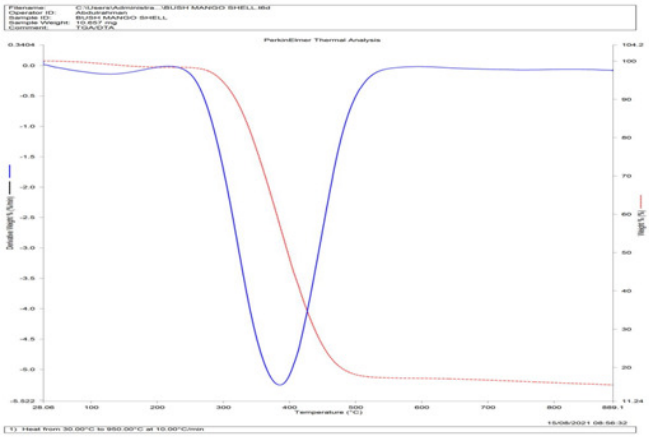

Figure 4: The TGA curves for bush mango shell

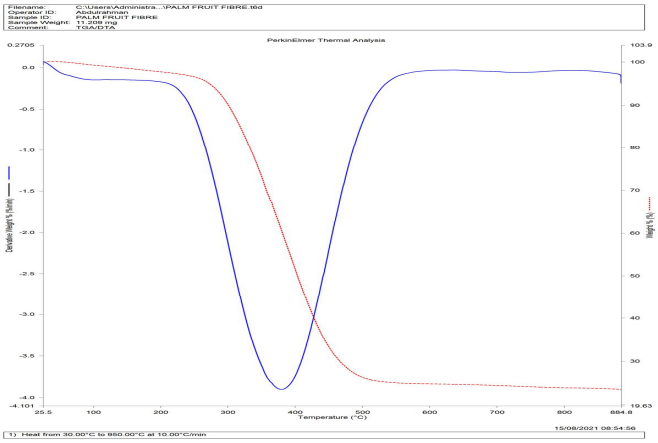

Figure 5: The TGA curves for palm pressed fibre

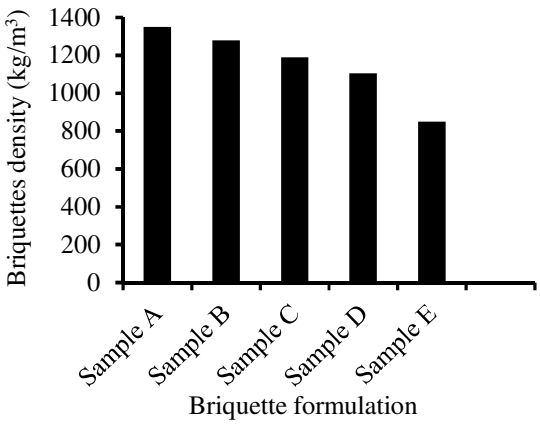

Figure 6: The effect of biomass concentration on the maximum density of briquettes

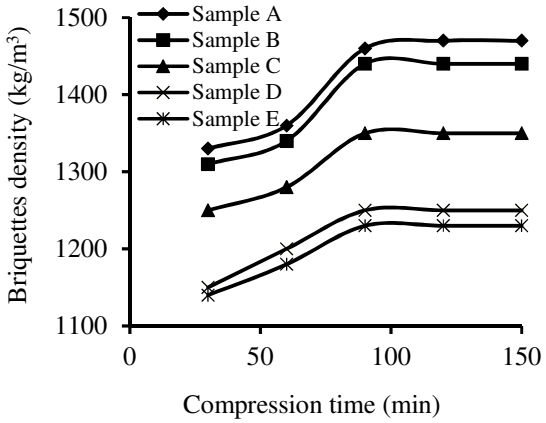

Figure 7: The effect density on compression time of briquette samples

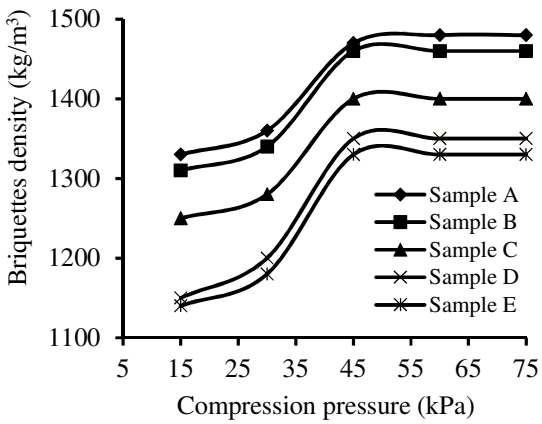

Figure 8: The effect of compression pressure of briquettes concentration on maximum density

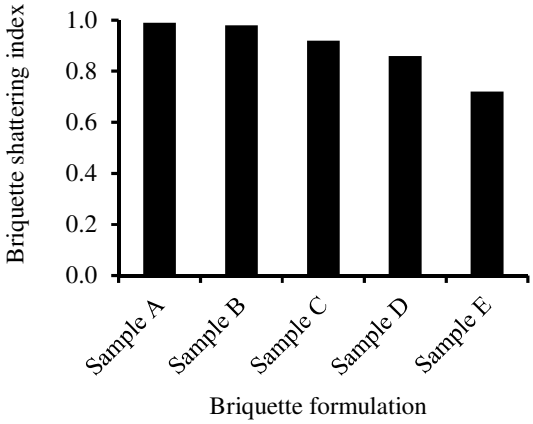

Figure 9: The effect of BMS and PPF proportions on the shattering index of the briquettes

The effect of bush mango shell and palm pressed fibre proportions on the shattering index are shown in Figure 9. It could be observed that the shattering index of the briquettes decreases as the amount of PPF in the briquette composite increases and this could be as a result of reduction in bonding forces due to the high ash content of PPF. The values of shattering index of briquettes that have up to 50 - 100% concentration of PPF were low. Among the briquettes produced from various proportion of BMS and PPF, briquettes with higher proportion of BMS as contained in samples A, B and C have higher shattering index and this indicate proper bonding of BMS in the composite (Kpalo *et al*., 2022). Therefore, shattering index of briquettes samples A, B and C falls within the acceptable range of DIN 51731 (17.7 - 99.8%) for production briquette (Kaliyan and Morey, 2006). However, Borowski (2007) posited that shatter index should attain a value higher than 90% for easy handling and transportation. This implies that the mixing ratios of the biomasses used in samples A, B and C are required to produce durable, reliable, and stable briquettes that stand mechanical handling and transportation, with economic feasibility and environmental friendliness. Similar result was obtained by Davies and Davies, (2013).

The effect of bush mango shell and palm pressed fibre proportions on calorific value of composite briquettes produced from them are shown in Figure 10. The calorific values of the composite briquettes were 16.81 and 18.65 kJ/kg for briquettes produced from sample A and B, 14.85 kJ/kg for sample C, 12.40 kJ/kg and 12.90 kJ/kg for samples D and E respectively. It was observed that the calorific value decreased as the concentration of PPF increased for all the biomass ratios considered due to high volatile matter content and existence of noncombustible minerals in PPF (resulting in higher ash content). This was expected since PPF has a lower calorific value compared to BMS as shown in Table 1. Thus, the formulation with 75:25 of BMS:PPF (B) mixing ratio has the highest calorific value while the 25:75 of BMS:PPF biomass mixing ratio, had the least calorific value of 12.94 kJ/kg. The energy value obtained for the briquettes' compositions of bush mango shell and palm pressed fibre at the mixing ratio of (75:25) was found to meet the minimum requirement of calorific value for producing commercial briquettes (>17,500 J/kg) (Oyelaran *et al*., 2014). They can therefore produce enough heat required for household cooking and small-scale industrial cottage applications. The results of the calorific value of the briquettes of sample (A) compare well with the results of rice husk briquette 12,600 J/kg (Musa, 2007); cowpea 14,372.93 J/kg; and soya-beans-12,953 J/kg (Enweremadu, *et al*., 2004).

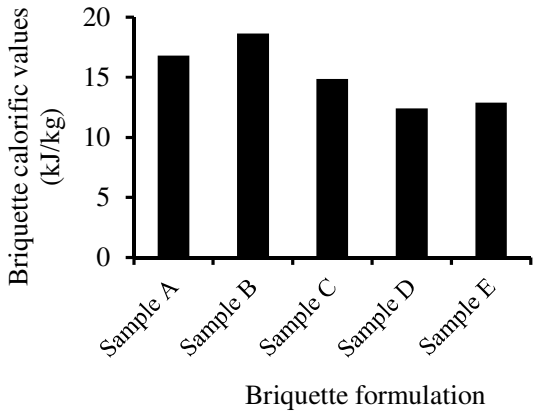

Figure 10: The effect of BMS and PPF proportions on calorific value briquettes

3.4. Performance Analysis of the Briquettes Composite Produced at Optimal Conditions

Figure 11 shows that bush mango shell and palm pressed fibre briquettes bonded with starch separately have low ignition time of 0.8 and 0.6 min, high burning rate and thermal efficiency of 46.6 and 54.2 g/min and 42.1 and 34.6 % respectively. The briquettes formulated from mixed BMS and PPF at ratio of 75:25 bonded with 10% starch and produced at optimum conditions of 25 MPa, 40 minutes compaction time recorded the best performance with a low ignition time of 0.4 min, low fuel consumption of (38.17 g/min) and high cooking efficiency of 59.8%. These performance parameters showed that composite briquettes made of 75% BMS and 25% PPF bonded with 10% by weight of starch is better compared to when separately produced because the water boiling and burning rate test conducted help to achieve higher efficiency of (59.8%). The result also compared better in energy content than the briquette produced by Olatunde *et al*, (2015) using groundnut shell.

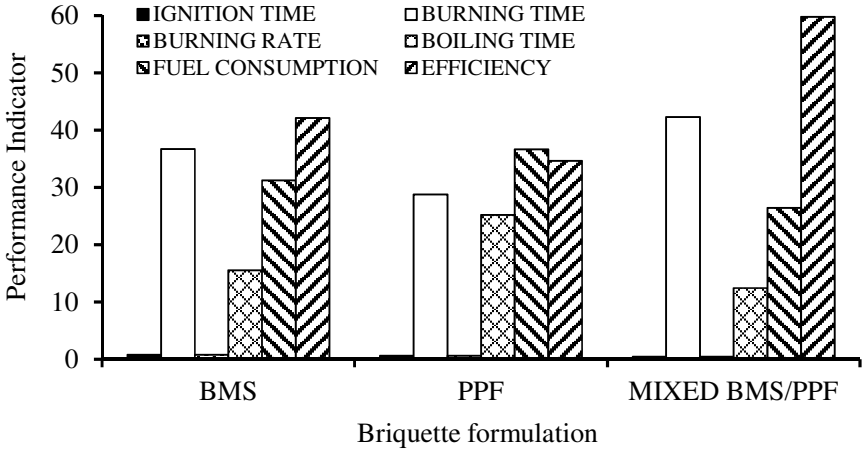

Figure 11: Performance Analysis of the briquettes composite produced at optimal conditions

4. CONCLUSION

The briquettes created from the mixed biomasses of bush mango shell and palm pressed fibre possess suitable properties for good biofuel than when produced from either of the separate biomass. The effects of pressure, biomass concentration and compaction time on the calorific value were very significant. Increase in these process parameters especially the BMS concentration improved the calorific value of the briquettes with reduction in burning rate thereby reducing fuel consumption. Maximum calorific value of 18.65 kJ/kg was

obtained for sample B with BMS: PPF ratio of 75:25, dwelling time of 40 min and pressure of 25 MPa at a burning rate of 38.17 g/min. The implication of this observation is that less fuel might be required for cooking with briquettes produced from high concentration of BMS biomass at optimum condition. Therefore, the production of briquettes from bush mango shells and palm pressed fibre and their utilization is recommended since their usage as renewable biofuel energy resource will promote environmental friendliness, reduces desertification for wood fuel, dependency on coal and fossil fuels and their environmental implications.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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