Effect of Process Factors on the Physical and Combustion Properties of Briquette Produced from Saw Dust

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Abstract- The quest for an alternative source of renewable energy has prompted the researchers to investigate the potential of using saw dust for briquette production. Effect of process factors on the physical and combustion properties of the briquette was studied as a guide to the optimum conditions that will be employed for the production. The briquettes were produced mechanically with a hydraulic operated briquette machine using cassava starch as a binder. Effect of binder ratio, compaction pressure and dwelling time on the porosity index, compressed density, durability index, relaxed density, water resistance and water absorption capacities of the briquette was studied. FTIR analysis of the uncarbonized saw dust, carbonized saw dust and saw dust briquette was studied. The result showed that all the process factors had effect on the properties of the produced briquette. It was observed that increase in compaction pressure, binder ratio and dwelling time increased the percentage resistance of the briquette to water penetration and lowered the porosity index. Increase on the three process factors increased the compression and relaxed densities and decreased the water absorption capacity. Increase on the three process factor equally increased the calorific value to a point that further increase on the process factors decreased the calorific value. The low nitrogen content of the briquette shows that there will be minimal release of nitrogen oxide into the atmosphere and is an indication that the produced briquette will not pollute the environment.

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1. Introduction

The rapid increase in human activities and change in people's lifestyle had globally placed a great demand on energy. There is serious drop in the use of fossil fuel as a source of energy due to the limitation of fossil fuel reserve. Fossil fuel which is non-renewable, provides about 80% of man's energy sources now and this may start to depreciate in the next twenty years (Emerhi 2011). Another disadvantage of using fossil fuel is the emission of green house gas.

These challenges led to the quest for an alternative source of energy to replace fossil fuel. Biomass has been used by many people as a substitute to the depleting non-renewable energy sources (Efomah and Gbabo 2015).

For a biomass to be considered as an alternative source of energy, its physical and thermal properties must be certified. For optimum properties to be obtained from the briquette, investigation should be made on the process factors that affect its production. Fuel briquettes produced under different process factors have been reported to have different handling characteristics. Those characteristics are also found to be strongly affected by the raw material properties (Efomah and Gbabo 2015).

Biomass is the term used to describe all the organic matter produced by photosynthesis that exists on the Earth's surface (NEED project 2012). It is an organic matter such as wood, crops, seaweed, animal wastes that can be used as an energy source (Danjuma et al. 2013).

There are many challenges with the use of biomass in their original form as source of energy. Some of the challenges are the variable quality of the residue, the cost of collection, handling and problems in transportation and storage (Sokhansanj et al 2006; Husan et al 2002). The application of biomass briquetting is an effective way to solve these problems and contribute towards alleviation of energy shortage and environmental degradation (El-Saeidy 2004).

Briquetting technology is the high pressure densification of biomass dust that improves the handling characteristics of raw materials and enhances volumetric calorific value of biomass (Oladeji 2010) which can be done at elevated temperatures (Ndagana et al 2014).

This work studied the effect of process factors on the physical and combustion properties of briquettes produced from sawdust.

2. Material And Methods

Saw dust was procured from timber market at Abakpa Nike Enugu, Enugu State Nigeria.

Cassava Starch was equally bought from Abakpa Market in Enugu State Nigeria.

Briquette Production and Characterization.

Methods for the briquette production and Characterization were according to the work published by the authors on the optimization of process conditions for briquette production from rice husk and saw dust (Enemuo et al 2018).

Compressed Density of Briquette

The compressed density (density immediately after compression) of the briquette was determined immediately after ejection from the moulds as the ratio of measured weight to the calculated volume. The mass was obtained by using a digital weighing balance, while the volume was calculated from external diameter and the height of the briquette by means of a vernier calliper.

$$Compressed\ Density = \frac{Mass(g)}{Volume(cm^3)}$$

Relaxed Density of Briquette

The relaxed density of the briquettes was determined in accordance with the work done by Olugbade and Mohammed (2015). It was determined in dry conditions after drying to constant weight. It was calculated simply as the ratio of the briquette's weight to the new volume. Relaxed density can be defined as the density of the briquette obtained after the briquette has remained stable. It gives an indication of the relative stability of the briquette after compression. It is also known as spring back density.

Water Resistance Capacity of Briquette

This was determined in accordance with the work done by Davies and Davies (2013). A known weight of briquette was immersed in cylindrical glass container containing distilled water at room temperature for 120 seconds. Relative change in weight of the briquette was measured. Percentage water gain was calculated using the following relationship.

$$\%\ Water\ gain\ by\ briquette = \frac{M_{2} - M_{1}}{M_1} \times 100$$

where M_1 is the initial weight of briquette before immersion and M_2 is the final weight of briquette after immersion.

The water resistance capacity was calculated from equation below

$$\%water\ resistance\ capacity = 100\% - water\ absorbed\ (\%)$$

Durability of the Briquette

The durability of the briquette was determined in accordance with the shattering index described by Davies and Davies (2013). This was determined after drying to a constant weight. The briquette was dropped from a height of 1.5 m onto a metal base. The fraction of the briquette that remained un-shattered was used as an index of briquette durability. The durability rating of the briquette was expressed as a percentage of the initial mass of the material remaining on the metal plate and this gives an indication of the ability of the briquette to withstand mechanical handling.

Porosity Index of the briquette

Porosity index was determined according to method used by Ikelle and Ivons (2014). This was based on the amount of water each sample was able to absorb. The porosity index was calculated as the ratio of the mass of water absorbed to the mass of the sample immersed in the water.

$$Porosity\ index = \frac{Mass\ of\ water\ abssorbed}{mass\ of\ sample} x100$$

Effect of Binder Ratio on the properties of the briquette

Different binder ratios (10, 20, 30, 40%wt corresponding to 10 g, 20 g, 30 g, and 40 g of the processed cassava starch using 100 g of the matrix were weighed and properly mixed with the matrix. The briquette was compacted using the production method specified above. Other process conditions were maintained at the optimum conditions specified on the work published by the authors on the optimization of the process factors (Enemuo, et al 2018)

Effect of the dwelling time

The briquettes was produced at the optimum conditions of the process factors while the dwelling time was varied at time intervals of 15 min, 30 min 45mins and 60 mins. At the end, the properties were determined.

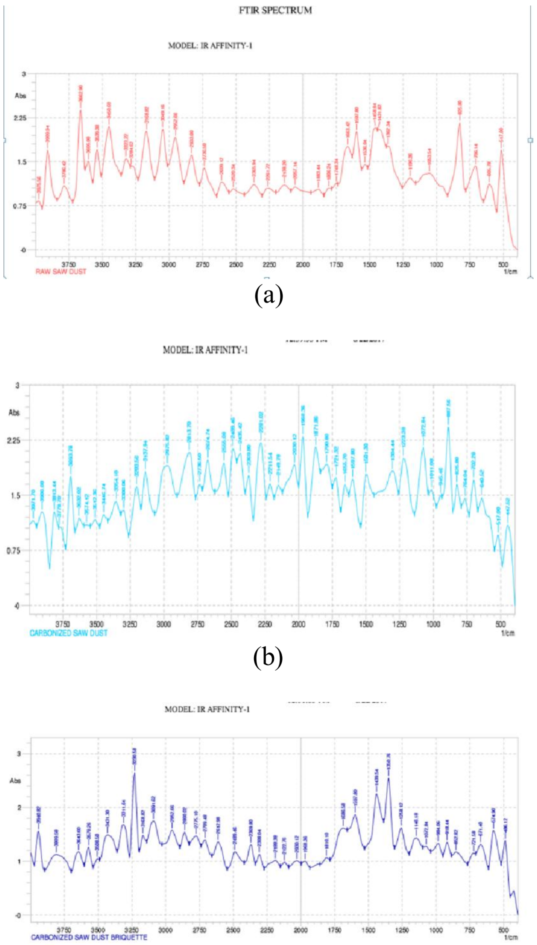
Effect of compression pressure on the properties of briquette

The optimum values of the other process conditions were applied and the effect of varying conditions of pressure (50, 60, 70, 80kgf) on the properties of the briquette was determined.

3. Results

The result on the proximate analysis of the briquette has been presented and discussed by the authors on their work on the optimization of process conditions for briquette production from saw dust and rice husk (Enemuo et al 2018)

The FTIR analysis was carried out to identify the functional groups present on the saw dust both carbonized and uncarbonized and on the produced briquettes as shown in Figure 1. Many peak present in the uncarbonized saw dust spectrum absolutely disappeared in the carbonized spectra while those remaining were weak to a great extent. This is consistent with the breaking of many bonds on the carbonized samples leading to the liberation and elimination of volatiles species during carbonization. As the release of light volatile matters in the heating process, a new band at 2338-2369 appeared that can be ascribed to C stretching vibrations in alkyne groups. The peak at 1790 which is observed in the uncarbonized disappears with the thermal treatment drastically reduced to 1721 for carbonized saw dust. Many bands decreased dramatically indicating the decrease in functionality from the main matrix.



(a)

(b)

(c)

Figure 1: FTIR analysis of (a) uncarbonized saw dust, (b) carbonized saw dust, (c) saw dust briquette

Effect of compaction pressure on porosity index of briquette

Figure 2 shows the effect of compaction pressure on the porosity index of the briquette produced at different binder ratios. It was found that the porosity index was influenced by the compaction pressure of the briquettes. The higher the compaction pressure the higher the percentage resistance of the briquette to water penetration and the lower the porosity index (Sengar et al, 2012). It was observed that the lower the porosity, the higher the resistance to water penetration of the briquettes. This could be attributed to the fact that higher pressure increased the inter-particle adhesion thereby reducing the void spaces and consequently increasing the resistance of the briquette to water penetration.

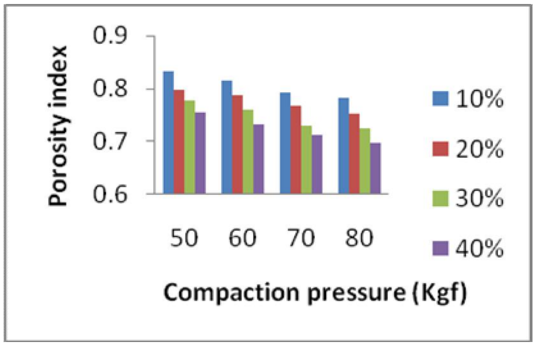


Figure2. Effect of compaction Pressure on the Porosity Index of briquette

Effect of compaction pressure on compressed density of the briquettes

The effect of compaction pressure on the compression density of the briquette was studied. It was observed from the Figure 3 that as the compaction pressure was increased the compression density also increased. The above position was also recorded by Japhet et al 2015.

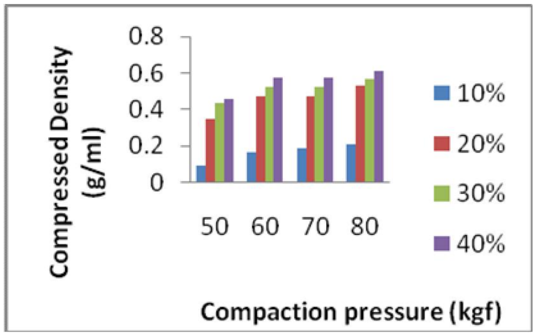


Figure 3: Effect of compaction pressure on the compressed density

Effect of compaction pressure on relax density of the briquette

The work also investigated the effect of compaction pressure on the relaxed density. The results showed that as the compaction pressure was increased the relax density was increased as shown in Figure 4. This was attributed to the fact that increase in compaction pressure ultimately reduced the volume and increased particulate bonding. This also increased the stability of the briquette and as well reduced the briquette spring back ability.

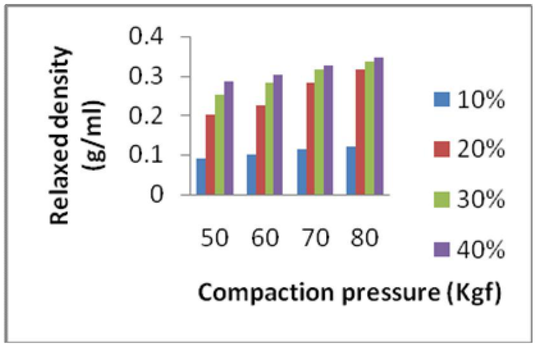


Figure 4: Effect of compression pressure on the relaxed density

Effect of compaction pressure on the durability index of the briquette

The effect of compaction pressure on the briquette durability was studied. From the Figure 5, it was observed that as the compaction pressure was increased, the durability was increased. This could be attributed to the fact that at high pressure, the briquette has a greater ability to withstand stress due to mechanical handling, thereby increasing the durability. Compaction pressure also influences the dimensional stability of the briquette.

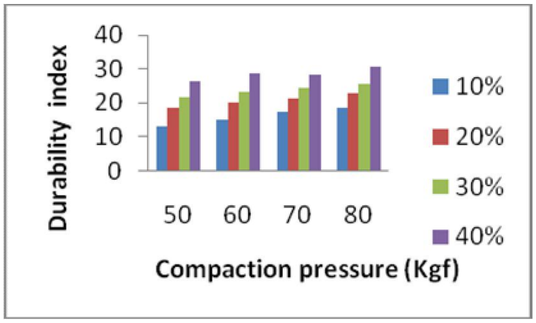
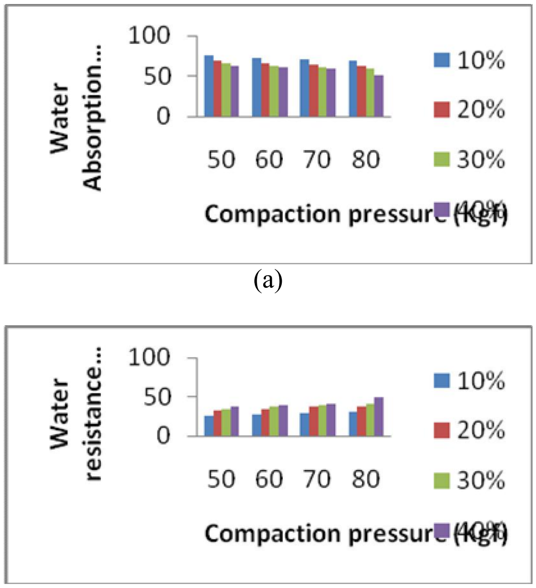


Figure 5: Effect of compaction Pressure on the durability index

Effect of compaction pressure on the water absorption and water resistance capacities of the briquette

The effect of compaction pressure on the water absorption and resistance capacities of the saw dust briquette was investigated. It was observed from Figure 6a that as the compaction pressure was increased the water absorption was decreased. This could be attributed to the fact that at higher pressures of compaction, more particles were brought closer thereby reducing the void spaces between the particles. This made it difficult for water to be absorbed into the briquettes as these void spaces are the pathways for water molecules. It was also observed from Figure 6b that as the compaction pressure was increased the water resistance capacity was increased. This was due to the reduced void spaces due to increased pressure which increased the resistance of the briquettes to water penetration.



(a)

(b)

Figure 6: Effect of compaction pressure on the (a) water absorption (b) water resistance capacities of the briquette

Effect of compaction pressure on the calorific value of the briquette

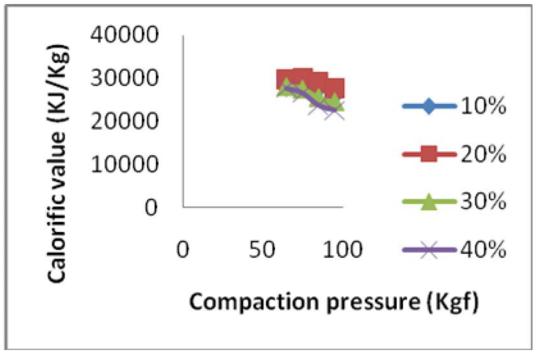


Figure 7: Effect of compaction pressure on the calorific value of the briquette

Figure 7 showed the effect of compaction pressure at various binder ratios on the calorific values of briquettes produced from saw dust. It was observed that increase in pressure increased the calorific value till the optimum condition that further increase in pressure resulted to decrease on the calorific value. Increase in pressure increased the compaction of briquette which in turn increased the calorific value. Increasing the pressure beyond the optimal value expelled more binder from the mould which reduced the amount of binder available for particulate adhesion of the biomass particles and in turn the compaction with attendant decrease on calorific value.

Effect of binder ratios on the compressed density of the briquette

The effect of binder ratio was studied. It was seen from Figure 8 that the compressed density varied significantly as the binder ratio was increased in favour of the binder. This could be attributed to the fact that as the binder ratio was increasing, more particulate adhesion was obtained, thereby decreasing the volume and at the same time increasing the mass.

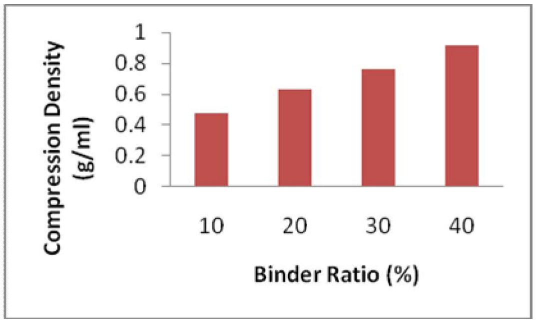


Figure 8: Effect of binder ratio on the compressed density

Effect of binder ratio on relaxed density of the briquette

The effect of binder ratio on relaxed density was studied. It was seen from Figure 9 that the relaxed density varied significantly as the binder ratio was increased in favour of the binder. This could be attributed to the fact that as the binder ratio was increasing, more particulate adhesion was obtained, thereby decreasing the volume and at the same time increasing the mass.

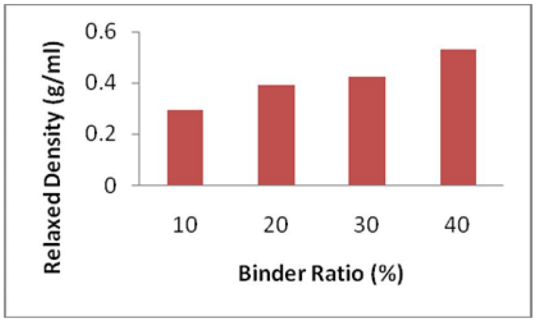


Figure 9: Effect of binder ratio on the relaxed density

Effect of binder of ratio on shattering/ durability index of the briquette

The effect of binder ratio on the shattering index (durability index) was studied. The shattering index (Figure 10) displayed visible increase as the binder ratio was increased. From the graph it was seen that increase in binder has a significant effect on the durability index of the briquette. As the binder ratio was increased, the durability index increased. This could be attributed to the fact that increasing binder ratio increased the briquette particle adhesion.

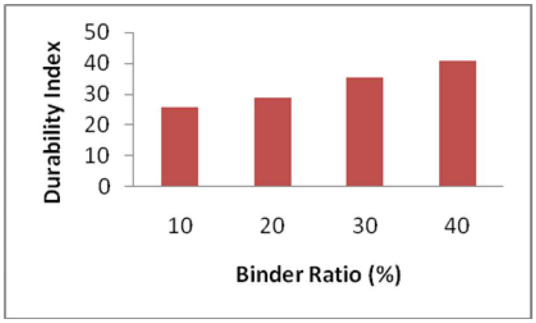


Figure 10: Effect of binder ratio on the durability index

Effect of binder ratio on water absorption capacity of briquette

Figure 11 shows the effect of binder ratio on the water absorption capacity of the briquettes. Water absorption decreased as the binder ratio increased. This could be attributed to the facts that increase in binder ratio decreases the void spaces in the briquettes. Reduced void spaces brought about reduction in water retention of the briquettes. This may be as a result of the better particulate adhesion achieved with increased binding agent.

The water absorption property of the briquettes produced showed decrease in water absorption with increase in the binder utilized. This is in agreement with the work done by Davies and Davies 2013.

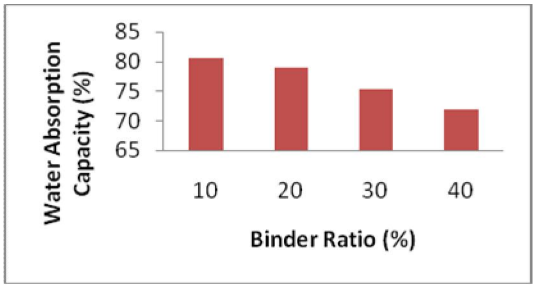


Figure 11: Effect of binder ratio on the water absorption of briquette

Effect of binder ratio on water resistance capacity for the briquette

Figure 12 revealed that as the binder ratio was increased, there was also a significant increase in the water resistance capacity of the produced briquettes. This could be attributed to the fact that the voids between the particles of the briquette might have been sealed up thereby resisting further water ingress into the pores. With increasing binder ratios, the water resistance capacity increased. The graphs in Figures 11 and 12 showed the opposite relationship of water absorption and water resistance.

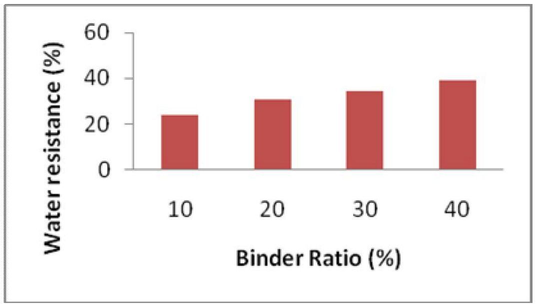


Figure 12: Effect of binder ratio on the water resistance capacity

Effect of binder ratio on the calorific values of briquette

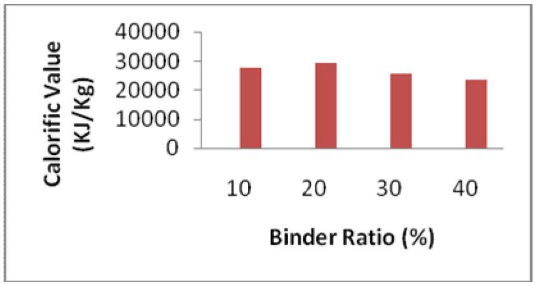


Figure 13: Effect of binder ratio on the calorific value of the briquette

The effect of binder ratio on the calorific values of briquettes produced from saw dust was studied. Figure 13 indicated that the calorific value increased with increase in binder ratio from 10% to 20% and further increase of the binder ratio resulted to decrease on the calorific value. Binder helps to increase the inter lock between the biomass particles thereby increasing the compaction which in turn increase the calorific value. Further increase in binder ratio beyond the optimal value resulted to a decrease in calorific value because of decrease on the quantity of biomass as the quantity of binder increased. Recall that biomass has higher calorific value compared to the starch (binder). Saw dust having high volume required more binder ratio (20%) for proper development of strong particulate interlocking of the biomass. This accounted for the steep decline after 20% binder ratio.

Effect of dwelling time on durability index of briquette

It was observed from Figure 14 that as the dwelling time was increased, the durability index increased for the briquette. This could be attributed to the fact that at constant pressure of 85kgf, particulate adhesion increased due to the more time that was made available for particulate bond formation.

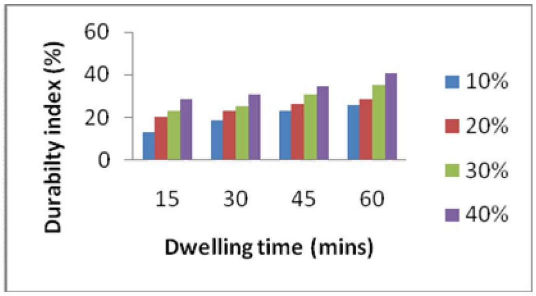


Figure 14: Effect of dwelling time on the durability index of the briquette

Effect of dwelling time on porosity index of briquette

It was observed from Figure 15 that as the dwelling time was increased the porosity index decreased for the briquette. This was due to the fact that as the dwelling time increased, the void spaces decreased due to the development of greater particulate adhesion. Also as the dwelling time was increased, greater opportunity was available for the binders to fill the void spaces, thereby blocking the voids and bringing about greater particulate adhesion which ultimately gave rise to decrease in porosity index.

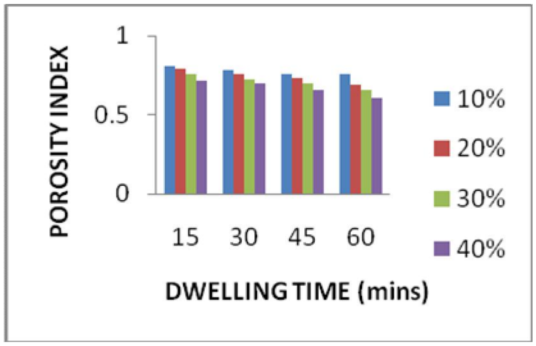
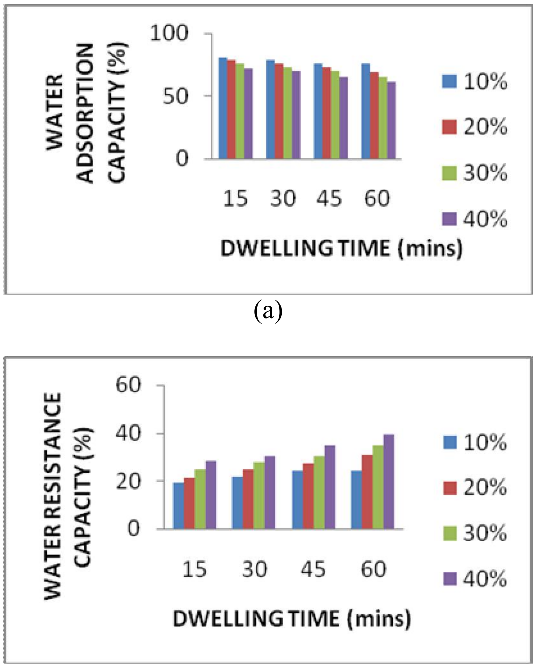


Figure 14: Effect of dwelling time on the porosity index of briquette

Effect of dwelling time on water absorption and water resistance capacities of briquette

It was observed from Figure 16a that as the dwelling time was increased the water absorption capacity decreased. This was due to the fact that at constant pressure of 85kgf particulate adhesion increased due to the more time that was made available for particulate bond formation. As the dwelling time was increased, greater opportunity was available for the binders to fill the void spaces thereby reducing the available spaces for further water adsorption. On the other hand, the water resistance capacity of the briquette increased as the dwelling time was increased. This could be attributed to the same reason deduced from water absorption capacity above.



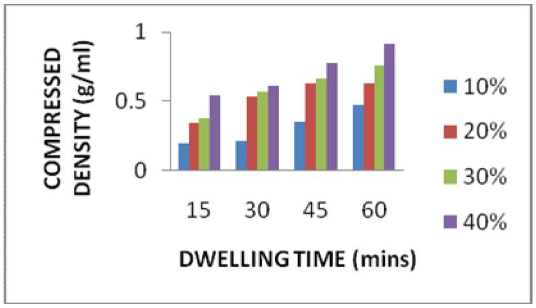
(a)

(b)

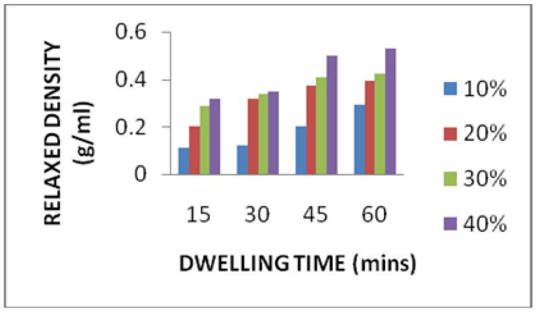
Figure 16: Effect of dwelling time on the (a) water absorption and (b) water resistance capacities of briquette

Effect of dwelling time on compressed and relaxed densities of briquette

It was observed from Figures 17a-b that as the dwelling time was increased the compressed and relaxed densities increased for the briquette. This could be attributed to the fact that at constant pressure of 85kgf particulate adhesion increased due to the more time that was made available for particulate bond formation.



(a)



(b)

Figure 17: Effect of dwelling time on the (a) compressed density and (b) relaxed density of the briquette

Effect of dwelling time on the calorific values of briquette

Figure 18 show the plots of the effect of dwelling time on the calorific values of saw dust briquette. The result revealed that the calorific values increased as the dwelling time was increased to a point that further increase in the dwelling time decreased the calorific values. It would be recalled that increase in dwelling time increased compaction, but prolonged stay of the briquette on the mould brought about expulsion of much of the binder from the briquette mould and consequent loss of compaction. At shorter dwelling time, the binder will be sufficient to hold the biomass particles together thereby increasing compaction which in turn increases calorific value.

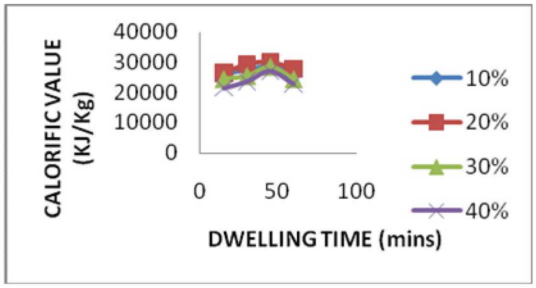


Figure 18: Effect of dwelling time on the calorific value

Conclusion

The need for alternative energy has rekindled the interest of researchers in the area of biomass as a viable alternative precursor for briquette production. In this light this project has been able to harness the available briquette technologies to produce saw dust briquette. This briquette has been found to be very effective in domestic energy generation and as well igniting easily with less smoke production. In conclusion therefore very high quality briquette has been produced from and saw dust for efficient energy generation.

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