A STUDY OF THE EFFECTS OF POULTRY FEATHER ADDITIVE ON SAWDUST BRIQUETTE

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Abstract— In this study, briquettes produced from saw dust with poultry feather as additive were analysed for combustion properties. The study also carried durability, water resistance and density test on the briquette samples and determined the effects of poultry feather additive on the test parameters. This was with a view to achieving effective utilization of saw dust. Briquettes were produced for the mixture of sawdust/rice husk using low pressure briquetting machine and starch mucilage as binder. Feather was added to sawdust at 0%, 5%, 10% and 15% by weight. The mixture was densified using a low pressure briquetting machine of 5×10^5 N/m^2 (0.5 bar) capacity. The influence of the feather additive on the combustion properties, shatter resistance, water resistance and density of the briquettes were investigated. It was observed that there was a decline in the heating value (HV) of the briquettes produced from saw dust as feather additive increased. This is associated with the moisture content increase which could be a result of the hygroscopic amino acids present in feather. However, the heating value of 19.84 MJ/kg obtained at 5% feather additive level was comparable to the heating value of briquette produced with pure saw dust (19.86MJ/kg) at P= 0.7817(P>0.05). With increase in the percentage feather additive there was an increase in the percentage volatile matter and a decrease in ash content. Comparing briquettes produced with pure sawdust(0% feather additive) to briquettes produced with 5% feather additive, there was a significant increase in the volatile matter from 73.4 to 75.9% at P= 0.032053086 (P<0.05). A reduction in the bulk density of the briquettes was observed with increasing feather additive. The bulk densities of all the briquettes produced from saw dust fell between 417.2 and 460.4 kg/m^3. There was an increase in water resistance with increase in feather additive. This may be related to the hydrophobic nature of feather. There was also a significant increase in the durability of the briquettes at 5% feather additive having durability of 94.1% as compared to the briquettes raw sawdust having durability of 66.1% at P= 0.000158306 (P<0.05).This result may be associated with larger particle size and mechanical interlocking of relatively long fibres from the feather. The study concluded that some desirable properties of briquettes were improved by the addition of feather to briquettes produced from saw dust. It was also concluded that 5% feather additive by weight generally produced briquettes with a balanced desirable briquette properties.

Index Terms— *Poultry Feather, Sawdust, Rice husk, Briquette, Heating Value, Feather additives, Bulk density.*

1 Introduction

Biomass can be converted into useful forms of energy using a number of different processes. Factors that influence the choice of conversion process are: the type and quantity of biomass feedstock, the desired form of the energy, environmental standards, economic conditions, and project specific factors [1]. Direct combustion is a thermo-chemical conversion process type that utilizes biomass feedstock wood, agricultural waste, municipal solid and residential waste to produce fuels for heat, steams or electricity [2]. Briquetting is the process of conversion of agricultural waste into uniformly shaped briquettes that are easy to use, transport and store. The briquetting of biomass improves its handling characteristics, increase the volumetric calorific value, reduces transportation costs and makes it available for a variety of application. Briquette is viewed as an advanced fuel because of its clean burning nature and the fact it can be stored for long periods of time without degradation.

Briquetting ensures maximum utilization of resources such that waste is converted to wealth thereby contributing to socio-economic development. Briquettes exhibit great potentials over fuel wood in terms of heat intensity, cleanliness, convenience in use and relatively smaller space requirement for storage [3],[4].Sawdust is readily available in large quantities as wastes in majority of wood processing industries. It has been proposed that the conversion of sawdust wastes through briquetting process will go a long way in reducing waste disposal problems in majority of the wood processing industries [5]. Poultry feathers removed during the processing of the birds for meat or other usage have little or no economic use, hence having great disposal problem.There is, therefore, need to convert these wastes into useful materials that will be environmental friendly and cost less. Since determination of the

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combustion characteristics is crucial to evaluating the briquetting potential of these wastes, hence this study focused on providing biomass as an alternative to wood charcoal using locally abundant sawdust with feather additive converted into briquettes on a small scale and also to investigate the energy effect of the blend of father to the sawdust briquettes produced

2 Materials and Methods

2.1 Materials Used

Sawdust and poultry feather as residue was used. Cassava starch was used as binder and a locally fabricated briquetting machine was used to mould the briquettes.

2.2 Material Preparation

Saw dust was sourced from Ondo road sawmill, Ile-Ife, Osun State. Sawdust was dried in open air over time and the moisture content checked at intervals until it was 10% which falls within the moisture content range suitable for briquetting process. The sawdust was seived and according to [6], sawdust with average size of 2 mm was collected.The chiken feather was obtained from the dump site of a chicken processing company in Obo road, Ilorin, Kwara State The feather collected was cleaned up since feathers directly collected from a chicken processing plant or slaughterer are always dirty and contain various foreign materials, such as skin, blood, faeces and flesh. The feather was therefore washed in detergent and rinsed several times in water so as to remove blood and other foreign substances from the feather. It was then dried in open air until the moisture content was 8% which was suitable for use as recommended by [7]. The feather was chopped into bits and then pounded using mortar and pestle so as to give the feather an even mix of all its component.The binder used for this experiment is starch mucilage. This was prepared from 9.1% cassava starch and 90.9% water [8]. Binders improve material viscosity and lower its sensitivity to moisture, which supports the briquetting of materials with higher moisture content without the risk of disintegration.

2.3 Briquetting Production

The briquetting machine used for this experiment has a maximum densification pressure of 5×10^5 N/m^2 (0.5bar) which makes this machine fall under the low pressure classification as stated by [9] that low pressure briquetting technology usually employs a pressure less than 50 bar with or without using a binder. This briquetting machine can accept raw material with moisture content between 8 – 25%. The ram has area of 700 mm^2, and base plate area of 4×10^4 mm^2. It has a total mould area of 9 $\times10^4$ mm^2 which is divided into four chambers. The average weight of a standard briquette produced from each chamber is 7 kg and the dimensions of the briquette produced are: 150 mm x 150 mm x 70 mm. Sawdust (SD) and Chicken Feather (CF) were thoroughly mixed in SD:CF ratios 100:0, 95:5, 90:10, 85:15 to a total of 2000 g. As stated by [10] that 25% binder level is the optimum binder concentration for briquette production. Therefore, starch mucilage 670 g was added to the mixture of saw dust and feather. This mixture was thoroughly mixed to form a mouldable composite. The mould was lined with a polythene bag material for easy removal after moulding. The resulting mouldable mixture was then fed into the mould of the briquetting machine and densified. As recommended by [11], holding time (i.e., duration of load application) of five minutes was observed. After release of pressure, the briquette was removed from the mould, dried and stored for 7 days. The resulting briquette samples for saw dust are shown in Plate 3.2 below.

Sample of briquettes produced from saw dust and feather.

3 Analysis of the Produced Briquettes

After production of the briquettes, drying them for 2 days and storing them for 7 days under room temperature in an air tight container as proposed by [11], Briquettes produced were taken to the Laboratory of Agronomy, University of Ibadan where the burning characteristics such as the moisture content, ash content, fixed carbon, volatile matter and heating value of the briquette was determined. The durability, water resistance and density of the briquettes which are practical factors in briquettes handling was also determined.

3.1 Moisture content (MC): Percentage MC was determined by measuring 2g (designated as M1) of pulverized briquettes into a crucible. The content was dried in an oven at 110℃ -120℃ for 2 hours to obtain oven dry weight (M2). Moisture Content (Dry Basis) was then calculated according to Davies and Abolude (2013) as:

$$MC = \frac{(M1)-(M2)}{(M1)} \times 100 \quad (1)$$

3.2 Volatile matter (VM): Percentage VM was determined by keeping the substance in crucible with oven dry weight (M2) in the furnace for 10 mins at 400℃ to obtain weight (M) after which the volatile matter in it might have escaped. The meth-

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od was used by [6]. This was used in calculating percentage volatile matter thus:

$$VM = \frac{(M2)-(M3)}{(M2)} \times 100 \quad (2)$$

3.3 Ash Content (AC): In determination of percentage ash, 2g of oven dried pulverized briquettes were weighed in a crucible (M2), this was placed in the furnace for 3 hours at 600°C to obtain the ash weight (M4). Percentage ash content was calculated as

$$AC = \frac{(M4)}{(M2)} \times 100 \quad (3)$$

3.4 Fixed carbon (FC): This was calculated according to [13] by subtracting the sum of %Moisture content, % volatile matter and % ash content from 100%.

$$FC = 100 - (VM + AC + MC)\% \quad (4)$$

3.5 Heating value (HV): Heating value was calculated using the following formula [14]

$$HV = 0.35[(147.6 \times F.C) + (144 \times VM) + AC)] \text{ kcal/kg} \quad (5)$$

*1 kcal/kg = 0.0041868 MJ/kg

3.6 Relative durability (RD): RD was tested to simulate the possible external conditions that may be encountered during the transportation of the briquettes. Durability was determined by dropping the briquettes for a total of four times from a height of 1.85 m onto a flat steel plate, and the remaining mass on the Plate was measured [15]. The durability, expressed as a percentage, is taken as a ratio of the final mass retained by the briquette to its initial mass of the briquette [16].

$$RD = \frac{M5}{M6} \times 100\% \quad (6)$$

Where M5= Weight after shattering
M6= Weight before shattering

3.7 Water Resistance: Short period of rain or high humidity conditions during transportation and storage could adversely affect the quality of briquettes from the mechanical strength point of view. The water resistance of the briquettes in this study was determined by recording the time the briquettes took to be fully immersed in tap water at room temperature [11].

3.8 Density (r): The importance of the study of the density of the briquette is to determine the level of compaction that is attainable from each stock composition. A briquette from each briquette composition sample was randomly selected. The length, breadth, height of the briquette was measured using a meter rule. The volume was calculated thereafter (Vb). The weight of the dried briquette (M7) was also determined using a digital weighing balance. Density of briquettes was calculated on the basis of this dimension measurement and weighing using the formula by [17].

$$r = \frac{(M7)}{(Vb)} \text{ Kg/m}^3 \quad (7)$$

4.0 Statistical Analysis: Statistical analysis was conducted using Microsoft excel with paired t-test to compare the raw sawdust briquette to the sawdust + feather briquettes. Paired t-test is generally used when measurements are taken from the same subject, before and after manipulation/intervention. For the test of significance, two-tailed p-value less than 0.05 were considered statistically significant.

5.0 Results and Discussions

This section highlight the results obtained from the analysis of the briquettes produced during these experiments. The properties of the briquette analysed are moisture content, volatile matter, fixed carbon, ash content, heating value, water resistance, relative density and durability

5.1 Moisture Content

Figure 1 shows that the highest moisture content of 12.3% was obtained in saw dust 15% feather additive respectively. As stated by [18], fibre dispersion allows easy transport of moisture through a continuous drying system. Hence, dense distribution of feather in briquettes will reduce ease of moisture escape. Due to the densification of briquette with denser distribution of feather at 15% feather additive, there was slow migration of the moisture out of the drying briquette, hence the high moisture content. The increase in moisture content with increasing feather could also be associated with the presence of the amino acids, Serine and Theronine, which constitute 35% of the amino acid composition and are hygroscopic in nature. The minimum moisture content of 9.3% was recorded in saw dust briquettes with no feather additive respectively. There was little or no change in the moisture content of the briquette with 5% feather additive at 9.3% moisture content as compared with briquettes with 0% feather additive. Comparing the results obtained with the DIN 51731 minimum moisture content standard of (<10%), it is evident that the briquettes with 5% feather additive and 0% feather additive fall within the accepted moisture content range. This is good for the storability and combustibility of the briquettes as recommended by [19]. Statistically, there was a significant difference in the moisture contents between briquette made from raw sawdust (μ=9.3%, SD=0%) and that made from with feather additives of 15% (μ=12.3%, SD= 0%); and P=1.75E-31 ($p<0.05$).

Where: μ is mean value
P is calculated probability
SD is standard deviation

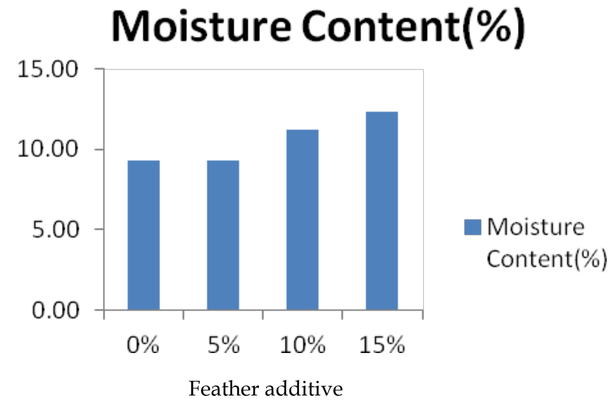

Fig.1. Moisture content of briquettes at different percentage feather additive

5.2 Volatile Matter

Briquettes made from saw dust had high volatile matter regardless of the percentage feather additive. This could be due to the higher cellulose content in saw dust as stated by [20] that volatiles increases with the increase of the cellulose content, but char yield decreases. Fig. 2 shows that the highest volatile matter content of 76.5% was witnessed in the saw dust briquettes with 15% feather additives. This increase in volatiles with increase in feather additive is associated with the high volatile of 92% from the proximate analysis of chicken feather by [21]. The saw dust briquettes having 0% feather possessed the lowest volatile contents of 73.37%.

From Figure 2 it is also seen that an increase in the percentage feather additive brought about an increase in percentage volatile matter. This is seen as an advantage in the briquettes produced with feather additive because they will not need much of pulverizing in order to burn effectively and an increase in the volatiles of the briquettes brings about a reduction in ash content. The volatile matter content obtained for sawdust briquettes in this work agree fairly well with the percentage volatile matter of 72-77% for briquettes from sawdust that were obtained by [6]. The high volatile matter content indicates that during combustion, most of the sawdust briquettes will volatise and burn as gas. Statistically, with the addition of 5% feather to the saw dust and 10% feather to the rice husk, there was a significant difference in the volatile matter contents obtained at $\mu=75.90$, $P= 0.032$ ($p<0.05$). This result suggests that the addition of feather at 5% level significantly increased the volatile content of the briquettes produced from sawdust.

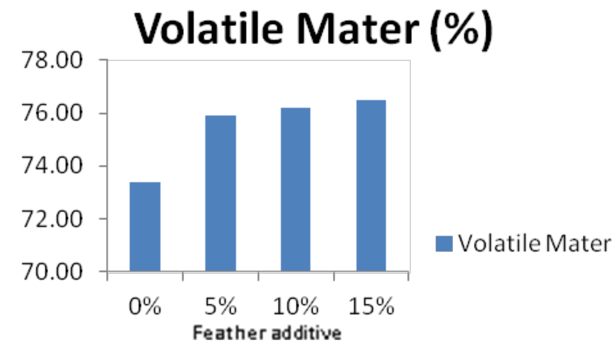

Fig.2. Volatile matter of briquettes at different percentage feather additive

5.3 Fixed Carbon

Fixed carbon gives an indication of the proportion of char that remains after the devolatisation phase. The fixed carbon content recorded in this study for briquettes produced from 0-15% feather additive to saw dust was between 15.1-15.6% as shown in fig. 3 below. This result agrees with 15.29% fixed carbon obtained by [22] for sawdust and there was also corroboration in the fixed carbon of 15.7% as obtained by [22]. A significant increase in the fixed carbon level was observed when the feather additive was raised to 15% at $\mu=15.6\%$ with significant difference $P= 0.02846$ ($p<0.05$).

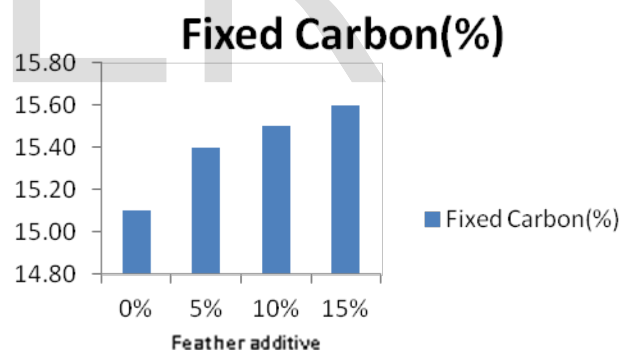

Fig.3. Fixed carbon of briquettes at different percentage feather additive

5.4 Ash Content

Ash, which is the non-combustible component of biomass, was found on the maximum to be 3.4% for the briquettes produced from sawdust 0% feather additive respectively. Fig. 4 shows the relationship between the percentage feather additive and ash content of the briquette. It was also seen that with increase in feather additive, a decrease in ash content was observed. Minimum ash content of 3.2% was observed for sawdust briquettes made from 15% feather additive respectively. This decrease in the level of ash content with increase in feather additive is associated with the high percentage volatility of feather present in the briquette and also from the low percentage of ash content of feather 1.5%. Statistically, there was a significant reduction of the ash content of the briquettes made from saw dust as the feather additive attains 10% level. The decrease in the ash content of these briquettes with increase in feather additive displays a desirable property for these briquettes.

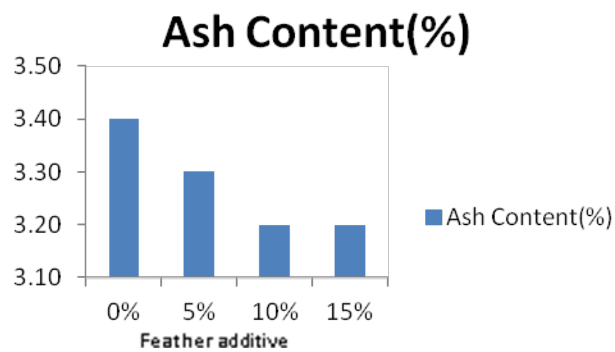

Fig. 4. Ash content of briquettes at different percentage feather additive

5.5 Heating Value

Briquettes produced from saw dust with 0% feather additive recorded the highest heating value of 19.86 MJ/kg with no significant reduction as compared to saw dust briquette with 5% feather additive which recorded a 19.84 MJ/kg, P= 0.7817 ($p>0.05$). Saw dust briquettes with 15% feather additive had heating values of 19.57 MJ/kg and 18.52 MJ/kg, respectively. This reduction in the heating value of the briquette with increasing feather additive could be associated with the increase in moisture content of the briquettes with increasing feather. High percentage of moisture in biomass materials prevents their applications for thermo-chemical conversion processes including combustion. According to [23] briquettes made from sawdust were observed to have heating value of 18,936kJ/kg. The heating value of the briquettes in this study is also higher than the value of 19,534kJ/kg reported by [24] for briquettes from a mixture of palm kernel cake (PKC) and sawdust. The heating value in this study is also above the DIN 51731 minimum standard of 17,500kJ/kg. Hence, the briquettes produced possess adequate heating value.

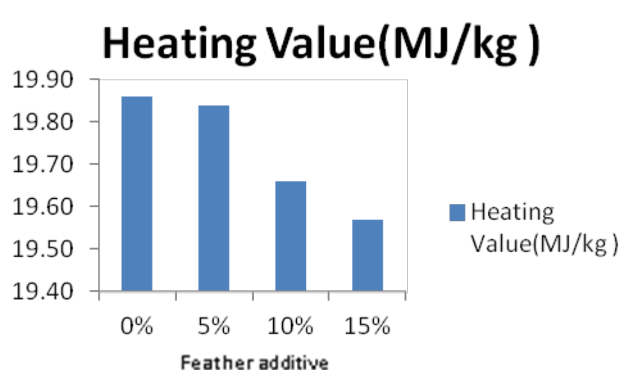

Fig.5. Heating value of briquettes at different percentage feather additive

5.6 Water Resistance

Fig.6 shows variation of time for complete immersion in water for different samples of briquette produced from both saw dust with feather additive at different percentages. The time spent for the briquette to be totally immersed in water at room temperature defines the water resistance property of the briquette. It was observed that the briquettes without any feather additive spent the shortest period of time to be totally immersed in water. The time spent for total immersion in water for these briquettes increased with the increase in percentage feather additive. The increase in the water resistance of the briquette with increase in feather additive is associated with the presence of hydrophobic amino acids (Tyrosine, Leucine, Isolesine, Valine, Cysyine, Alanine, Phenylalanine, Methionine) as a major composition of feather. The briquettes with 15% feather additive spent longer time to become totally immersed in water although before total immersion, there was slight disintegration of the briquette in water. Briquettes with 5% feather additive still remained intact during the time spent in water as there was little or no disintegration of the briquettes during this time.

Statistically, the addition of 5% feather to briquettes made from saw dust displayed a significant increase in the time spent by the briquette to be completely immersed in water, P= 0.0042 ($p<0.05$). This shows that with just the addition of 5% feather to briquette produced from saw dust and rice husk, there was a significant increase in the water resistance of these briquettes.

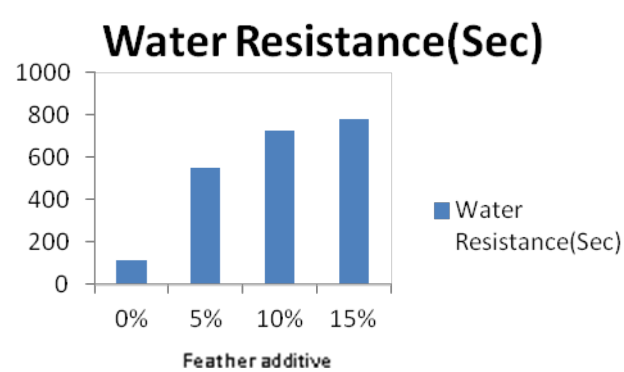

Fig.6. Water resistance of briquettes at different percentage feather additive

5.7 Bulk Density

There was reduction in density of all the briquettes with the increase in the quantity of feather added. Statistically, there was a significant drop in the density of the briquettes from saw dust as the density was seen to drop from μ=460.4kg/m^3 at 0% feather additive to μ=442.2460.4kg/m^3 at

5% feather additive having a significant difference of P=0.00700(P<0.05).This variation in density of the briquette samples could be linked to naturally low density of feather and as the feather added increases, there was a replacement of the sawdust with a low density feather. The general bulk density of the briquettes fall short of *SS 18 71 20* standard of greater than 500kg/m^3 although it falls within the range of the bulk density of briquettes produced by [25] with bulk densities ranging between 314 and 420 kg/m^3. The low densities of these briquettes as compared to the *SS 18 71 20* standard was as a result of the low pressure machine of 0.5 bar available for the briquette production.

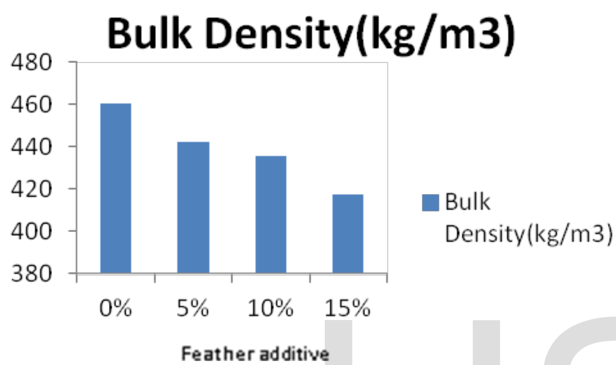

Fig.7. Bulk density of briquettes at different percentage feather additive

5.8 Durability (Shatter Resistance)

Briquettes produced from saw dust with 0%feather briquettes recorded the highest weight losses of 33.9. This is significantly higher than weight loss recorded for briquettes with feather additive form 5 to 15% which experienced weight losses ranging between 1.9 and 2.2%. This represents durability range between 97.8- 98.9%.The high shatter resistance (low weight loss) of briquettes with feather additives may be associated with larger particle size and mechanical interlocking of relatively long fibres from the feather. From the Fig.8 below, it is seen that the increase in the percentage of feather added to the briquette brought about an increase in the durability of the briquettes for greater stability and resistance to handling stresses. The result for briquettes with feather additive between 5% and 15% conform to the CTI - R 04/5 standard of ≥90% durability. Statistically, the weight loss observed from the saw dust briquettes with just 5% feather additive was significantly low as analysed to be μ=0.17, P=3.99932E-05 (p<0.05. This indicates that the increase in feather in the briquettes produced from saw dust brought about a significant increase in the durability of the briquettes since a significantly low weight loss was observed.

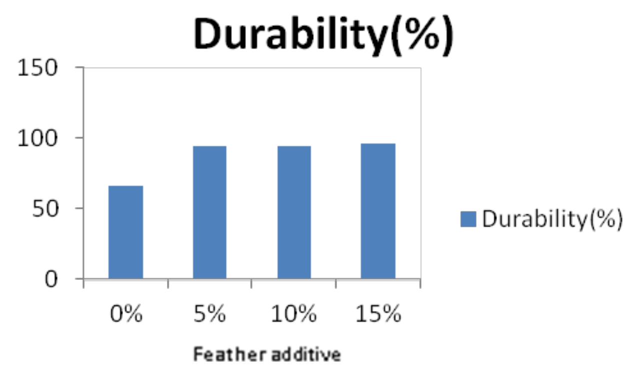

Fig.8. Durability of briquettes at different percentage feather additive

6.0 Conclusion and Recommendations

6.1 Conclusion

This work was carried out to examine the physical and combustion properties of briquettes produced from sawdust and rice husk with feather additive and to determine the effect of the feather additive on the properties these briquettes. From the results of the investigations, the following conclusions have been made.

i It was observed that there was increase in the moisture content, volatile matter, water resistance and durability of the briquettes produced from saw dust and rice husk with increase in percentage feather added. However, bulk density, ash content, and fixed carbon reduces with an increase in the percentage feather added.

ii The bulk density, moisture content, volatile matter, fixed carbon and heating value of briquettes made from saw dust were generally found to be higher than those of the briquettes made from rice husk, while the durability, water resistance, and ash content of briquettes produced from rice husk were seen to be higher than those of briquettes produced from saw dust.

iii In general, briquettes produced from 5% feather additive possessed desirable test results from the series of tests carried out on the briquette samples. Therefore best strategy for producing briquette from sawdust and rice husk with the blend of feather is by producing the briquettes with 5% blend of feather.

6.2 Recommendations

This study recommends that:

1. In producing briquettes of this nature, small size of briquettes should be produced to increase the speed and ease for drying. This will cause a reduction in moisture content and will also reduce or eliminate the growth of mould observed in the briquettes with feather additive. This is to yield maximum heating value.

2. The use of briquette should be given wide publicity in Nigeria. Feather should be considered as an additive as it has been seen to improve the quality of the briquette produced from this study.

3. The briquettes produced from this study should be used in well aerated environment due to the high discharge of volatile matter which may pose health risks to end users.

4. Research on the user friendliness of the briquettes should be undertaken to ascertain the ease of burning and emissions of the briquettes.

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