Densification and Fuel Characteristics of Briquettes produced from Corncob

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Abstract: Corncob residues are usually dumped and flared on the farms, where they constitute health risk to both human and ecology. Densification of corncobs would improve their bulk handling, transportation and storage properties. This work investigated densification characteristics of corncobs using an experimental briquetting machine. Raw corncobs were milled into particles by a hammer mill. The blends of ground corncob and cassava starch gel were compacted in a 4-compartment briquetting machine, which operates on hydraulic principle with a dwell time of 120 seconds. The ASAE standard methods were used to determine the moisture contents (dry basis) and densities of the milled residues and briquettes, while ASTM standard methods were used to determine the proximate and ultimate analyses of the residues. The compaction, density and relaxation ratios of the briquettes were also determined. The mechanical properties were determined using instron universal testing machine, while the heating value was determined with the aid of Gallen Kamp Ballistic Bomb calorimeter. The mean moisture content of the corncob was 9.64 %, while the relaxed briquette was 7.46 %. The corresponding value of bulk density of the residue material was 95.33 kg/m^3. The initial, maximum and relaxed densities of produced briquette were 193; 757 and 389 kg/m^3 respectively, while the density, compaction and relaxation ratios of the briquette were 0.77, 4.38 and 1.71 respectively. The compressive strength of briquette was 2.34kN/m^2, while the higher heating value of briquettes was found to be 20,890kJ/kg. The study concluded that the densification and fuel parameters were good enough and that briquettes produced from corncob would make good biomass energy.

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1. Introduction

The importance of energy in nation development cannot be overemphasized as this can contribute immensely to economic and social life of such nation. The vision of our country, Nigeria to be among the 20 largest economies in the world by the year 2020 may after all be a mirage, if the issue of energy is not properly addressed. At present, there is a problem of energy shortage world-wide; Nigeria inclusive.

One of the principal sources of energy is fossil fuels. According to El-Saeidy 2004 and Kaliyan and Morey, 2009, 86 % of energy being consumed all over the world is from fossil fuels. It must be admitted that, the use of fossil fuels is very convenient. However, many problems are associated with their application. One of such problems is the issue of global warming, the seriousness of which was underscored by the United Nation sponsored conference on climate change held at Copenhagen in Sweden in early December, 2009, where notable world leaders rubbed minds on how best to reduce global warming (Oladeji, 2011). Therefore, there is the need to gradually shift attention from fossil fuels and in this regards agricultural residues can play a significant role in alternative energy generation on a renewable basis.

One of the processes through which these residues could be converted to biomass energy is briquetting. Olorunnisola 2007, Wilaipon 2008 described briquetting as a process of compaction of residues into a product of higher density than the original material, while Kaliyan and Morey 2009 defined briquetting as a densification process. According to Tabil 1997, briquetting process can be classified under two broad groups, which are briquettes without binder and briquettes with binding agent. In terms of technique of briquetting, there are low-pressure and high-pressure briquetting processes (Joseph and Histop, 1999).

Efforts of previous researchers were reviewed from three perspectives. These are: development of briquetting, residues investigated and investigation of factors affecting briquetting process. For examples, Adekoya 1989 developed briquetting machine, which was based on hydraulic principle to produce briquettes from sawdust, while Olorunnisola 2007 developed briquetting machine in form of extruder to produce pellets from admixture coconut husk and waste paper. Some of the residues investigated were banana peel (Wilaipon, 2008), palm waste (Ilechie, et al., 2001), rattan furniture (Olorunnisola, 2004), cotton stalk, (El-Saeidy, 2004), wood wastes

(Kaliyan and Morey, 2009) and so on. Some of the factors investigated by researchers were pre-heating of biomass feedstock (Joseph and Histop, 1999), effects of moisture content (Grover and Mishra, 1996), pressure/density relationship (Wilaipon, 2008) and effects of particle size (Gilbert et al., 2009). They are concluded that all those aforementioned factors have one effect or the other not only on briquetting process, but as well as on the quality of briquettes produced.

The overall aim of this work was to investigate densification characteristics and fuel properties of briquettes produced from the blend of ground corncob and cassava starch gel.

2. Materials and Methods

The agro-residue selected for briquetting was corncob from maize (***Zea mays***). This is because; Nigeria is second producer of maize in Africa, after South Africa, U.S.A. being the largest producer of maize worldwide (Adesanya and Raheem, 2009). Raw corncob was procured from corn processing mill at Odo-Oba, a suburb of Ogbomoso. The raw corncobs were sun-dried until stable moisture content was obtained and were later subjected to size reduction through the hammer mill. Sieve analysis was carried out, where a particle size of 2.40mm representing medium series was selected. To facilitate conversion of ground corncob into briquettes, a prototype briquetting machine was fabricated (Figure 1).

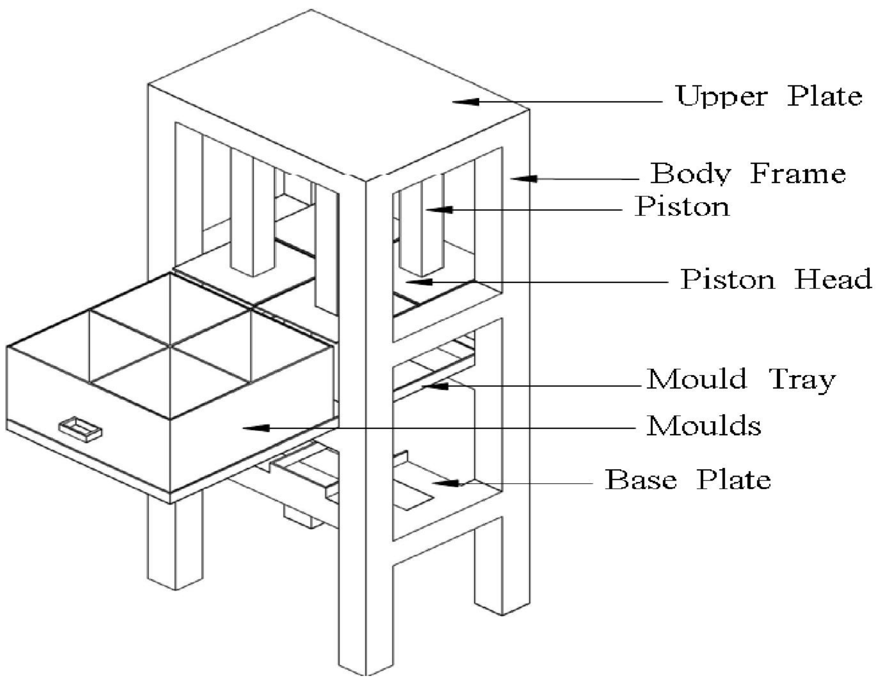

Figure 1: Isometric View of the Experimental Briquetting Machine

A low-pressure technique was employed; hence a binding agent in form of cassava starch gel was used and the procedure highlighted by Musa 2007 was followed. For the production and formation of briquettes proper, the biomass feedstock was mixed with cassava starch gel and compaction was carried out in the fabricated machine.

The briquettes produced (Plate 1) were late ejected after the dwell [holding] time of 120 seconds was observed. This was followed by immediate measurement of briquette's dimensions and densities. The ejected briquettes were later sun-dried and their densification characteristics were determined.

Plate 1: Sample of Produced Corncob Briquettes

2.1 Determination of densification characteristics of the briquettes

The density of briquette from both species was determined immediately after ejection from the mould and this was calculated from the ratio of the mass to the volume of briquette.

The relaxed density of the briquettes was determined in the dry condition. Relaxed density can be defined as the density of the briquette obtained after the briquette has remained stable. It is also known as spring-back density. It was calculated simply as the ratio of the briquette's mass to the new volume.

Equilibrium moisture content of the briquettes produced was determined in accordance with ASAES 269-4 (2003), while the percentage carbon, hydrogen, oxygen, nitrogen and sulphur were determined in accordance with ASTM standard D5373-02 (2003).

Proximate analysis of the briquette samples was carried out to determine the percentage volatile matter content, percentage ash content and percentage content of fixed carbon. The procedure of ASTM standard D5373-02 (2003) was adopted.

The flame propagation rates of the briquette samples were determined as highlighted by Musa 2007. To do this one piece of the oven-dried briquette was graduated in centimetre and ignited over a bunsen burner in laboratory environment until the fire extinguished itself. The flame propagation rate was estimated by dividing the distance burnt by the time taken in seconds.

The afterglow time was also evaluated and determined. This became necessary in order to estimate how long the individual briquette would burn before restocking when they are used in cooking and heating. The procedure of Musa 2007 was also used. One piece of oven-dried briquette was ignited over a bunsen burner and after a consistent flame was established, the flame was blown out. The time in seconds within which a glow was perceptible was recorded.

Furthermore, the heating value of the two biomass briquettes was also examined and the procedure in accordance with ASTM E 711-87 (2004) was followed. The apparatus used was Parr isoperibol bomb calorimeter.

The compressive strength of the briquettes was investigated by using a universal testing machine. Compressive strength was determined in accordance with ASTM 1037-93 (1995).

Density ratio was calculated as the ratio of relaxed density to maximum density i.e. Density ratio

$$= \frac{\text{Relaxed Density}}{\text{Maximum Density}} \qquad (1)$$

In this formula, maximum density is the compressed density of briquette immediately, after ejection from briquetting machine.

Relaxation ratio was calculated as the ratio of maximum density to relaxed density, i.e. Relaxation

$$\text{Ratio} = \frac{\text{Maximum Density}}{\text{Relaxed Density}} \qquad (2)$$

The compaction ratio which is defined as the density of the in-die briquette divided by the initial density of the residue was determined and calculated, i.e.

$$\text{Compaction ratio} = \frac{\text{Maximum Density}}{\text{Initial Density(before comression)}} \qquad (3)$$

3. Results

The results of the determination of physical and combustion characteristics of corncob briquettes are shown in Tables 1 and 2, while the results of burning characteristics of the briquettes are presented in Table 3. From the result of ultimate analysis, the moisture content of corncob residue was 9.64 %, while the moisture content of the briquettes was found to be 7.46 %. These results are within the limits of 15 % recommended by Wilaipon 2009, and Kaliyan and Morey 2009, for briquetting of agro-residues. Other results of ultimate analysis for corncob residue gave 20.08 %, 15.56 %, 61.76 %, 0.38 % and 0.82 % for contents of carbon, hydrogen, oxygen, nitrogen, and sulphur respectively. The amount of carbon and hydrogen contents is very satisfactory, as they contribute immensely to the combustibility of any substance in which they are found (Musa, 2007). The low sulphur and nitrogen contents in the specimen is a welcomed development as there will be minimal release of sulphur and nitrogen oxides into the atmosphere and that is an indication that the burning of briquettes from corncob will not pollute the environment (Enweremadu, et al., 2004).

Table 1. Physical and fuel characteristics of corncob briquettes

Parameter	Unit	Value
Moisture content of corncob	%	9.64
Length of the briquette	m	0.270
Breadth of the briquette	m	0.088
Thickness of the briquette	m	0.008
Weight of the briquette	kg	0.05
Carbon content	%	20.08
Hydrogen content	%	15.56
Oxygen content	%	61.76
Sulphur content	%	0.82
Ash content	%	1.40
Nitrogen content	%	0.38
Volatile matter	%	83.06
Fixed carbon	%	2.57

Table 2. Combustion characteristics of corncob briquettes

Parameter	Unit	Value
Moisture content of the briquettes	%	7.46
Compressive strength	kN/m^2	2.34
The heating value	kJ/kg	20,890
Initial density	kg/m^3	193
Maximum density	kg/m^3	757
Relaxed density	kg/m^3	389
Density ratio	-	0.77
Compaction ratio	-	4.38
Relaxation ratio	-	1.71

Table 2. Burning characteristics of corncob briquettes

Parameter	Unit	Value
After glow time	sec.	369
Flame propagation rate	cm/s	0.12

For the proximate analysis, the % content of fixed carbon, ash content and volatile matter for corncob residue were 2.57 %, 1.40 %, and 83.06 % respectively. The values of volatile matter and ash content are good and acceptable. This is because higher percentage of the briquettes from the corncob would be made available for combustion.

The higher heating value calculated for corncob briquette was 20,765kJ/kg. This energy value is sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. It also compares well with most biomass energy. For examples, groundnut shell briquette-12,600 kJ/kg, (Musa, (2007), cowpea-14,372.93 kJ/kg and soy-beans-12,953 kJ/kg, (Enweremadu, et al., 2004)

The values of 757 kg/m^3, 389 kg/m^3 and 1.71 were obtained for maximum density, relaxed density and relaxation ratio for produced briquettes respectively. The density obtained in this work compares well with densities of notable biomass fuels such as coconut husk briquette-630 kg/m^3, banana peel-600 kg/m^3, groundnut shell briquette-524 kg/m^3 and melon shell briquette-561 kg/m^3 (Olorunnisola, 2007; Wilaipon, 2008; Oladeji et al., 2009). The relaxation ratio obtained is also good enough and it is close to the values obtained by Olorunnisola 2007, where a relaxation ratio of between 1.80 and 2.25 was achieved for briquetting of coconut husk and Oladeji et al. 2009, where values of 1.97 and 1.45 were obtained for groundnut and melon shell briquettes respectively.

The compressive strength for the feedstock was found to be reasonable. The implication of this is that, briquettes will suffer less damage during transportation and storage.

The afterglow times of 369 sec. was recorded for produced briquettes, while the propagation rates of 0.12 cm/s was calculated. The longer afterglow time and slow propagation rate imply that briquettes will ignite more easily and burn with intensity for a long time.

4. Conclusions

The present work examined the densification characteristics and fuel properties of corncob briquettes. Thereafter, physical and combustion characteristics of briquettes produced from the corncob were evaluated. Based on the various results obtained and the findings of this study, the following conclusions can be drawn.

1. The briquettes produced from the raw corncobs would make good biomass fuels.
2. Corncob briquettes will not crumble during transportation and storage because the value obtained for their relaxed density is sufficient enough.
3. There would be minimum environmental pollution and emission of greenhouse gases from the corncob briquettes. This is not unconnected with low values of sulphur and nitrogen contents which are 0.82 % and 0.38 % for sulphur and nitrogen.
4. The relaxed density of the relaxed briquettes which is 389 kg/m^3 is higher than the initial density of the residue materials which are 193 kg/m^3 and 185 kg/m^3 for white and yellow corncob respectively. This translated into a volume reduction, which provides technological benefits and a desirable situation for material storage, packaging and transportation.
5. The average energy value of 20,890kJ/kg (SD, 25) obtained is sufficient enough to produce heat required for household cooking and small scale industrial cottage applications.
6. In a similar manner, the average value of compressive strength of 2.34kN/m^2 (SD 0.06) obtained for corncob briquette is sufficient and found to be reasonable. The implication of this is that, briquettes from corncob residues will suffer less damage during packaging, transportation and storage.

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