Comparative Study of Briquetting of Few Selected Agro-Residues Commonly Found in Nigeria.

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ABSTRACT

Biomass can play a significant role in alternative energy generation. Briquetting of agro-residues can alleviate some of the problems of energy shortage being encountered world-wide. This work investigated briquetting of five selected agro-residues commonly found in Nigeria.

A briquetting machine capable of producing four briquette pieces per batch was designed and fabricated. The five residues were milled and sieved. ASTM standard methods were used to determine the proximate and ultimate analyses of the residues. The compaction, density, relaxation ratios and percentage expansion of the briquettes were also determined. Their mechanical properties and the heating value were determined using universal testing machine and Ballistic bomb calorimeter respectively.

The mean moisture contents of corncob, groundnut shell, melon shell, cassava, and yam peels were 9.47, 11.53, 9.60, 10.19, and 9.27% respectively, while the moisture contents of their briquettes were 7.48, 9.18, 7.45, 8.78, and7.95% respectively. The maximum, relaxed densities and relaxation ratio for briquettes produced from corncob, groundnut shell, melon shell, cassava, and yam peels were respectively (650kg/m^3, 385kg/m^3, 1.60); (524kg/m^3, 236kg/m^3, 2.20); (561kg/m^3, 286.42kg/m^3, 1.95); (741.13kg/m^3, 386.2kg/m^3, 1.92); and (911.45kg/m^3, 512.54kg/m^3, 1.78). The heating value calculated for briquettes from corncob, groundnut shell, melon shell, cassava, and yam peels were 20,890, 18,634.34, 21,887, 12,765, and 17,348kJ/kg, respectively, while the corresponding values of compressive strengths in the order listed above were 2.34, 1.69, 2.30, 1.53, and 1.76kN/m^2.

Briquettes produced from these residues would make good biomass fuels, with briquettes from corncob and melon shell having a slight edge.

(Keywords: agro-residue, briquette, cassava peel, corncob, melon, shell)

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 twenty 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. 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.

A lot of agricultural residues and wastes are generated in the country, but they are poorly utilized and badly managed, since most of these wastes are left to decompose or they are burned, resulting in environmental pollution and degradation (Jekayinfa and Omisakin, 2005). However, scientific studies have concluded that a lot of potential energy abounds in these residues (Jekayinfa and Scholz, 2009). These residues could however, be used to generate heat for domestic and industrial cottage applications (Oladeji, et al., 2009).

Among several kinds of biomass, agricultural residues have become one of the most promising choices. Some agricultural wastes such as wood can be directly utilized as fuels. Nevertheless, majority of them are not suitable apparently because they are bulky, uneven and have low energy density (Oladeji, 2010). All of these characteristics make them difficult to handle, store, transport, and utilize in their raw form (Kaliyan and Morey, 2009). Hence, there is the need to subject them to one process of conversion or the other in order to mitigate these problems. One of the processes through which these residues could be converted to biomass energy is briquetting.

Wilaipon (2008) and Olorunnisola (2007) described briquetting as a process of compaction of residues into a product of higher density than the original material, while Kaliyan and Morey (2009) described briquetting as a densification process. The briquetting process can be classified as briquettes without binder and briquettes with binding agent depending on whether binder is used or not. According to the magnitude of the applied compaction force, there is a low-pressure and high-pressure technique briquetting process. Many researchers (Kaliyan and Morey, 2009; Wilaipon, 2008; Olorunnisola, 2007) had carried out a lot of work on briquetting process. Their efforts were focused on three areas, which are development of machines, investigation of residues that could be subjected to briquetting process and those factors that could affect briquetting process as well as quality of produced briquettes. For example, Adekoya (1989) developed briquetting machine that produced six briquette pieces at a time, while Ilechie et al. (2001) produced briquettes from palm wastes.

Olorunnisola (2007) designed and fabricated a prototype briquetting machine in form of die extruder to produce pellets from waste paper plus admixture of coconut husk. Among other residues investigated are cotton stalk (El-Saeidy, 2004); banana peel (Wilaipon, 2008); rattan furniture waste (Olorunnisola, 2004), and so on. The researchers went further to study factors such as preheating of biomass feed stocks, pressure/density relationship, effects of moisture content and particle sizes. They all came to conclusion that all those factors have one effect or the other on briquetting process as well as quality of briquettes.

Many agricultural residues are generated in Nigeria from farming activities and in order to make judicious use of these residues, there is the need to investigate how these residues lend themselves to process of briquetting. The fuel properties of agro-waste briquettes vary from one type to another, so briquettes from these residues are expected to vary in properties. Since briquettes can be made from wide varieties of agro-residues, selection of the best briquettes has to be made based on the ones that have better fuel properties or positive attributes. This will go a long way to ensure judicious use of these wastes.

The overall aim of this work was to investigate the briquetting process of few selected agro-residues, which are commonly found in Nigeria and evaluate the densification characteristics of briquettes produced from them. The five agro-residues selected were cassava and yam peels, corncob, groundnut and melon shells.

MATERIALS AND METHODS

The residues that were utilized in this experiment were obtained from farm dumps. The residues were chosen because they are produced in large quantity in the country and most often they are dumped or flared resulting in health hazards to both human and ecology. All the residues were sun-dried until stable moisture contents were obtained. They were further subjected to size reduction using a hammer mill and 2.00 mm particle size representing medium series was chosen for each residue.

The procedure as highlighted in ASAE S 424.1 (2003) was followed to determine the chosen particle size. Since a low-pressure technique was employed, there was the need for a binding agent and 5% by weight of cassava starch in form of gel was used as binder in line with works of Musa (2007). To facilitate conversion of these residues into briquettes, there was the need to design and fabricate an experimental briquetting machine.

The briquetting machine that was used (Figure 1) was based on hydraulic principle and consists of four molds, where the blend of cassava starch gel and the residues was fed into the molds of the briquetting machine and compressed by a hydraulic press.

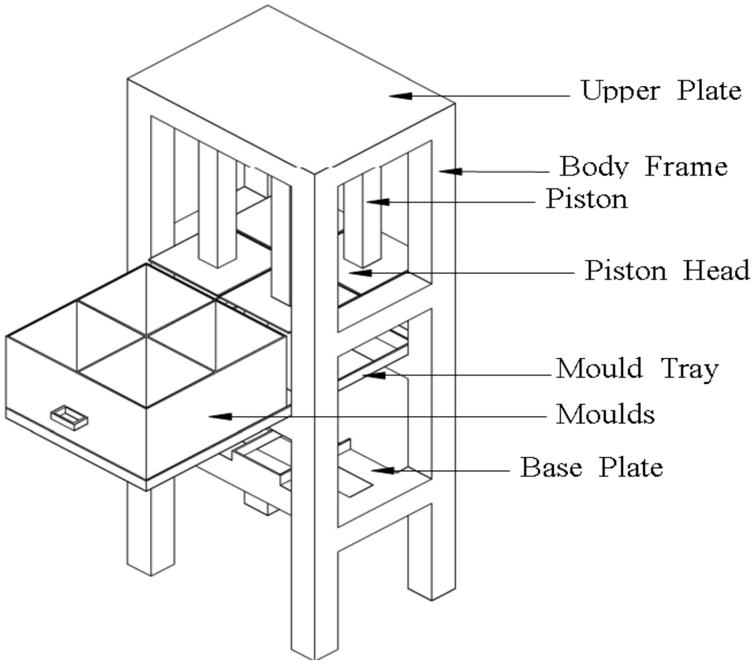

Figure 1: Isometric View of an Experimental Briquetting Machine.

Two critical parts, the mold and the pressure bars (compactors) because of enormous force they were subjected to were designed against failure and buckling, respectively.

According to the design of the molds, four briquettes were produced per batch (Plates 1 and 2). The briquettes were later ejected after the holding time (i.e., duration of load application of five minutes) was observed as suggested by Musa (2007).

Plate 1: Samples of Briquettes from one of the Residues (Yam peel).

Plate 2: Briquette Samples from Corncob.

<u>Determination of Densification Characteristics of the Briquettes</u>

The densities of briquettes formed from each residue were determined immediately after ejection from the mould and this was calculated from the ratio of the mass to the volume of briquette. The mass was obtained by using a digital weighing scale, while the volume was calculated by measuring the length, breadth and thickness of the briquettes by means of a Vernier caliper.

The relaxed densities of the briquettes from the five residues were determined after the stable moisture contents of briquettes produced were obtained. The relaxed density which is also known as a spring back density can be defined as the density of the briquette obtained after the briquette has remained stable and was calculated simply as the ratio of the briquette's mass to the new volume.

Equilibrium moisture contents of the briquettes formed were determined in line with ASAE S269.4 (2003), while the ultimate and proximate analyses of the briquettes were evaluated as highlighted in ASTM Standard D5373-02 (2003). The flame propagation rates of the briquette samples were determined as highlighted by Musa (2007) and this was estimated by dividing the length of the briquette burned by the time taking in seconds to effect the burning.

The afterglow time was estimated and determined. This became necessary in order to estimate how long the individual briquette will burn before restocking when they are used in cooking and heating. The procedure of Musa (2007) was also used and this was done by estimating the time in seconds within which a glow was perceptible.

Furthermore, the energy values of the five biomass briquettes were also examined using Parr isoperibol bomb calorimeter. The procedure in accordance with ASTM Standard E711-87 (2004) was followed.

The compressive strengths of the briquettes were also investigated by using a universal testing machine. Compressive strength was determined in accordance with ASTM Standard D1037-93 (1995).

The following density related ratios were determined:

(i) $$\textit{Density Ratio} = \frac{\textit{Relaxed Density}}{\textit{Maximum Density}} \quad (1)$$

(ii) $$\textit{Relaxation Ratio} = \frac{\textit{Maximum Density}}{\textit{Relaxed Density}} \quad (2)$$

(iii) $$\textit{Compaction Ratio} = \frac{\textit{Maximum Density}}{\textit{Initial Density}} \quad (3)$$

Density ratio was calculated as the ratio of relaxed density to maximum density, while relaxation ratio was calculated as the ratio of maximum density to relaxed density. In this formula, maximum density is the compressed density of briquette immediately after ejection from briquetting machine. The compaction ratio is defined as the maximum density of the briquette divided by the initial density of the residue.

RESULTS AND DISCUSSION

The results of the determination of densification characteristics of briquettes produced from the five residues are shown in Tables 1 and 2, while the results of burning characteristics of the briquettes produced from five residues examined in this study is presented in Table 3.

Table 1: Physical and Fuel Characteristics of Briquettes Produced from Five Residues.

Parameter	Unit	Briquettes produced from				
		Corncob	Groundnut shells	Melon shells	Cassava peels	Yam peels
Length of the briquette	m	0.030	0.030	0.030	0.030	0.030
Breadth of the briquette	m	0.030	0.030	0.030	0.030	0.030
Thickness of the briquette	m	0.005	0.005	0.005	0.005	0.005
Mass of the briquette	kg	0.024	0.025	0.025	0.024	0.025
Compaction pressure	N/mm^2	2.10	2.10	2.10	2.10	2.10
Carbon content	%	19.72	16.49	21.67	22.08	25.29
Hydrogen content	%	19.56	16.42	14.76	13.54	15.19
Oxygen content	%	62.12	68.79	64.19	37.31	49.79
Sulphur content	%	0.82	0.28	0.35	1.82	1.39
Ash content	%	1.40	5.00	6.57	4.40	3.86
Nitrogen content	%	0.38	1.10	0.26	2.38	1.41
Volatile matter	%	86.53	88.47	82.90	83.06	82.87
Fixed carbon	%	12.57	6.53	10.27	2.57	3.29

Table 2: Combustion Characteristics of Briquettes Produced from Five Residues.

Parameter	Unit	Briquettes produced from				
		Corncob	Groundnut shells	Melon shells	Cassava peels	Yam peels
Moisture content						
The Residue	%	9.47	11.53	9.60	10.19	10.95
The Briquette		7.48	9.18	7.45	8.78	7.98
Compressive strength	kN/m^2	2.34	1.67	2.30	1.53	1.76
The heating value	kJ/kg	20,890	18,634.34	21,887	12,765	17,348
Initial density	kJ/kg	155.00	138.00	142.87	251.50	283.40
Maximum density	kg/m^3	650.00	524.00	561.00	741.13	911.45
Relaxed density	kg/m^3	385.00	236.00	286.42	386.40	512.54
Density ratio	-	0.59	0.45	0.51	0.52	0.56
Compaction ratio	-	4.19	3.80	3.93	2.94	3.21
Relaxation ratio	-	1.69	2.22	1.95	1.92	1.78

Table 3: Burning Characteristics of Briquettes Produced from Five Residues.

Parameter	Unit	Briquettes produced from				
		Corncob	Groundnut shells	Melon shells	Cassava peels	Yam peels
After glow time	sec.	370.00	354.00	367.00	367.00	375.00
Flame propagation rate	cm/s	0.12	0.10	0.10	0.13	0.16

From the result of ultimate analysis, the moisture contents of 9.47, 11.53, 9.60, 10.19 and 9.27% were recorded for corncob; groundnut shell; melon shell; cassava and yam peels, respectively, while the corresponding moisture contents of their briquettes were 7.48, 9.18, 7.45, 8.78, and 7.95%. The moisture contents of the residues are within the limits of 15 % recommended by Grover and Mishra (1996) and Kaliyan and Morey (2009) for agro-residues, while the moisture contents of the briquettes obtained in this study are also satisfactory as they are within the limits recommended by Yang et al. (2005), which stated that the difference between the moisture content of agro-residues and their briquettes ideally should be in the region of about 2%.

The low sulphur and nitrogen contents in all the five specimens are 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 these specimens will not pollute the environment (Oladeji, 2011). The values of volatile matter obtained for these residues are good and acceptable and fall within the limits of between 80 – 85% as recommended by Yang et al. (2007).

The higher heating value calculated for briquettes produced from corncob, groundnut shell, melon shell, cassava and yam peels were 20,890, 18,634.34, 21,887, 12,765, and 17,348kJ/kg, respectively. These energy values are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. Furthermore, these energy values compare well with most popular biomass residues. For examples, rice husk 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 650 kg/m3, 385 kg/m^3 and 1.69 were obtained for maximum density, relaxed density and relaxation ratio for briquette produced from corncob respectively, while the corresponding values for briquettes from groundnut shell, melon shell, cassava and yam peels in the order listed above were 524 kg/m^3, 236.0kg/m^3, 2.20; 561 kg/m^3, 286.42 kg/m^3, 1.95; 741.13kg/m^3, 386.4 kg/m^3, 1.92 and 911.45kg/m^3 512.54 kg/m^3, 1.78, respectively. The densities obtained in this work compare well with density of notable biomass fuels such as coconut husk briquette-630 kg/m^3 (Olorunnisola, 2007); banana peel-600 kg/m^3 (Wilaipon, 2008), and groundnut shell briquette-524 kg/m^3 (Musa, 2007).

In terms of maximum, relaxed densities and relaxation ratio briquettes produced from cassava and yam peels appear better than the other three specimens. This is because, the lower the value of relaxation ratio and the higher the value of relaxed density, the higher is the stability of briquettes produced (Yang, et al., 2005). The relaxation ratio obtained for corncob briquette appears to be the best. Generally, all the relaxation ratios obtained are good enough and they are close to the values obtained by Olorunnisola (2007), where a relaxation ratio of between 1.80 and 2.25 was achieved for briquetting of waste paper plus the admixture of coconut husk.

The compressive strengths for briquettes obtained from corncob, groundnut shell, melon shell, cassava and yam peels were 2.34, 1.67, 2.30, 1.53 and 1.76kN/m^2 respectively. The briquettes from corncob and melon shells were better and found to be reasonable than that of groundnut shell, cassava and yam peels. The implication of this is that, briquettes from these two specimens will suffer less damage during transportation and storage than the briquettes from other three residues (Musa, 2007).

The values of afterglow and propagation rate obtained for all the five specimens are reasonable and satisfactory as the longer afterglow and slow propagation rate obtained in this study imply that briquettes from the five biomass residues will ignite more easily and burn with intensity for a long time. In this regards, briquettes from corncob and yam peel appear better, while in terms of propagation rate, briquettes produced from groundnut and melon shells are the best.

CONCLUSIONS

Based on the various results obtained and findings of this study, the following conclusions can be drawn:

i. Briquettes from all the specimens examined in this study would make good biomass fuels.

ii. All the briquettes produced from these residues will not crumble during transportation and storage because their relaxation ratios are low.

iii. Generally, briquettes produced from corncob and melon shells have more positive attributes of biomass fuel than briquettes from other specimens. However, going by the values of maximum and relaxed densities and relaxation ratio, briquettes from cassava and yam peels cannot be written off.

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