UTILIZATION OF POTENTIAL OF THREE SELECTED AGRICULTURAL RESIDUES FOR BRIQUETTING AS BIOMASS FUELS

Oladeji, J. T. *

ABSTRACT

In this work, investigations were carried out on densification characteristics of briquettes produced from corncob; melon shell and cassava peel residues with a view to finding out which of them would make the best biomass fuels. Ultimate and proximate analyses were carried out to determine the average composition of their constituents. A simple prototype briquetting machine was fabricated to facilitate compaction of these residues into briquettes. Thereafter, densification and fuel characteristics of produced briquettes such as initial, maximum and relaxed densities were determined. Also determined were density, compaction and relaxation ratios. The energy values and compressive strengths of briquettes from the three specimens were also evaluated.

The mean moisture contents of corncob, melon shell and cassava peel were 9.47%, 9.60% and10.76% respectively, while the moisture contents of briquettes were 7.48%, 7.45% and 8.78% respectively. The initial, maximum and relaxed densities were 155, 650, and 325kg/m^3 respectively for briquettes produced from corncob, while the corresponding values for briquettes produced from melon shell and cassava peel were 142.87, 561, 286.42kg/m^3; 251.50, 741.13, 386.40kg/m^3 respectively. The relaxation ratios of 1.69, 1.95 and 1.92% were obtained for briquettes produced from corncob; melon shell and cassava peel respectively. The heating value calculated for briquettes from corncob, melon shell and cassava peel were 20,890, 21,887 and 12,765kJ/kg respectively, while the corresponding values of compressive strengths were 2.34, 2.30 and 1.53kN/m^2.

The results show that briquettes produced from corncob is the best, strictly followed by melon shells.

Key words: Agro-residue, briquette, cassava peel, corncob, melon shell

* Mechanical Engineering Department, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria.

1.0 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. Therefore, there is the need to 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 are generated in the country, but they are poorly utilized and badly managed, since most of these residues are left to decompose or they are burnt resulting in health hazards to both human and ecology (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 application (Oladeji, et al., 2009).

Among several kinds of biomass, agricultural residues have become one of the most promising choices. Some agricultural residues 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 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. Olorunnisola (2007) and 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) described briquetting as a densification process. 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 (Wilaipon, 2008; Olorunnisola, 2007; Kaliyan and Morey, 2009; Gilbert et al., 2009, etc) had carried out a lot of work on briquetting process. Their efforts were focussed 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, (2007), 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 the countries 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.

Agro-residues can play a significant role in alternative energy generation. Briquettes produced from different agro-residues depend on the physical and fuel properties of the residues. The overall aim of this work was to, investigate the briquetting process of 3 selected agro-residues commonly found in Nigeria and evaluate the densification characteristics of briquettes produced from them. The three agro-residues selected were cassava peels, corncob, and melon shells.

2.0 Materials and Methods

The residues used 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 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 binding agent 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 used (Plate 1) was based on hydraulic principle and consists of four moulds, where the blend of cassava starch gel and the residues was fed into the moulds of the briquetting machine and compressed by a hydraulic press, which is in form of hydraulic jack.

Two critical parts, the mould and the compactors because of enormous force they were subjected to were tested against failure and buckling respectively. Figure 1shows the isometric view of the briquetting machine, where the piston acts as a compactor. According to the design of the moulds, four briquettes were produced per batch (Plates 2 and 3). The briquettes were later ejected after the holding time i.e duration of load application of five minutes was observed as suggested by Olorunnisola (2007).

Plate 1: The Briquetting Machine

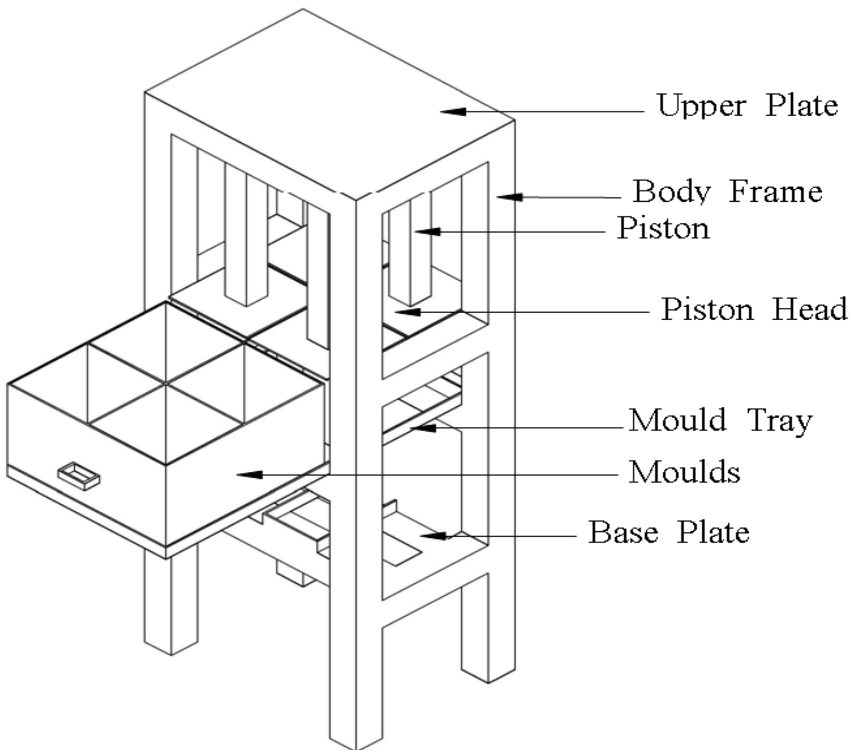

Figure 1: Isometric View of an Experimental Briquetting Machine

Plate 2: Samples of Briquettes from Corncob

Plate 3: Briquette Samples from Melon Shells

3.0 Determination of Densification Characteristics of the Briquettes

The densities of briquettes produced 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 calliper.

The relaxed densities of the briquettes from the three residues were determined after nineteen days. 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 ASAES-269-4 (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 burnt 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 three biomass briquettes were also examined using Parr isoperibol bomb calorimeter. The procedure in accordance with ASTM E 711-87 (2004) was followed. The compressive strengths of the briquettes were also determined with the aid of a universal testing machine in accordance with ASTM 1037-93 (1995).

The following density related ratios were determined

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

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

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 commpaction ratio which is defined as the maximum density of the briquette divided by the initial density of the residue was determined and calculated. Put in equation form:

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

3.0 Results and Discussion

The physical characteristics and ultimate analysis of briquettes produced from the three residues are shown in Tables 1, while the Table 2 and 3 show the densification and combustion characteristics respectively. The values shown in the Tables are mean values from three replicates.

Table 1: Physical Characteristics and Ultimate Analysis of Briquettes produced from the 3 Residues

Parameter	Unit	Corn cobs	Melon shells	Cassava peels
Length of the briquette	m(metre)	0.030	0.030	0.030
Breadth of the briquette	m	0.030	0.030	0.030
Thickness of the briquette	m	0.005	0.005	0.005
Volume of the briquette	$10^{-6}m^3$	4.50	4.50	4.50

Compaction pressure	N/mm^2	2.10	2.10	2.10
Carbon content	%	19.72	21.67	22.08
Hydrogen content	%	19.56	14.76	13.54
Oxygen content	%	62.12	64.19	37.31
Sulphur content	%	0.82	0.35	1.82
Ash content	%	1.40	6.57	4.40
Nitrogen content	%	0.38	0.26	2.38
Volatile matter	%	86.53	82.90	83.06
Fixed carbon	%	12.57	10.27	2.57

Table 2: Densification Characteristics of Briquettes produced from the 3 Residues

Parameter	Unit	Corncobs	Melon shells	Cassava peels
mc (residue)	%	9.47	9.60	10.19
mc (briquette)	%	7.48	7.45	8.78
Compressive strength	kN/m^2	2.34	2.30	1.53
The heating value	kJ/kg	20,890	21,887	12,765
Initial density	kg/m^3	155.0	142.87	251.50
Maximum density	kg/m^3	650.0	561.0	741.13
Relaxed density	kg/m^3	385.0	286.42	386.40
Density ratio	-	0.59	0.51	0.52
Compaction ratio	-	4.19	3.93	2.94
Relaxation ratio	-	1.69	1.95	1.92

Table 3: Combustion Characteristics of Briquettes produced from the 3 Residues

Parameter	Unit	Corncobs	Melon shells	Cassava peels
After glow time	sec.	370.0	367	367.00
Flame propagation rate	cm/s	0.12	0.10	0.13

From the result, the moisture contents of 9.47%, 9.60% and 10.19% were recorded for corncob; melon shell and cassava peel respectively, while the corresponding moisture contents of their briquettes were 7.48%, 7.45% and 8.78%. 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. The moisture contents of the briquettes obtained in this study are also satisfactory as they in line with suggestion of Yang et al. 2005, which stated that the difference between the moisture content of agro-residue and briquette produced ideally should be in the region of about 2 %. The results of ultimate analysis for corncob gave 19.72%, 17.56%, 62.12%, 0.38% and 0.82% for contents of carbon, hydrogen, oxygen, nitrogen, and sulphur respectively. The corresponding values for melon shell in the order listed above were 21.67%, 14.76%, 64.19%, 0.26%, and 0.35%, while that of cassava peel are 22.08%, 13.64%, 37.31%, 2.38% and 1.82%. The amount of carbon and hydrogen content in the three residues examined 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 three 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 the three specimens will not pollute the environment (Enweremadu et al., 2004).

For the proximate analysis, the percentage content of fixed carbon, ash content and volatile matter for corncob were 12.57%, 1.40%, and 86.53% respectively, while the corresponding value of melon shell were 10.27%, 6.57% and 82.90%. The corresponding values for cassava peel were 2.57%, 4.4% and 83.06%. The values of volatile matter and ash content are good and acceptable. This is because higher percentage of the briquettes from the three residues would be made available for combustion.

The higher heating value calculated for briquette produced from corncob was 20,890kJ/kg, while that of melon shell and cassava peel were 21,887 and 12,765kJ/kg, respectively. These energy values are sufficient, especially the ones from corncob and melon shells 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 briquette from melon shells and cassava peels were 561 kg/m^3, 286.42 kg/m^3, 1.95 and 741.13, 386.4 and 1.92 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 (Oladeji et al., 2009). In terms of maximum and relaxed densities, briquettes produced from cassava peels appear better than the other two specimens, while in terms of relaxation ratio, briquettes from corncob appear better than briquettes from melon shells and cassava peels. This because the lower the value of relaxation ratio, the higher is the stability of briquettes produced (Oladeji, 2011). The relaxation ratios obtained are also 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 admixture of coconut husk and Oladeji et al. (2009), where value of 1.45 was obtained for groundnut shell briquette. The lower relaxation ratio of corncob briquette is a pointer to the superiority.

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

The values of afterglow and propagation rate obtained for the three sample products are reasonable and satisfactory as the longer afterglow and slow propagation rate obtained in this study imply that briquettes from the three biomass residues will ignite more easily and burn with intensity for a long time. In this regards, briquettes from corncob and melon shells appear better than their cassava peel counterpart.

Conclusions

Based on the results obtained in this study, the following conclusion may be drawn:

i. Briquettes from the corncobs, melon shells and cassava peels examined in this study would make good biomass fuels. This is because their heating values are sufficient enough for domestic and small industrial cottage applications.

ii. Briquettes produced from the three residues will not crumble during transportation and storage because their relaxation ratios are low. Furthermore, their compressive strengths were sufficient enough to enable them withstand the rigours that may be encountered during packaging and transportation.

iii. Briquettes produced from corncob and melon shell are better than briquettes from cassava peels. This is because their higher heating values as well as their compressive strengths are far higher than that of cassava peel. Furthermore,

iv. Briquettes from corn cob and melon shell will be more environmentally friendly as they have lower values of nitrogen and sulphur contents compared to cassava peel.

References

Adekoya, L.O., (1989) "Investigations into Briquetting of Sawdust" The Nigerian Engineer.Vol.24, No 3, pp1-10

ASAE S 424.1. (2003) Method of determining and expressing particles size of chopped forage materials by screening 606-608, St. Joseph, Michigan

ASAE, S269.4 (2003) – Cubes, pellets and crumbles – definitions and methods for determining density, durability and moisture content. 567 – 569. St. Joseph, Mich.: U.S.A.

ASTM, Standard D1037-93 (1995) American Society for Testing and Material Standard Methods of evaluating the properties of word-based fibre and particle pained materials Philadelphia P.A

ASTM, Standard D5373-02, (2003) Standard Test Methods for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Laboratory Samples of Coal and Coke, ASTM International, West Conshohocken, P.A

ASTM, Standard E711-87, (2004) Standard Test method for Gross Calorific Value of Refuse-Derived fuel by the Bomb Calorimeter, ASTM International, West Conshohocken, PA

El-Saeidy, E. A., (2004) "Technological Fundamentals of Briquetting Cotton Stalks as a Bio-fuel" An Unpublished Ph.D Thesis, Faculty Agriculture and Horticulture, Humboldt University, Germany

Enweremadu, C.C., Ojediran, J.O., Oladeji, J.T., and Afolabi, L.O., (2004) "Evaluation of Energy Potential in Husks from Soy-bean and Cowpea" Science Focus Vol. 8 pp. 18-23.

Gilbert, P., Ryu, C., Sharif, V., and Switchenbank, J., (2009) "Effect of processing parameters on pelletisation of herbaceous crops" Fuel 88:1491-1497

Grover, P.D., and Mishra, S. K., (1996) "Biomass Briquetting, Technology and Practices", Regional Wood Energy Development Programme in Asia, Field document No. 46 Bangkok, Thailand; FAO.

Ilechie, C. O., Omoti, U., Bafor, M., Albangbe, S., Ogblechi, R. and Amiolemhen, P. E., (2001) "Development of a substitute for Fuel wood-palm waste Briquette and stove" Conference Proceeding on New Products and Technologies for Small and Medium Enterprises PATASD. University of Benin, Nigeria, pp. 151 – 153.

Jekayinfa, S. O., and Scholz, V., (2009) "Potential Availability of Energetically Usable Crop Residues in Nigeria" Energy Sources, Part A, Vol. 31: 687-697.

Jekayinfa, S. O., and Omisakin, O. O., (2005) "The energy potentials of some agricultural wastes as local fuel materials in Nigeria". Agricultural Engineering International, the CIGR E-Journal of Scientific Research and Development, Vol. III, Manuscript EE 05 003:10

Kaliyan, N. and Morey, R. V. (2009) "Factors affecting strength and durability of densified biomass products" Biomass and Bioenergy 33, 337-359

Musa, N.A., (2007) "Comparative Fuel Characterization of Rice Husk and Groundnut Shell Briquettes" NJRED, Vol. 6, No. 2.pp 23-26.

Oladeji, J.T., (2011) "The Effects of Some Processing Parameters on Physical and Combustion Characteristics of Corncob Briquettes" An unpublished Ph.D Thesis of Mechanical Engineering Department, Ladoke Akintola University of Technology, Ogbomoso pp150-157

Oladeji, J.T., (2010) "Fuel Characterization of Briquettes Produced from Corncob and Rice Husk Residues". Pacific Journal of Science and Technology 11(1):101-106.

Oladeji, J. T., Enweremadu, C.C., and Olafimihan, E. O., (2009) "Conversion of Agricultural Wastes into Biomass Briquettes" IJAAAR 5 (2): 116-123

Olorunnisola, A. O., (2007) "Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixture" Agricultural Engineering International: the CIGR E-journal. Manuscript EE 06 006 Vol. IX Phitsanulok, Thailand" American Journal of Applied Sciences 5 (12):1808-1811.

Wilaipon, P., (2008) "The Effect of Briquetting Pressure on Banana-Peel Briquette and the Banana Waste in Northern Thailand". American Journal of Applied Sciences 6(1): 167-171.

Yang, B. Y., Changkook, R., and Adela, K., (2005) "Effect of fuel properties on biomass" combustion (Part II) modelling approach- identification of the controlling factors Fuel 84, 2116-2130