Journal of Research in Forestry, Wildlife & Environment Vol. 12(3) September, 2020
E-mail: jrfwe2019@gmail.com; jfewr@yahoo.com
http://www.ajol.info/index.php/jrfwe
jfewr ©2020 - jfewr Publications
ISBN: 2141 – 1778
Ladapo et al., 2020

EVALUATION OF ENERGY POTENTIALS OF BRIQUETTES PRODUCED FROM MAIZE AND SAWMILL RESIDUES

***Ladapo, H. L.; Alli, A.A. and Dickson P. O.**
Department of Agricultural and Bio-Environmental Engineering, School of Engineering,
Yaba College of Technology, P. M. B. 2011, Yaba, Lagos State, Nigeria

***Corresponding Author:** *mrladapo@yahoo.com;* +2348066672712

ABSTRACT

This study investigated the energy potentials of briquettes made from maize residues (cobs, husks and stalks) and sawmills residues (sawdust, wood shavings and wood chips). These residues were collected from a farm and sawmill located in Epe, Lagos State. They were burnt and converted to briquettes using a cylindrical mould (70 x 100 mm) for maize residues and a rectangular mould (30 x70 x100 mm) for sawmill residues. They were subjected to proximate, elemental and chemical analyses using American Society of Testing Materials (ASTM) and Technical Association of the Pulp and Paper Industry (TAPPI) standards. Maize residues briquette had moisture content (11%), volatile matter content (9.6%), ash content (12.6%), density (287.1 kg/m^3) and calorific value (2899.7 Kcal/kg). Sawmill residues briquette had moisture content (12.6%), volatile matter (15.8%), ash content (14.8%), density (332.4 kg/m^3) and calorific value (3259 Kcal/kg). The Fuel Value Index of maize residues briquette was 207.3 and sawmill residues briquette was 197.3. A t-test statistical tool was used to determine whether there was a significant difference between the two samples. The absolute t value calculated (=0.0966) was less than the tabulated value (2.074) for equality of energy potentials. This revealed that energy properties of briquettes produced from maize and sawmill residues is not significantly different. Hence, both briquettes would be good sources of domestic energy.

Keywords: Briquette, Biomass, Energy Potentials, Maize Residues, Sawmill Residues

INTRODUCTION

Fossil fuels are available in limited reserves with their demands ever growing because of industrial development and rapid population growth (Adegoke *et al.*, 2014; Dutta *et al.*, 2013). Fossil fuels have impacted negatively on the environment in a great way (Dutta *et al.*, 2013). So to avoid depletion and reduce their impacts on the environment, an alternative way of generating fuel is sourced .One of the ways is the use of biomass renewable energy. Biomass resources can be harvested for a longer period of time without significant depletion (Akhator *et al.*, 2017). Nigeria has vast renewable energy resources majorly water, solar, wind and biomass which are largely untapped for uses (Akinrinola *et al.*, 2014).

Presently, majority of the people living in the rural areas use bioenergy sources for their basic energy needs like cooking and heating. These are mostly carried out in the inefficient ways (Akinrinola *et al.*, 2014). Some examples of biomass resources in Nigeria are wood, agricultural and crop residues, sawdust, wood shavings, bird and animal, litter and dung, industrial and solid wastes (Akinrinola *et al.*, 2014). Agricultural residues include corn husks and stalk, rice husk, cassava peels, palm kernel shells, coconut shells, sugarcane bagasse, groundnut shells and jute sticks (Akinrinola *et al.*, 2014; Sotannde *et al.*, 2010). The nations of the world generate billions of tonnes of agricultural residues yearly (Quartey, 2011). Agricultural biomass waste when converted to energy can significantly replace fossil fuels, reduce greenhouse gases emissions and provide renewable energy to people in developing nations (Quartey, 2011).

Densification or briquetting is the process of compacting biomass residue into a uniform solid fuel briquette. A briquette has higher density, energy content and less moisture compare to its raw material. Various methods can be used either with or without binder addition for the biomass briquetting (Sotannde *et al.*, 2010). Hence, this study evaluated the energy potentials of the two briquettes made from maize and sawmills residues.

MATERIALS AND METHODS

Collection and Preparation of Materials

Dried maize residues (cobs, husks and stalks) and sawmill residues (sawdust, wood shavings and wood chips) were collected from a commercial farm and sawmill respectively, both located at Epe, Lagos State. The maize residues were mixed together in the ratio of 3:1:1 (cobs 9 kg, husks 3 kg and stalks 3 kg). Similarly, the sawmill residues were also mixed together in the same ratio (sawdust 9 kg, wood shavings 3 kg and wood chips 3 kg). All the residues were further sun-dried for 2 weeks to reduce their moisture contents and ensure homogeneity. The mixed maize and sawmill residues were burnt separately in a metallic drum which served as a kiln. The residues were ignited and allowed to burn for a while. Later on the lid was put on the drum to allow the residues to smoulder and fire put out. The charred residues are shown in Plates 1 and 2 respectively. The burnt residues were crushed, pounded and sieved (using 1.00mm sieve) to have powdered materials. The sieved powdered maize residues weighed 4.5kg and sawmill residues weighed 4kg. The sieved residues were mixed with cassava starch solution (binder).

Plate 1: Charred Sawmill Residues

Plate 2: Charred Maize Residues

Briquetting and Drying

A cylindrical briquetting mould (70 × 100 mm) was used for moulding maize residues while a rectangular mould (30 × 70 × 100 mm) was used for sawmill residues. The briquettes were sundried for 7 days. The dried maize residues and sawmill residues briquette weighed 0.4 kg and 0.3 kg respectively. Samples of maize and sawmill residues briquettes were later taken to the Agronomy laboratory at the University of Ibadan, Oyo State where Proximate, Chemical and Element analyses were carried out according to American Society of Testing Materials (ASTM) and Technical Association of the Pulp and Paper Industry (TAPPI) Standards. The Fuel Value Index (FVI) is calculated based on the calorific value, wood density and ash content. The expression is given by Saravanan *et al*., (2013) as:

$$FVI = CV - D/A \quad \text{....... [1]}$$

Where: FVI = Fuel Value Index; CV = Caloric Value; D = Density; A = Ash

Data Analysis

A *t-test* statistical tool was used to determine whether there is a significant difference between any two given samples. In evaluating the equality of energy potentials of briquettes produced from maize and sawmill residues, maize residues briquette was represented as x_1 and sawmill residues briquette as x_2. It was assumed that the observations were taken independently.

RESULTS

The results of the proximate, element and chemical analyses of test briquettes are presented in the Table 1. Maize residues briquette had moisture content of 11% which was lower than sawmill residues briquette of 12.6%. The volatile matter content of sawmill residues briquette was 15.8% and much higher than that of maize residues briquette of 9.6%.

The ash content of maize residues briquette was lower with value of 12.6% while sawmill residues briquette was 14.8%. Maize residues briquette had a lower density of 287.1 kg/m^3 while that of sawmill residues briquette was 332.4 kg/m^3. The calorific value of maize residues briquette was 2899.7 Kcal/kg lower than sawmill residues briquette with 3259 Kcal/kg.

Both oxygen and hydrogen contents of maize residues briquette were higher 3.07 and 1.97% than sawmill residues briquette with 2.83 and 1.60% respectively. Sawmill residues briquette had sulphur and nitrogen contents as 3.67 and 1.93% while that of maize residues briquette were 2.13 and 1.37%. The hemicellulose content was 3.37% for maize residues briquette and 3.73% for sawmill residues briquette. The lignin content of sawmill residues briquette was 1.83% and maize residues briquette had a higher content of 2.23%. The extractives content of sawmill residues briquette of 7.90% was higher than maize residues briquette with 5.10% content. The briquettes are shown in Plates 3 and 4 respectively.

Plate 3: Sawmill Residues Briquettes

Plate 4: Maize Residues Briquettes

Table 1: Results of Proximate, Element and Chemical Analyses of Test Briquettes

Test	Maize Residues Briquette	Sawmill Residues Briquette
Proximate Analysis		
Moisture content %	11.0	12.6
Volatile matter %	9.6	15.8
Ash content %	12.6	14.8
Calorific value (Kcal/kg)	2899.7	3259
Density (Kg/m^3)	287.1	332.4
Analysis of Element		
Oxygen content %	3.07	2.83
Sulphur content %	2.13	3.67
Nitrogen content %	1.37	1.93
Hydrogen content %	1.97	1.60
Chemical Analysis		
Hemicellulose %	3.37	3.73
Lignin %	2.23	1.83
Extractives %	5.10	7.90

The results of the *t-test* statistical analysis on the results of proximate, element and chemical analyses of test briquettes were shown in the Table 2. The absolute *t* value calculated was 0.0966 and lesser than the tabulated value of 2.074. The null hypothesis of equality of energy potentials could not be rejected.

Table 2: Data Analysis of Proximate, Element and Chemical Analyses Results

Parameters	Estimates
Sample size(s)	$n_1 = n_2 = 12$
Sample means	$\bar{x}_1 = 269.9367$ $\bar{x}_2 = 304.8408$
Sample variances	$s_1^2 = 69243.00756$ $s_2^2 = 87428.82210$
Pooled Variance	$s_p^2 = 78335.91717$
Test statistic	$t_{cal} = -0.0966$ for which $\lvert t_{cal} \rvert = 0.0966$
Critical value	$t_{tab} = t_{22,\ 0.9750} = 2.074$

DISCUSSION

The moisture content of the two test briquettes were 11.0 and 12.6%. This is in line with Wilaipon (2008) who cited the range of 10-15% moisture content as the best for briquette. This will aid complete combustion of the briquette. Rotting and decomposition of briquettes in storage are prevented by low moisture content (Noah *et al.*, 2019). However, Noah *et al.*, (2019) in their work reported mean moisture content of the briquettes produced ranged from 32.72% to 60.24%. Dora (2008) also cited the lower the moisture content of the biomass, the more desirable it is as a biofuel. While high moisture content makes briquettes swell and easy degrade easily (Zubairu and Gana, 2014). The maize residues briquette in this study with lower moisture content of 11.0% would be desirable out of the two briquettes.

Low volatile matter means the briquette won't be ignited easily, however once it does, it burns smoothly with clean smokeless flame according to Sotannde *et al*., (2010). The authors in their work reported volatile matter content of 10 to 13% for neem-wood residues briquettes. However, Falemara *et al*., (2018) reported volatile matter values ranged from 24.2% to 34.95% for agro- waste and wood residues briquettes. Volatile matter of the maize residues briquette of 9.6% was lower compared to 15.8% of sawmill residues briquette. It means maize residues briquette will burn faster and better than sawmill residues briquette without smoldering.

The ash content of the two test briquettes were 12.6 and 14.8%. This is in agreement with Garcia *et al.*, (2012) reporting that lower ash content indicates good quality briquette and should be in the range of 5-20%. High ash content makes fuel less desirable because it is non-combustible which reduces combustion heat (Sadiku *et al.*, 2016). Emerhi (2011) reported ash content of 14.89 ± 0.05% to 28.13 ± 0.037 % for briquettes produced from sawdust of three hardwood species. While Sotannde *et al*., (2010) reported ash content of 4.95 and 4.47% for both starch and gum Arabic bonded charcoal briquettes from neem wood residues. The maize residues briquette with a lower ash content of 12.6% makes it desirable out of the two briquettes in this study.

Falemara *et al*., (2018) opined that high density indicates longer burning time. Densities for briquettes in this study were 287.1 and 332.4 kg/m^3. This result was higher than what Adetogun *et al*., (2014) reported that briquettes produced from maize cobs had density range of 150-270 kg/m^3 (0.15-0.27 g/m^3). However, higher densities were reported by Falemara *et al*., (2018) as 440 kg/m^3 and 530 kg/m^3 (0.44 and 0.53 g/m^3) for briquettes made from wood residues and groundnut shells respectively. Considering density, sawmill residues briquette will burn for longer time than maize residues briquette. The energy content of a fuel is determined by the calorific value (Oyelaran and Tundunwada 2015).

Sawmill residues briquette had a higher calorific value of 3259 Kcal/kg (13.64MJ/kg) than maize residues briquette with 2899.7 Kcal/kg (12.13MJ/kg). This was similar to calorific value of 14.1MJ/kg for maize cob briquette as reported by Wilaipon (2007). Musa (2007) cited calorific value groundnut shell briquette as 12.6MJ/kg (12600 kJ/kg). Enweremadu *et al.*, (2004) reported the values of 14.4 MJ/kg (14372.93 kJ/kg) and 13MJ/kg (12953 kJ/kg) for both cowpea and soybeans husks respectively**.**

Low sulphur and nitrogen contents indicate minimal release of oxides which are harmful and environmental pollutants (Dora 2008; Akowuah *et al*., 2012). Considering this maize residues briquette will be desirable since it produces minimum harmful oxides and environmental pollutants. High hemicellulose and lignin contents are desirable in biomass meant for combustion (Dora 2008; Nguyen *et al.*, 2016). According to Nemestothy (2008), high extractive content increases the heating value. Higher values of both hemicellulose and extractives contents will make sawmill residues briquette better than maize residues briquette. According to Sadiku *et al*., (2016) fuel value index (FVI) is the most appropriate for the determination of the suitability of a woody species as fuel material. FVI for maize residues briquette was 207.3 and 197.3 for sawmill residues briquette.

CONCLUSION

It is evident from the findings of this study that both maize and sawmill residues briquettes can be good sources of domestic energy for the nation. Some of the energy potentials of these two briquettes were found to be similar to other briquettes in comparison. The moisture content of the briquettes was within the stipulated range of 10-15%, and the ash content also found within the acceptable range of 5-20%. The calorific values of 2899.7 Kcal/kg and 3259 Kcal/kg for the two briquettes were similar in comparison to others. It is evident from the data analysis that the energy potentials of briquettes produced from maize and sawmill residues are not significantly different, that is, their potentials are almost equal. Moreover, the problem of managing agricultural wastes can be solved to a large extent. Converting the wastes to briquettes with the assistances of government can also reduce the unemployment rate in the nation.

REFERENCES

Adegoke, O. A., Fuwape, J. A., Fabiyi, J. S. (2014). Combustion Properties of Some Tropical Wood Species and Their Pyrolytic Products Characterization. *Energy and Power.* 4(3): 54-57.

Adetogun, A.C, Ogunjobi, K.M and Are, D.B. (2014). Combustion Properties of Briquettes Produced from Maize Cob of Different Particle Sizes. *Journal of Research in orestry, Wildlife and Environment*. 6 (1): 28-38

Akhator, E. P., Obanor, A. I., and Ugege, A. O. (2017). Physico-Chemical Properties and Energy Potential of Wood Wastes from Sawmills in Benin Metropolis, Nigeria, Nigerian *Journal of Technology,* 36 (2): 452 – 456

Akinrinola, F.S, Darvell L.I., Jones, J.M., Williams, A., and Fuwape, J.A. (2014). Characterisation of Selected Nigerian Biomass for Combustion and Pyrolysis Applications. *Energy and Fuels*. 28 (6): 3821-3832

Akowuah, J. O., Kemausuor, F. and Mitchual, S. J. (2012). Physico-Chemical Characteristics and Market Potential of Sawdust Charcoal Briquette. Proceedings of the 55th International Convention of Society of Wood Science and Technology August 27-31, 2012 - Beijing, CHINA EC-6.pp1-11.

Dora, S. (2008). Bamboo as a Source of Bioenergy Feedstock in Ghana. An unpublished M.Sc. Thesis Submitted to the Department of Wood Science and Technology. Kwame Nkrumah University of Science and Technology. Ghana.

Dutta, P.P., Pandey, V., Sen, S., Das, A. R., Nath, A., and D.C. Baruah (2013) . Fuel Characteristics of Some Indigenous Plants. *International Journal of Emerging Technology and Advanced Engineering.* 3(3): 570-576

Emerhi, E. A. (2011). Physical and Combustion Properties of Briquettes Produced from Sawdust of Three Hardwood Species and

Different Organic Binders. *Advances in Applied Science Research*, 2 (6): 236-246

Enweremadu, C. C., Ojediran, J. O., Oladeji, J.T. and Afolabi, I.O. (2004). Evaluation of Energy Potential of Husks from Soy-Beans and Cowpea, *Science Focus*, 8: 18-23.

Falemara, B. C., Joshua, V.I., Aina, O. O., and Nuhu, R.D., (2018). Performance Evaluation of the Physical and Combustion Properties of Briquettes Produced from Agro-Wastes and Wood Residues. *Recycling.* 3(37): 1-13.

Garcia, R., Pizarro, C., Lavin, A.V., and Bueno J. L. (2012). Characterization of Spanish Biomass Wastes for Energy Use, *Bioresource Technology*. 12, 103, 249-258. doi:10.1016/j.biortech.2011.10.004

Musa, N., (2007). Comparative Fuel Characterization of Rice Husk and Groundnut Shell Briquettes. *Nigerian Journal of Renewable Energy Development*, 6(4): 23-27.

Nemestothy, K .P. (2008): "Wood fuels: Characteristics, standards, production technology," E.V.A-The Austrian Energy Agency.

Nguyen, Q. N., Cloutier, A., Achim, C. and Stenanovic, T. (2016). Fuel Properties of Sugar Maple and Yellow Birch Wood in Relation with Tree Vigor. *Bio-Resources*. 11(2): 3275-3288.

Noah, A.S., Okon-Akan, O.A. and Abiola , J.K. (2019). Energy Characterisation of Briquettes Produced from Admixture of *Arundo donax L*. and Coconut Coir. *American Scientific Research Journal for Engineering, Technology, and Sciences,* 56 (1): 136-151.

Oyelaran, O. A. and Tudunwada, Y. Y. (2015). Determination of the Bioenergy Potential of Melon Shell and Corn Cob Briquette. *Iranica Journal of Energy and Environment* 6 (3): 167-172.

Quartey, Ebo Tawiah (2011). Briquetting Agricultural Waste as an Energy Source in Ghana. Recent Researches in Environment, Energy Planning and Pollution. Pp 2000-2004.

Sadiku, N. A, Oluyege, A. O. and Sadiku, I. B. (2016). Analysis of the Calorific and Fuel Value Index of Bamboo as a Source of Renewable Biomass Feedstock for Energy Generation in Nigeria. *Lignocellulose.*5(1): 34-49.

Saravanan V., Parthiban K.T., Kumar P., Anbu P.V. and P. Ganesh Pandian (2013). Evaluation of Fuel Wood Properties of *Melia dubia* at Different Age Gradation. *Research Journal of Agriculture and Forestry Sciences.* 1(6): 8-11.

Sotannde, O.A., Oluyege, A.O., and Abah, G.B. (2010). Physical and Combustion Properties of Charcoal Briquettes from Neem Wood Residues. *International Agrophysics*, 24(1): 189-194

Wilaipon, P. (2007). Physical Characteristics of Maize Cob Briquette under Moderate Die Pressure. *American Journal Applied Science*, 4(12): 995-998.

Wilaipon P., (2008). Density Equation of Bio-Coal Briquettes and Quantity of Maize Cob in Phitsanulok, Thailand. *American Journal of Applied Science*., 5(12): 1808-1811

Zubairu, A and Gana, S. A. (2014). Production and Characterization of Briquette Charcoal by Carbonization of Agro-Waste. *Energy and Power*, 4(2): 41-47. DOI: 10.5923/j.ep.20140402.03