



Research Article

Preparation and Characterization of Biomass Briquettes Produced from Coconut Shell and Corncobs

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ABSTRACT

In this work, coconut shells and corncobs were effectively utilized to produce briquettes. The combustion performances of both briquettes with different binders were investigated as fuel. The briquettes were characterized and a water boiling test was carried out. The study revealed that corncob briquettes took a longer time to boil the same quantity of water compared to coconut shell briquettes. Coconut shell briquette produces more quantity of heat than the corncobs briquette. In addition, corncobs briquettes have a higher percentage of ash content than coconut shell briquettes. The volatile matter of Corncobs is 19.30% and 13.33% with starch and Gum Arabic respectively, while for coconut shell is 16.49% and 7.74% with starch and Gum Arabic. Corncobs briquettes have a higher moisture content of 24.24% and coconut shell briquettes has 14.02% whereas the briquettes produced from coconut shell with Gum Arabic has a higher calorific value of 24.04 Kcal/kg. The resistance to water penetration of each of the samples shows that briquettes made with coconut shells have more water penetration resistance with both binders than corncobs briquettes. The higher calorific value of 24.04 Kcal/kg of coconut shell with Gum Arabic implies that the energy in coconut shell particles was greater when compared to corncobs. Hence, it is more preferable to use coconut shell briquettes as solid fuel than corncobs briquettes due to the lower rate of combustion compared to corncobs briquettes.

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INTRODUCTION

The use of wood is increasing on daily basis especially in less technologically developed countries of the world (Agarry *et al.*, 2013). Heavy reliance on wood for domestic cooking would not solve the present energy crisis; rather it would lead to deforestation or desertification resulting in further scarcity of this resource (Babagana *et al.*, 2012). The use of kerosene and gas for cooking and domestic heating is very expensive and hence not economically viable for low income earner. In Nigeria a country that is so much endowed with many natural resources, there is problem of energy scarcity (Adekoya, 2015). Agricultural biomass residues have the potential for the sustainable production of bio-fuels and to offset greenhouse gas emission (Bhattacharya and Salam, 2002).

Corncoobs and Coconut shells are examples of biomass wastes and are readily available in Nigeria. Their utilization, especially in rural communities, is direct fuel, while their disposal is by open burning or being dumped and left to rot on farmlands. Generally, biomass displays poor energy characteristics when used in its natural state (Demirbas *et al.*, 2004). They also show low bulk densities due to their porous structure which makes processing, shipping, storage and combustion difficult. The disposal method is inefficient and leads to environmental pollution and degradation. Biomass must be converted into a ready-to-use, high-energy resource to be considered a viable fuel (Muazu and Stegemann, 2015). The production of briquettes from biomass is an alternative fuel source that can be utilized for space heating and power generation (Chaney *et al.*, 2009; Chaney *et al.*, 2010; Bintu *et al.*, 2014). Briquettes produced from biomass are high heat intensity, easy to store, environmentally friendly and mostly immortally low combustion rate (Bhattacharya *et al.*, 2002). Therefore, the

objectives of this work are to Produce and characterize biomass briquettes from corncoobs and coconut shells using different binders and ascertain their combustion performance.

METHODOLOGY

Sample Collection and Preparation

Corncoobs were collected from the processing sites at a corn mill, Bama market Maiduguri –Nigeria, while coconut shells were from the commercial market University of Maiduguri. Cassava Starch and Arabic gum were used as binding agents. The biomass was sorted, impurities were removed, and sun-dried for 3 days before hammer-milled and sieved to uniform size. The residues are well sun-dried to the lowest moisture content and carbonized.

Briquettes Production

The binders are measured in a ratio of 2:8 regarding the biomass. The binders were soaked in water to dilute for 2 hours. The binder and the biomass were mixed, in a fixed quantity of 2:8 ratio that is 20g binder and 80g biomass. The mixed samples were placed in the briquetting machine and compacted. The dwelling time of 5 minutes was used for each to achieve proper compaction at 50 kN/m² (Yuliah *et al.*, 2017). After the compaction, the briquettes were then divided into two portions, the first portion of the Briquettes was collected in a tray and Sundried under the sun for about 1-2 days while the other portion was dried using an electric dryer to remove the moisture from the briquette, it is then packed and sealed for further usage.

Determination of Physical Properties

Moisture content

The moisture content of raw biomass was determined by calculating the loss in weight of

material using the hot air oven drying method at a temperature range of 105 °C to 110 °C for one hour

and up to constant weight loss. (Mardoyan and Braun, 2015).

$$\text{Moisture content (\% Wb)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad 1$$

Volatile matter

The dried sample left in the crucible was covered with a lid and placed in an electric furnace, maintained at about 925 ± 20 °C for 7 minutes. The

crucible was cooled first in the air, then inside a desiccator and weighed again. Loss in weight was reported as a volatile matter on a percentage basis.

$$\text{Volatile matter (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad 2$$

Ash content

The residual sample in the crucible was heated without a lid in a furnace at 700 ± 50 °C for one-half hour. The crucible was then taken out, cooled

first in air, then in desiccators and weighed. Heating, cooling and weighing were repeated, till a constant weight was obtained. The residue was reported as ash on a percentage basis (ASTM, 2009).

$$\text{Ash content (\%)} = \frac{W_4 - W_1}{W_2 - W_1} \times 100 \quad 3$$

Shatter indices

Shatter indices was used for determining the hardness of briquettes. The briquette with known weight and length was dropped on RCC floor and concrete floor from the height of one meter. The

weight of disintegrated briquette and its size was noted down. The percent loss of material was calculated.

The shatter resistance of the briquettes was calculated by using (Ghorpade, 2006):

$$\text{Percent weight loss (\%)} = \frac{W_5 - W_6}{W_5} \times 100 \quad 4$$

$$\text{\%Shatter resistance} = 100 - \text{\% weight loss} \quad 5$$

Resistance to water penetration

It is measured of the percentage of water absorbed by a briquette when immersed in water. Each briquette was immersed in 50 cl of water at 27°C for 30 seconds. The percent water gain was then calculated and recorded by using:

$$\text{\% Water gained by briquette} = \frac{W_8 - W_7}{W_7} \times 100 \quad 6$$

$$\text{\% Resistance to water penetration} = 100 - \text{\% water gain} \quad 7$$

Where:

W_1 = weight of crucible, g; W_2 = weight of crucible + sample, g; W_3 = weight of crucible + sample, after heating, g; W_4 = weight of the crucible + ash, g; W_5 = Weight of briquette before shattering; W_6 = Weight of briquette after shattering; W_7 = Initial weight of briquette; W_8 = Final weight of briquette.

Water boiling test

This test measures the time it takes a given quantity of fuel to heat a given quantity of water to its boiling point. The fuels that is the corncobs and the coconut shells briquettes were measured and then stacked into a briquette burning stove and ignited to test the water boiling rate as reported by Mbamala (2019).

Determination of calorific value

Calorific value is one of the most important characteristics of a fuel. This is the measurement of the heat or energy released by a fuel during the complete combustion and expressed mostly as kcal/kg (Islam *et al.*, 2014). Lecco AC-350 Oxygen Bomb Calorimeter interfaced with a

microcomputer was used to assess the heat values of the produced briquettes.

RESULTS AND DISCUSSION

Table 1 shows proximate analysis of both corncob and coconutshell with binders (starch and gum Arabic). The volatile matter of each of the samples shows that corncobs and starch have 19.30% and gum Arabic 13.33% while coconut shell and starch have 16.49% and gum Arabic 7.74%, High volatile matter content in corncob with starch is an indication of the readiness of fuel samples to ignite. In terms of quality of the briquette, the high volatile matter implied that the briquette would readily ignite with a high proportionate flame during combustion (Koppejan and Van, 2012). The ash content of corncobs with starch and Gum Arabic are 30.39% and 27.64% while coconutshell with starch and Gum Arabic showed 25.79% and 26.59% respectively. In addition, coconutshell reveals a lower moisture content with different binders compared to corncobs. And as for the binders it is noticed that briquettes with starch binder produces less ash content than the other binder (Ajimotokan *et al.*, 2019)

Table 1: Proximate analysis of corncob and Coconutshell

Sample	Binder	Volatile Matter (%)	Ash Content (%)	Percentage moisture (%)
Corncobs	Starch	19.30	30.39	25.87
	Gum Arabic	13.33	27.64	24.24
Coconut shell	Starch	16.49	25.79	17.58
	Gum Arabic	7.74	26.59	14.02

The water boiling test of both coconut shell and corncob briquettes with the binders at different times are presented in Table 2. The corncob briquette with starch binder attained a temperature of 45 °C and 44 °C with Gum Arabic in 2 minutes respectively from an initial temperature of 25 °C at 0 minutes. This can be attributed to the fact that starch contains less viscosity than Arabic gum, thus, burns faster than the Arabic gum (Aransiola *et al.*, 2019). Thereafter, the temperature continues to rise until the water boils at 12 minutes, this shows that it takes corncob briquette 12 minutes to boil 1 litre of water. For the coconut shell briquettes, it also attained a temperature of 54 °C in 2 minutes for starch binder and 50 °C for gum Arabic respectively, showing that it takes coconut shell briquette 10 minutes to boil 1 litre of water. The Shatter indices were evaluated to determine the hardness of briquettes. The briquette with known weight and length was dropped on the RCC floor and concrete floor from the height of one

meter (Tembe *et al.*, 2014). While the resistance to water penetration is a measure of the percentage of water absorbed by a briquette when immersed in water. Each briquette was immersed in 25 mL of water at 27°C for 30 seconds. Table 3 shows the shatter indices and percentage of water penetration for both briquettes. The corncob briquettes have to shatter indices of 66.49% with gum Arabic and 92.01% with starch while coconut shell with starch has 74.08% with gum Arabic and 87.21% with starch respectively, showing that the coconut shell briquettes have higher shatter resistance than the corncob briquettes. Furthermore, High water resistance is a desirable quality that enables briquettes to remain impermeable to water for a long period before losing their shape (Jitthep and Akarawit, 2013). The resistance to water penetration of each of the samples shows that briquette with coconut shell has more water penetration resistance with both binders than corncob briquette.

Table 2: Water Boiling Test for Corncobs and Coconut Shell

Time (min)	Temperature (°C)		Temperature (°C)	
	Corncob		Coconut) Shell	
	Starch	Gum Arabic	Starch	Gum Arabic
0	25	25	25	25
2	45	44	54	50
4	55	53	67	60
6	70	67	80	77
8	82	80	39	90
10	95	91	100	100
12	100	100	-	-

Table 3: Resistance to Water Penetration and Shatter Indices

Briquettes	Binder	Resistance to water penetration (%)	Shatter indices
Corncobs	Starch	55.68	66.49
	Gum Arabic	67.31	92.01
Coconutshell	Starch	90.92	74.80
	Gum Arabic	91.32	87.21

Table 4 shows the heat capacity and Calorific value of the briquettes. The calorific value was determined using a bomb calorimeter. Calorific value is one of the most important characteristics of a fuel which measures the heat or energy released during complete combustion. The result reveals a heat capacity of 0.31 kJ/K and 0.32kJ/K for corncobs with starch and gum Arabic while coconut shell briquettes have 0.98kJ/K and 1.11kJ/K for starch and gum Arabic respectively. The higher calorific value of coconut shell with Gum Arabic implies that the energy in coconut shell particles was higher when compared to corncob, hence, better combustion characteristics (Ilochi, 2010).

Table 4: Heat capacity and Calorific value

Briquettes	Binder	Heat Capacity (kJ/K)	Calorific value (Kcal/kg)
Corncobs	Starch	0.31	24.22-25.60
	Gum Arabic	0.32	23.59-25.59
Coconutshell	Starch	0.98	23.94-25.74
	Gum Arabic	1.11	24.04-25.99

CONCLUSION

The comparative study between the performance of Corncobs and Coconut shell briquettes as solid fuel as well as the effect of binder was investigated. Coconut shell reveals a lower moisture content with both binders compared to corncob. And as for the binders, it is noticed that briquettes with starch binder produce less ash content than the other binder. In addition, coconut shell briquette took 10 minutes to boil 1 litre of water, this is because the coconut shell briquette is

more well compacted and burns at a constant rate than the corncobs briquette. The resistance to water penetration of each of the samples shows that briquette with coconut shell has more water penetration resistance than corncobs. Briquette with starch as a binder has the least water penetration resistance compared to gum Arabic. Therefore, it is seen that in terms of the time factor, coconut shell briquette is better compared to corncobs briquette and also, the rate at which

coconut shell briquette is consumed by the flame produced is slower compared to that of corncobs briquette. It is also noticed that briquettes with gum Arabic as binder appeared to be stronger than

that of the other binder (starch). Therefore, in terms of usage it is better to use the briquettes of coconut shell with gum Arabic as binder than the briquettes of corncobs.

REFERENCES

- Adekoya, L. O. (1989). Investigation into the briquetting of sawdust. *The Nigerian Engineer*, 24(3), 1-10.
- Agarry, S. E., Aremu, M. O., & Aworanti, O. A. (2013). Kinetic modelling and half-life study on enhanced soil bioremediation of bonny light crude oil amended with crop and animal-derived organic wastes. *J Pet environ biotechnol*, 4(02), 137.
- Ajimotokan H.A., Ehindero A.O., Ajao K.S., Adeleke A.A., Ikubanni P.P., Shuaib-Babata Y.L (2019). Combustion characteristics of fuel briquettes made from charcoal particles and sawdust agglomerates, *Scientific African* 6 (2019) e00202
- Aransiola, E. F., Oyewusi, T. F., Osunbitan, J. A., & Ogunjimi, L. A. O. (2019). Effect of binder type, binder concentration and compacting pressure on some physical properties of carbonized corncob briquette. *Energy reports*, 5, 909-918.
- ASTM Committee D-5 on Coal and Coke. (2009). *Standard test methods for proximate analysis of the analysis sample of coal and coke by instrumental procedures*. ASTM International.
- Babagana Gutti, Mohammed M. Aji and Garba Magaji (2012). Environmental impact of natural resources exploitation in Nigeria and the way forward. *Journal of Applied Technology in Environmental Sanitation*. Vol. 2, No. 2, 95 – 102
- Bhattacharya., S.C. And Salam P.A, (2002). "Low Greenhouse Gas Biomass Options for Cooking in The Developing Countries, Biomass and Bio-Energy", Vol. 22, Pp. 305-317.
- Bintu Grema Mustafa, Mohammed M. Aji, Ali L. Yaumi, B.K.Highina And Sani I. Sulaiman, (2014). Comparative studies of the combustion performance of Briquettes produced from selected biomass residues in Maiduguri. *World Journal of Sciences and Engineering*, Vol 1, No. 1, December 2014, pp. 1-8.
- Bhattacharya, S.C., Leon, M.A. and Rahman, M.M., (2002), "A study on improved biomass briquetting" energy for sustainable development vol. 2 pp. 106 - 110.
- Chaney, J.O., Clifford, M.J, and Wilson, R. 2009."An Experimental Study of the Combustion Characteristics of Low-Density Biomass Briquettes". Nottingham, Uk
- Chaney, J. (2010), "Combustion characteristics of biomass briquette" fuel processing technology, progress in energy and combustion science, Vol. 30 (2), 219–230.
- Demirbas, A., & Sahin-Demirbas, A. Y. S. E. (2004). Briquetting properties of biomass waste materials. *Energy Sources*, 26(1), 83-91.
- Ghorpade, S; Moule, A.P. (2006). Performance Evaluation of Deoiled Cashew Shell waste

- for fuel properties in Briquetted form. B. Tech. Thesis (unpub.), Dapoli 15.
- Ilochi, N. O. (2010). Comparative Analysis of Coal Briquette Blends with Groundnut Shell and Maize Cob. *Eng Thesis, Dept of Pure and Industrial Chemistry, Nnamdi Azikwe University, Awka, Nigeria.*
- Islam Md. Hamidul, Mosharraf Md. Hossain and Md. Abdul Momin (2014). Development of Briquette from Coir Dust and Rice Husk Blend: An Alternative Energy Source, *Int. Journal of Renewable Energy Development (IJRED)* 3 (2) 2014: 119-123
- Jitthep P., Akarawit M.,(2013). Properties of Solid Fuel Briquettes Produced from Rejected Material of Municipal Waste Composting, *Procedia Environmental Sciences*, Volume 17, Pages 603-610,
- Koppejan, J., & Van Loo, S. (Eds.). (2012). *The handbook of biomass combustion and co-firing*. Routledge.
- Mardoyan, A., & Braun, P. (2015). Analysis of Czech subsidies for solid biofuels. *International Journal of Green Energy*, 12(4), 405-408.
- Mbamala, E. C. (2019). Burning rate and water boiling tests for differently composed palm kernel shell briquettes. *engineering*, 2(1), 22-27.
- Muazu, R. I., & Stegemann, J. A. (2015). Effects of operating variables on durability of fuel briquettes from rice husks and corn cobs. *Fuel processing technology*, 133, 137-145.
- Standard, A. S. T. M. (2011). Test method for volatile matter in the analysis sample of coal and coke
- Tembe, E.T., Otache, P.O. and Ekhuemelo, D.O (2014). Density, shatter index and combustion properties of briquettes produced from groundnut shells, rice husks and saw dust of *Daniellia oliveri*, *ournal of Applied Biosciences* 82:7372 – 7378
- Yuliah, Y., Kartawidjaja, M., Suryaningsih, S., & Ulfi, K. (2017, May). Fabrication and characterization of rice husk and coconut shell charcoal based bio-briquettes as alternative energy source. In *IOP Conference Series: Earth and environmental science* (Vol. 65, No. 1, p. 012021). IOP Publishing.