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EVALUATION OF RICE HUSK-GROUNDNUT SHELL BIO-BRIQUETTE AS AN ALTERNATIVE FUEL FOR DOMESTIC COOKING IN NIGERIA

[1](**Bori, Ige**, *Department of Mechanical Engineering, Federal University of Technology Minna, Niger State*)
[2](**Muhammad, A.B.**, *Department of Mechanical Engineering, University of Maiduguri, Borno State*)
Corresponding Author: abms4real@gmail.com
[3](**Maina, M.B.**, *Department of Mechanical Engineering, University of Maiduguri, Borno State*)
[4](**Iyodo, H.M.,** Department of Chemical Engineering, University of Maiduguri, Borno state)

ABSTRACT : *This research work involves the evaluation of biomass briquettes produced from the blends of rice husk and groundnut shell as feed stocks and gum Arabic as a binder. Five briquettes of different compositions of groundnut shell/rice husk where produced and evaluated in this research. The moisture content, ash content, volatile matter, fixed carbon, compressive strength, afterglow time, flame propagation time, heating value and water boiling test were investigated to determine the physic-thermal properties of the briquettes produced. The results of the investigation showed that moisture content of the briquettes ranged from 3.96 – 5.63%, the heating value ranges from 130, 62.2 – 141, 62.56 kJ/kg, the compressive strength also ranges from 5.63-10.2 kN/m2, the range of ash content is 6.10 - 9.32 %, for fixed carbon is 7.67 - 20.2 %, the after afterglow time ranges from 238-271 sec and the range for water boiling test time is 10m, 34s – 13m, .22s. These values satisfactorily compares well with values obtained by other researchers in the literature. Therefore, the groundnut shell-rice husk briquettes are good alternative source of thermal energy for cooking. It is an economical and also an environmental friendly source of energy and waste disposal.*

KEYWORDS*: groundnut shell, rice husk, gum Arabic and briquette*

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I. INTRODUCTION

Nigeria is a developing country with an insufficient supply of energy to meet the continuously growing demand (Jekayinfa et al., 2020). The household cooking sector in Nigeria is the largest consumer of energy (Kpalo and Zainuddin, 2020). The ever decreasing availability of domestic cooking fuels such as woods and charcoals as well as the ever-rising prices of other sources of cooking energy such as kerosene and cooking gas in Nigeria has became an issue of great concern. Akinbami, (2001) reported that woodfuels and charcoal has been the major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption. The demand and the rate at which wood based fuels are used in Nigeria are increasing geometrically at an alarming rate, while their supply is diminishing due to non availability as a result of deforestation.

Armed conflict in some parts of the country has driven millions from their homes and poor energy access has exposed vulnerable people to a number of challenges linked to food insecurity and malnutrition (e.g. insufficient fuel to cook food), deforestation (e.g. unsustainable felling of trees for fuel), protection risks (e.g. harassment, assault, physical and sexual violence when collecting wood fuel) (FAO, 2019). Energy availability in the rural as well as urban areas of Nigeria is fast becoming a great challenge with the high cost of cooking gas and kerosene as well as environmental problems associated with firewood (Tembe, et al., 2014). Therefore, in response to these, there is the need to consider alternative sources that are renewable and accessible to low income earners in the society for domestic utilizations.

Nigeria with a population size of over 193.3m people (National Bureau of Statistics, NBS, 2018) and a total land mass of 923, 768 sq. km with about 730,885 sq. km of arable land, agriculture has remained a major preoccupation and major economic activity of the people in the rural areas (Mohammed et al., 2019). Agricultural biomass residues are sources of renewable and sustainable biofuels, which can contribute significantly to mitigate the effect of greenhouse gas (GHG) emissions if properly managed and utilized (Akpenpuun et al., 2020). Large quantities of agricultural and forestry residues are produced annually in rural areas of Nigeria and vast of these residues are under-utilized or burnt with all the ecological problems associated with their disposal methods (Olorunnisola, 2007, Jekayinfa and Omisakin, 2005 and Tembe et al., 2014). An estimation of the technical energy potential of the biomass resources revealed that about 2.33 EJ could be generated from the available resources in Nigeria (Jekayinfa et al., 2020). These residues have poor performance characteristics such as low heating values and bulky in transportation and storage, however, studies have shown that such residues can be processed and upgraded into more useful fuel products such as briquettes similar to wood or charcoal (Olorunnisola, 2007 and Bello, 2021). According to a report by Olaoye and Kudabo (2017) agricultural residues such as straws, tree leaves, maize husks, grass, rice ground nut shells, banana leaves and sawdust can be used for briquette production, though some materials have better calorific value than others, the selection of feedstock is usually dependent on what is readily available. Jekayinfa et al. (2020) suggested that the agricultural sector needs to be developed to generate more biomass resources, more research, development, and implementation have to be carried out on biomass resources and bioenergy generation processes. This work aimed at evaluating rice husk-groundnut shell hybrid briquettes as an alternative fuel for domestic cooking in Nigeria. Briquettes can be made out of any biomass material, although the choice of feedstock can determine its heating potential as a fuel (Ferguson, 2012). Depending on the material, the pressure and the speed of compaction, additional binders such as starch or clay soil, starch and or gum Arabic may also be needed to bind the matter together (Pallavi et el, 2013).

II. MATERIALS AND METHODS

A. RAW MATERIALS PREPARATION AND BRIQUETTE PRODUCTION

The agricultural residues used in this research are groundnut shells (Plate 1) and rice husk (Plate 2) obtained as residues from the processing sites at Sabon Tasha and Yarimaram areas respectively in Potiskum Local Government Area of Yobe State. These residues were chosen based on their abundance and availability as agricultural residues that became nuisance to the environment. The residues were milled separately and sieved using a 2 mm sieve to take out the oversized particles. A gum Arabic (Plate 3) bought from Maiduguri Monday market in Borno State was dissolved in water, stirred properly to form a gel (Plate 4) and was used as a binder.

Plate 1: Groundnut shell

Plate 2: Rice husk

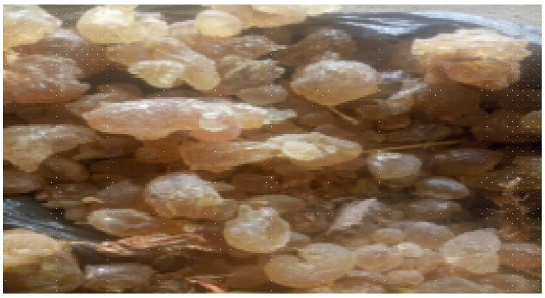

Plate 3: Gum Arabic (Binder) **Plate 4: Dissolved gum Arabic in water**

The individual residues were mixed thoroughly in a ratio of rice husk: groundnut shell as follows: 100:0; 75:25; 50:50; 75:25 and 100:0. Thereafter the residues were thoroughly mixed with 5% by weight of gum Arabic used as binder. A fixed quantity of each mixture was separately hand-fed into a manually operated mould to compact the briquettes using compaction pressure of 19.2 MPa and compression dwell time of 60 seconds. Thereafter, the briquettes were ejected and placed on drying racks and left in the sun for drying.

B. Physical Properties Determination

For physical properties evaluation, the compressed density, relaxed density and moisture content of four randomly selected briquette samples were determined. The compressed density of the briquettes was determined immediately after removal from the mould as a ratio of measured weight to calculated volume (Olorunnisola, 2007). For relaxed density determination, the sampled briquettes were air dried to constant weight and dimension. The relaxed density which is the density obtained after the briquette has remained stable in air dried condition was then evaluated as the ratio of the air-dry weight to air-dry volume of the briquette. The moisture content was determined after oven dried to constant weight at 105^0C using equation 1 (ASTM Standard D2016-77 (1989).

a) Determination of the briquettes densities

The mean compressed density of the briquettes was determined immediately after removal from the mould as a ratio of measured weight to calculated volume (Olorunnisola, 2007). The weights of produced briquettes were determined using a digital weighing balance, while the average diameters and heights of the briquettes were taken at 2 different positions using calipers to determine the volume. The volume of the briquettes was determined by subtracting the outer volume from the inner volume to obtain the actual volume of the briquettes. The compressed and relaxed densities of the briquettes were determined at 0 minutes, 30 minutes, 1 hour, 24 hours and 7 days using the die dimensions and ASTM, (2004) standard method of determining densities. Density was determined for each briquette as ratio of briquette weight to volume. 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 (Oladeji and Lucas, 2014). Equations (1) and (2) were used to determine the briquette's volume and density.

$$volumeofbriquette = \frac{\pi}{4}\left(d_2^2 - d_1^2\right)L \qquad (1)$$

d_1 diameter of the briquette before drying (m)
d_2 diameter of the briquette after drying (m)
L length of the briquette

$$Density\ of Briquette = \frac{weightofbriquette}{volumeofbriquette} \qquad (2)$$

Density ratio was calculated as the ratio of relaxed density to maximum density (Oladeji, 2012). The relaxation and compressed ratios of the briquettes were determined in accordance with the American Society of Agricultural and Biological Engineering (ASABE, S269.4.2003). Relaxation ratio was calculated as the ratio of compressed density to relaxed density as reported by (Akpenpuun, 2020). The relaxation and compaction ratios were determined and calculated using equations (3) and (4) as reported by (Oladeji and Lucas, 2014).

$$Relaxation\ ratio = \frac{compressed\ density}{relaxation\ density} \quad (3)$$

$$Compaction\ Ratio = \frac{Compressed\ density}{bulkdensity} \quad (4)$$

b) Determination of compressive strength and Density ratio

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) and Equation (5) was used to calculated the density ratio

$$\text{Density ratio} = \frac{\text{relaxed density}}{\text{compressed density}} \quad (5)$$

C. Determination of the Thermal Properties

a) The flame propagation rates

The flame propagation rates of the 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 a laboratory environment until the fire extinguished itself. The flame propagation rate was estimated by dividing the distance burnt by the time taken in seconds.

b) The afterglow time

The afterglow time was evaluated and determined. 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 in line with Musa, (2007).

c) Heating value

The heating values of the briquette samples were also examined in accordance with ASTM E-711-87 (2004) using Parr isoperibol bomb calorimeter.

d) The moisture contents

The moisture content of the briquettes were determined using Equation (6) as reported by Ikelle et al, (2020)

$$\%\ \text{Moisture content} = \frac{w1-w2}{w1} \times 100 \quad (6)$$

d) Determination of ash content

The Ash content was determined according to Oyelaran, (2015) where 1 gram of each sample was measured into known weighted ash tray with lid. The sample was then placed into a high temperature carborlite furnace already set at 825^{0}C and heated for 1 hour. Then, the ash tray is taken out from the furnace and it is cooled in the desiccators to room temperature and final weights were recorded. The ash content was calculated as in Equation (7) (Oyelaran et al, 2015).

$$\text{Ash Content, }\% = \frac{Wf}{Wi} \quad (7)$$

e) Volatile matter determination

The dried samples of the briquettes left in the crucibles were covered with a lid and placed in an electric furnace maintained at 925^{o}C for seven minutes. The crucibles were first cooled in air, then inside desiccators and weighed again. Losses in weights were reported as volatile matter on percentage basis, the value of the volatile matter was determined using Equation (8) (Awulu et al., 2015)

$$VM\ \% = \frac{w2-w1}{w2-w3} \times 100 \quad (8)$$

f) Determination of fixed carbon

The fixed carbon of the briquettes produced were determined using Equation (9) as reported by Akpenpuun et al. (2020)

Fixed Carbon (%) = 100 – (% VM + % ash content+ % moisture content) (9)

g) Boiling water analysis

The burning quality of the briquettes was determined by using 200g of the briquettes to boil 1 litre of water in a 1.5 litre aluminium pot. The time taken for the water to boil was noted; the colour of the flame and the smoke were also observed. After the water had boiled, the remaining (un-burnt) briquettes weights were measured as reported by (Ajiboye et al., 2016).

III. RESULTS AND DISCUSSIONS

The results of the investigation showing the Physico-thermal properties of the briquette blends are presented in Table 1. Ash is an impurity that will not burn and is typically in the range of 5% to 40% (Shuaibu et al., 2016). The results showed that as the amount of groundnut shell was increased, the ash content increases in the blend in the range of (6.10 - 9.32 %). Ikelle et al. (2020) reported that the higher the fuel's ash content, the lower the heating value, the heating values of the briquettes ranges from 130,62.2 – 141,62.56 kJ/kg. The briquette with 100% groundnut shell has the least heating value of 13062.2kJ/kg while the briquette with 100% rice husk has higher heating value of 141, 62.56kJ/kg. However, this heating values match up satisfactorily with the heating values of cowpea (14,372.93KJ/Kg) and soybeans (12,953KJ/Kg) as reported by Emerchi, (2011) and groundnut shell 13,631.60 - 21,162.59KJ/Kg as reported by Shuaibu et al. (2016). In addition, Oyelaran et al. (2015) reported that this heating value is sufficient enough to produce heat required for household cooking applications. The values of the moisture content also compares well with most biomass energy. For examples cowpea-14,372.93 kJ/kg, soy-beans-12,953 kJ/kg, (Enweremadu, et al., 2004) and groundnut shell briquette 12,600 kJ/kg, (Musa, (2007).

Ikelle et al. (2017) reported that the fixed carbon of a fuel is the percentage of carbon available for char formation during combustion. The Table 1 showed that the hybrid briquettes produces from the blends of rice husk and groundnut shell resulted in producing briquettes with less fixed carbon content values ranging from 7.67 to 20.2 % and these findings compares favourably with the findings of Ikelle et al. (2020) with 16.77 % for a groundnut shell briquette and 9.1 - 19.68 % for rice husk, sawdust and paper blend briquettes and groundnut shell, sawdust and paper blend briquettes by Akpenpuun, et al. (2020).

Moisture content is another important factor for predicting ignition behaviour as well as the durability of a briquette. As depicted in Table 1, the feed stock used, binder and their interactions haves effects on moisture content of the briquettes. The moisture content of the briquettes ranged from 3.96 – 5.63% with average of 3.96% in 100%RH briquette, 3.80% in 25%GS:75%RH briquette, 4.60% in 50%GS:50%RH briquette, 5.41% in 100%GS:0%RH briquette and 5.63% in 75%GS:25%RH briquette. The moisture content range of the briquettes produced from the three biomass materials was quite encouraging and compared well with average range of 2.43 - 6.44% recorded for coal dust and groundnut husk (Ikelle, 2020), 2.50 – 6.76% for sawdust briquette from Neem wood (Sotannde *et al*., 2010) and 7.50 - 8.00% for some selected herbaceous plants (Onuegbu *et al.*, 2012). The low moisture content of the briquettes is expected to influence the durability and lower the energy required for water evaporation during combustion.

Onuegbu *et al. (*2010) reported that the compressive strength of a briquette is one of the indicators used to measure its capability to be handled and transported without being damaged (broken). The values of the compressive strength obtained in this research ranges from 5.63-1.02 kN/m^2. The pattern of the result showed that as the percentage composition of the groundnut shell reduces, so also the value of compressive strength reduces. This is most likely due to the nature of feedstock with fibre content which facilitates to bind the briquette together.

Table 1: Proximate Analyses of Rice husk-groundnut shell Briquettes

Sample	Ash content (%)	Volatile matter (%)	Fixed carbon (%)	Moisture content (%)	Compressive strength (kN/m^2)
100%GS	9.32	74.26	11.01	5.41	5.63
75%GS:25%RH	7.61	78.08	8.68	5.63	3.99
50%GS:50%RH	7.60	80.13	7.67	4.60	2.07
25%GS:70%RH	6.21	72.22	17.77	3.80	2.46
100%RH	6.10	69.74	20.2	3.96	1.02

Briquette with 100%RH recorded a highest flame propagation time of 0.11 cm/sec, this is may be due to its low moisture content of 4% and high heating value of 14162.56 Kj/kg, while the briquettes from other mixing ratios recorded an average value of flame propagation time of about 0.08 cm/sec. In addition, Table 2 shows that the briquette with 25%GS:75%RH has the longest afterglow time of 271 sec, followed by briquette with mixing ration of 50%GS:50%RH with an afterglow time of 267 sec while briquette 75%GS:25%RH has the least afterglow time of 238 sec. The afterglow time and the flame propagation values are good enough and have the implication of that the briquettes will be ignited more easily and burn with intensity for a long time (Ajiboye, 2016).

Table 2: Combustion characteristics of the Rice husk-groundnut shell Briquettes

Sample	Heating value (kJ/kg)	After glow time (s)	Flame propagation rate (cm/s)	Water boiling test (min)
100%GS	13062.2	246	0.08	12m, 57s
75%GS:25%RH	13147.26	238	0.08	13m, 22s
50%GS:50%RH	13483.73	267	0.09	11m, 46s
25%GS:70%RH	13891.34	271	0.08	11m, 14s
100%RH	14162.56	243	0.11	10m, 34s

Densification of biomass can address handling, transportation, and storage problems and also lend itself to an automated loading and unloading of transport vehicles and storage systems (Karunanithy et al., 2012). All the briquettes showed promising values of compressed and relaxed densities as contained in Fig.1, but 50%GS:50%RH briquette has the highest values of 3387.56kg/m^3, 1573.32kg/m^3 and 2.15 for compressed density, relaxed density and relaxation ratio respectively. The density obtained for the produced briquettes in this work compares well with densities of notable biomass fuels such as coconut husk briquette - 630 kg/m3, banana peel - 600 kg/m3, groundnut shell briquette - 524 kg/m3 and melon shell briquette - 561 kg/m3 (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 were 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.

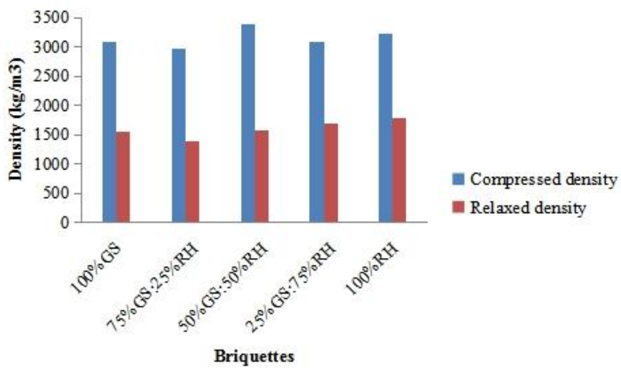

Fig.1. Densities of briquettes

IV. CONCLUSION AND RECOMMENDATIONS

This research work dwells on the evaluation of bio-briquettes produced from blending groundnut shell and rice husk. The research therefore tries to offer solution to the problems of cooking fuels for domestic applications and problems associated with open disposal and burning of groundnut shell and rice husk as wastes after harvest. The produced briquettes ignited faster and generated sufficient heat for cooking. The briquettes can be transported and stored easily. The briquetting process is economical, cheap and affordable to the rural dwellers and low income earners. The briquetting technology has a great capability of converting agricultural residues into fuel for household use in an affordable, efficient and environment friendly manner. The research concluded that briquettes produced from groundnut shell and rice husk would make good biomass energy. The research recommends that further researches be conducted on how to improve the efficiencies of briquettes produced from agricultural residues.

REFERENCES

Akinbami, J.F.K. (2001). Renewable Energy Resources and Technologies in Nigeria: present situation, future prospects and policy framework. Mitigation and Adaptation Strategies for Global Change 6:155-181

Akpenpuun, TD; Salau, RA; Adebayo, AO; Adebayo, OM; Salawu J; & Durotoye, M (2020). Physical and Combustible Properties of Briquettes Produced from a Combination of Groundnut Shell, Rice Husk, Sawdust and Wastepaper using Starch as a Binder. J. Appl. Sci. Environ. Manage. Vol. 24 (1) 171-177

Awulu, J. O., Audu, J., & Ijabo, O. J. (2015). Effects of Briquettes and Binders on Combustible Properties of Selected Biodegradable Materials. Asian Academic Research Journal of Multidisciplinary, 2(3), 1 - 11.

Ajiboye, T.K, Abdulkareem, S, Anibijuwon, A. O. Y. (2016). Investigation of Mechanical Properties of Briquette Product of Sawdust-charcoal as a Potential Domestic Energy Source J. Appl. Sci. Environ. Manage, 20(4) 1179-1188

Emerchi, E. A. (2011). “Physical and Combustion Properties of Briquettes from Sawdust of Three Hardwood Species and Different Organic Binders”. Adv. APPl. Sci. Res. 2(6): 236-246.

Enweremadu, C.C., Ojediran, J.O., Oladeji, J.T. & Afolabi, L.O. (2004). Evaluation of energy potentials in husk from soybean and cowpea. *Science Focus* 8: 18-23.

Ferguson, H. (2012). Briquette Businesses in Uganda. The potential of briquette enterprises to address the sustainability of Ugandan biomass fuel market. GVEP International 73 Wicklow Street, London, UK

Ikelle, I.I, Sundaya, N.J., Sundayb, N.F., Johnb, J., Okechukwu, O.J., & Elom, N.I. (2020). Thermal Analyses of Briquette Fuels Produced from Coal Dust and Groundnut Husk, Acta Chemica Malaysia (ACMY), 4(1)24:27, *DOI: 10.2478/acmy-2020-0004*

Jekayinfa, S.& Omisakin, O. (2005). The energy potentials of some agricultural wastes as local fuel materials in Nigeria”. Agricultural Engineering International: the CIGR Ejournal. Vol. VII., EE 05 003.

Jekayinfa, S.O., Orisaleye, J.I., and Pecenka R., (2020) An Assessment of Potential Resources for Biomass Energy in Nigeria, Resources 9(92)1:41; doi:10.3390/resources9080092

Karunanithy, C., Wang, Y., Muthukumarappan, K., & Pugalendhi, S., (2012). Physiochemical Characterization of Briquettes Made from Different Feedstocks Hindawi Publishing Corporation Biotechnology Research International Volume 2012, Article ID 165202, doi:10.1155/2012/165202

Kpalo, S. Y. & Zainuddin, M. F. (2020). Briquettes from agricultural residues; an alternative clean and sustainable fuel for domestic cooking in Nasarawa State, Nigeria. Energy and Power, 10(2): 40-47 DOI: 10.5923/j.ep.20201002.03

Mohammed, I. S., Othman, M. F., & Osman, N. B. (2019). Nigerian National Population and Housing Census and Sustainable Development: Issues at Stake. Journal of Techno Social 11(1): 16-28

Musa, N.A. (2007). Comparative Fuel Characterization of Rice husk and Groundnut shell Briquettes”. NJRED.

6(2):23-26.

Oyelaran, O. A., Bolaji, B. O., Waheed M. A., & Adekunle, M. F. (2015). Characterization of Briquettes Produced from Groundnut Shell and Waste Paper Admixture. Iranica Journal of Energy and Environment, 6 (1): 34-38.

Oladeji, J. T., & Lucas E.B. (2014). Densification and Fuel Characteristics of Briquettes produced from Corncob. Rep Opinion; 6(7):71-76]. (ISSN: 1553-9873

Oladeji, J.T. (2012). Comparative Study of Briquetting of Few Selected Agro-Residues Commonly Found in Nigeria. Pacific Journal of Science and Technology. 13(2):80-86.

Olorunnisola, A., (2004). Briquetting of rattan furniture waste. Journal of Bamboo and Rattan, 3(2): 139-149.

Olorunnisola, A.O. (2007). Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixture. American Journal of Applied Sciences. 5(12):1808-1811.

Olaoye, J. O., & Kudabo, E. A. (2017). Evaluation of Constitutive Conditions for Production of Sorghum Stovers Briquette. Arid Zone Journal of Engineering, Technology and Environment, 13(3), 400 – 412

Pallavi, H.V; Srikantaswamy, S.; Kiran B.M., Vyshnavi, D. R. & Ashwin, C.A. (2013). Briquetting agricultural waste as an energy source. Journal of Environmental Science, Computer Science and Engineering & Technology, JECET, Vol.2.No.1, 160-172

Shuaibu, N., Dandakouta, H. & Bello, A. A. (2016). Evaluating groundnut shell briquettes as high grade fuels for domestic cooking; part 2: modeling the effect of processing parameters on the combustion characteristics of the briquettes International Journal of Engineering and Modern Technology , 2(1):1-7

Sotannde, O. A., Oluwadare, A. O., Ezekiel. S., & Anguruwa, G. T. (2017). Influence of production variables on eco-friendly briquettes from coconut and bambara nut shells. *Arid Zone Journal of Engineering, Technology and Environment, 13(4):489-501*

Tembe, E.T., Otache, P.O. & Ekhuemelo, D.O. (2014) Density, Shatter index, and Combustion properties of briquettes produced from groundnut shells, rice husks and saw dust of Danielliaoliveri. Journal of Applied Biosciences, 82:7372 – 7378. http://dx.doi.org/10.4314/jab.v82i1.7

Onuegbu, T. U. (2010). Improving Fuel Wood Efficiency in Rural Nigeria: (A Case of Briquette Technology).International Journal of Chemistry in Nigeria. Vol. 3 (4) Pp. 35-39.

Onuegbu, TU., Ogbu, IM. & Ejikeme, C. (2012). Comparative Analyses of Densities and Calorific Values of Wood and Briquettes Samples Prepared at Moderate Pressure and Ambient Temperature. International Journal of Plant, Animal and Environmental Sciences. 2(1): 40-45.

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

Nomenclature

Cv	Heating value of the fuel (residue) (kJ/kg)
d_1	Diameter of the briquette before drying (m)
d_2	Diameter of the briquette after drying (m)
FC	Fixed carbon (%)
GS	Groundnut shell
RH	Rice husk
W_1	weight of empty crucible, (g)
W_2	weight of crucible + sample, (g)
W_3	weight of crucible + sample after heating, (g)
FC	fixed carbon (%)
VM	volatile matter (%)

