**PHYSICO-MECHANICAL AND COMBUSTION ANALYSIS OF BRIQUETTES PRODUCED FROM BAMBARANUT SHELL.**

**Ikelle Issie Ikelle1, Eze Nkechinyere Olivia2 and Esonye Chibuzoo3**

**1Department of Chemistry, Nigeria Maritime University, Okerenkoko Nigeria.**

**2Department of Industrial Chemistry, Ebonyi State University, Abakaliki, Nigeria.**

**3Department of Chemical Engineering, Alex Ekwueme Federal University Ndufu Alike, Nigeria.**

**Corresponding Author :** **iikelle@ymail.com**

**Abstract:**

 The work involved the usage of bambaranut shell to produce briquette fuel. The bambaranut shell was ground into powdery form which was compacted via screw press method at a pressure of 12.3kpa, and the binder used is starch to produce bio-coal briquettes. The bambaranut shell and bambaranut shell briquette was subjected to proximate analyses. The briquettes produced were tested to determine their combustible characteristics. The results showed that the bambaranut shell had the following results; moisture content (6.4 %), volatile matter content (73.31 %), ash content (4.25 %), fixed carbon (16.02 %) and with calorific value 18.90 MJ/kg. Furthermore, the proximate analysis of the briquettes showed the following results; moisture content 7.38%, fixed carbon content 15.71%, ash content 3.51%, volatile matter content 73.40%, and calorific value 22.10MJ/kg. The results of the mechanical properties of the briquettes produced yielded the following, relaxed density (0.950 g/cm3), porosity index (1.81), and durability (83 %) all after 7 days, while combustion characterics of the briquettes showed ignition time (18.05 secs), water boiling time (18.36 minutes), and burning time (33 mins). These characteristics exhibited in the combustion, mechanical and physical tests results of the bio-coal briquettes showed that bambaranut shell is a good option for production of briquettes.

**Key words**: Bambaranut, Briquette, Fuel, Starch.

**Introduction:**

 Nigerian economy is witnessing a new development trajectory and requires new sources of energy as energy consumption is on the increase. Nigerians over-dependence on oil and gas for her energy supply both for domestic and industrial purposes has been a problem for the long-while the only source of energy that is so far well developed. As a result of this, the demand for oil and gas is higher than its supply. The rise in political instability has caused drastic increases in the prices of oil and gas. As a result of the increases most residents of rural and sub-urban areas rely on fuel wood as their source of heating. The pressure on fuel wood as a source of energy has increased tremendously with attendant demand on wood that is tilting towards crisis point. The pressure does not seem to show signs of reduction in the nearest future as it is projected to rise to 2134000 kg as at 2030[1]. The use of wood as fuel source is attributable to such man-made disasters like deforestation that causes global warming, soil erosion, desertification, and in some cases, extinction of wild life [1]. As a result of the aforementioned reasons, there is need for another energy system in Nigeria.

 A lot of researches have been carried out on renewable sources of energy in other to find alternative to crude oil. The energy source that has become widely mentioned is briquettes. A briquette is a block of compressed coal, biomass or charcoal that is used as fuel [2]. Charcoal briquettes, biomass, coal and bio-coal have been used today to produce different ranges of briquettes. The compression of different amounts of pulverized coal, biomass materials, coal and biomass, and charcoal dust have resulted in the successful briquette production [3]. Countries like Japan and India have made tremendous progress in terms of briquetting technology but Nigeria is still lagging behind.

 The practice of Agriculture remains a major occupation of most Nigerians and Agricultural activities is known to generate wastes that are not properly disposed. These wastes can be reintegrated to produce biomass briquettes. Generally, all renewable organic materials that contain energy in a chemical form are regarded as biomass that can easily be converted to fuel by briquette formation. The term biomass refers to wastes from agricultural operations and food processing, forest residues, biological municipal solid wastes and others from plantations [4]. The bio-wastes can be reused to produce biomass briquettes. The briquetting of biomass is done when the pulverized bio-waste is compacted in the presence of pressure with or without the aid of a binder. Briquetting is a process of densifying pulverized materials by applying pressure with or without a binder. The conversion of agricultural wastes to briquettes have numerous advantages that includes [5]

1. With regards to movement of agricultural wastes the act of briquetting has provided a suitable means of conversion of these wastes into suitable energy sources for cooking.
2. The gases they produce during usage does not pose much threat to the environmental.
3. In most cases the raw materials used for the production of the briquettes are sourced from disposed biomass wastes such that the whole process is a bio-waste to energy conversion procedure.
4. The briquettes find usage in boilers and stoves.
5. They increase strength, density, heat emitted per volume of the biomass.

 Briquettes have been produced using bio-wastes of rice husks [6], maize cobs [7], grasses [8] and residues of cotton plants [9]. There are some reasons why biomass wastes are of great interest in briquette materials because of related miscellaneous advantages such as abundance, low price, and very high worldwide potential. Bambaranut shells have proved satisfactory in briquette production. Bambaranut *(Vigna subterranean*) is among the most commonly eaten legume that includes groundnut and cowpea in Nigeria [10], as a result of its rich content of protein and energy. It has helped to solve the problem of poor dietary in humans and livestock [11]. The annual world production is 330,000 tonnes, 45-50% of which are produced in West Africa (Nigeria, Ghana, Niger, Burkina Faso) [11]. In Nigeria, it is mostly grown in the north. The seeds can be cooked, roasted and chewed, or milled into flour and used to prepare a steamed gel known as *Okpa* by people in the urban and rural areas of eastern part of Nigeria. Gurujia a popular snacks in the northern part of the country is prepared from bambaranut. In Nigeria, large quantities of agro-wastes are produced in the processing line of bambaranut and are discarded indiscriminately as agricultural waste, which constitutes nuisance to the environment. It becomes imperative to state that beyond the conversion of the wastes into useful sources of fuel by briquetting, there is also the advantage of proper disposal of the wastes resulting in a healthy and clean environment.

**Research Objectives:**

 The research is geared towards the determination of some physico-combustion characteristics of briquettes produced using bambaranut shell. There is also the need to reduce the level of deforestation, find a way to reduce the impact of usage of wood fuel to the health of people cooking with fuel wood, and seek for effective agro-waste management has necessitated this work. The work is also an avenue to provide another source of energy and reduce the overdependence on fossil fuel.

**Materials and Methods:**

 The bambaranut shells were collected from various milling sites that pods were cracked in Abakaliki Metropolis. The shells were also sourced from different dumpsites where they were disposed off.



**Plate 1: Bambaranut shell.**

**Preparation of the Materials:**

The bambaranut shells were sundried to reduce their moisture content for two weeks. This is followed by pulverization using electrical milling machine and the pulverized material are sieved using a standard sieve to obtain materials of particle size ≤3mm in diameter. After sieving the pulverized material was stored in a polyethylene bag to prevent caking.

**Analysis of the bambaranut shell:**

 The proximate analyses of the pulverised bambaranut shell was carried out following the procedures of ASTM E711-87[12] and the calorific value determined using an Oxygen Bomb Calorimeter Bulk Model XRY-IA. The amount of sulphur content was analyzed according to procedures of [3].

**Production of the briquettes:**

 Briquette samples were produced using the pulverized bambaranut shells with a 20% by mass of cassava starch serving as the binder during the briquette production. The starch was extracted from raw cassava root which was peeled, washed, sundried and pulverized [5].

 A known quantity 100g of cassava flour was dissolved in 100ml of water to make a paste of it. To the cassava dissolved in water was added 400ml of boiling water, turned properly until a starchy gel is formed. The starch gel was poured into a big bowl, 500g of the pulverized bambaranut shell was added continuously followed by stiring to obtain a homogenous mixture. The homogenous mixture was added to the manual screw press, briquettes were produced at a pressure of 12.3kpa and dwell time of 2 mins. After the production the briquettes were dried in the sun for one week.

 

 **Plate 2: Bambaranut shell briquettes produced.**

**Characterization of the briquettes:**

**Proximate analysis:**

 The ASTM E711-87[12] procedures were employed in the determination of the proximate analyses of the briquettes. The calorific value was determined using an Oxygen Bomb Calorimeter Bulk Model XRY-IA

**Mechanical properties:**

 According to procedures in [11] the analysis of the briquettes compressed and relaxed densities were carried out. Using the Instron Machine, Model 2914 [13], the Compressive strength of the briquettes were determined. Porosity was determined and porosity index calculated as described by [14].Durability was determined in accordance with the chartered index described by [15].

**Combustion analysis:**

 The combustion analysis was carried out to determine the combustion properties of the briquette fuel. These includes the ignition time, burning time, water boiling time, specific fuel consumption, burning rate, and thermal efficiency of the briquette fuel was determined according to the procedures of [16-18].

**Results and discussion:**

**Table 1: Result of proximate analyses of bambaranut shell**  .

Moisture content (%) 6.42

Volatile matter content (%) 73.31

Ash content (%) 4.25

Fixed carbon content (%) 16.02

Calorific content (MJ/kg) 18.90

Sulphur content (%) 0.100 .

 According to table 1, the bambaranut shell possesses low moisture content of 6.42%, and ash content of 4.25%. The features are very indicative of biomass that are suitable for briquettes production [15]. With a high volatile matter content of 73.31% this implies faster ignitable property when used to produce briquettes [15]. The value for fixed carbon content is 16.02 %. The calorific value, 18MJ/kg is significantly high and comparable to other biomass materials suitable for briquette formation like *Pennisetum purpurem* grass with 14.66MJ/kg [3], cassava stalk with 16.39MJ/kg [19], rice husk with 13.2MJ/kg and maize stalk with 14.3MJ/kg as calorific values [20].

**Table 2: Physico-mechanical properties of the briquette .**

Moisture content (%) 7.38

Volatile mater (%) 73.40

Ash content (%) 3.51

Fixed carbon content (%) 15.71

Calorific value (MJ/kg) 22.71

Compressed density (0 mins) (g/cm3) 1.611

Relaxed density (30mins) (g/cm3) 1.597

Relaxed density (60mins) (g/cm3) 1.547

Relaxed density (1440mins) (g/cm3) 1.327

Relaxed density (10,080mins) (g/cm3) 0.950

Compressive strength (N/mm2) 3.19

Porosity index 1.81

Durability (%) 83

Ignition time (secs) 18.05

Burning rate (g/mins) 18.36

Specific fuel consumption (kg) 0.55

Thermal efficiency (%) 12.19 .

 According to table 2, the briquettes produced showed low moisture content of 7.38%, (<10%), indicating good combustibility property according to the report of Mills (1998) [21]. The briquette has low ash content of 3.51%, and significantly high calorific value of 22.10MJ/kg, the briquettes will generate less ash upon combustion [15]. With a high volatile matter content of 73.40%, this implies easy ignitability of the briquettes produced as reported by [22]. The ignition time of the briquettes formed is 18.05 secs.

 The briquette showed high durability of 83%, relaxed density (at 7 days) of 0.950g/cm3, and with compressive strength of 3.19 N/mm2. The implication is that the briquettes formed can be easily stored and transported from one place to another. The compressive strength of the briquette is comparable to those spear grass briquettes with 2.10N/mm2 [3] and *Pennisetum purpurem* briquettes with 3.50 N/mm2 [14]. The density result obtained is higher than that reported by [3], 0.319g/cm3 for *Pennisetum purpurem* briquettes, and [5], 1.65g/cm3 for palm kernel shell charcoal briquettes. With porosity index value of 1.81 signifying adequate porosity, there is higher tendency for air inflow into the briquette and helping in ensuring uniform combustion of the briquette. To avoid the issue of briquettes breaking into pieces during handling and movement, production of briquettes with high porosity index should be discouraged.

 The briquettes produced had ignition time of 18.05seconds, and was able to boil 500ml of water in 18.36 minutes. Although the value was below that of palm kernel shell charcoal briquettes a charcoal briquette, the bambaranut shell briquette is made from biomass. The specific fuel consumed is 0.55g, the value is similar to the work done by [14], 0.32g for spear grass briquettes. Thermal efficiency (12.19%) was higher than that reported by [5], 3.2% for palm kernel shell briquettes. The burning rate of 9.09g/minutes was also higher than 3.2g/minutes as reported by [5].

**Summary**

 In summary, the research showed a suitable and adjustable procedure for the production of briquettes using bambaranut shell. The knowledge gained from the research is of great importance with regards to the means of disposing bambaranut shell wastes. It was discovered that the briquettes produced was fast to ignite, produced significant heat during burning with fewer amount of ash during cooking. With regards to their non-fragile nature, the briquettes did not pose any danger in terms of movement and storing them. The briquetting technology exhibits great potential for conversion of waste biomass into a fuel for household use with an attendant affordability, efficient and environment friendly manner. The briquetting process is economical, cheap and affordable to the rural and low income urban dwellers. It is noteworthy to say that the use of bambaranut shell for briquette production goes a long way to increase financial status of the farmer’s income, thereby encouraging more production of briquettes with bambaranut shells. It will also create job opportunities. It is also imperative to advocate for the wider usage of briquettes in Nigeria due to the imminent wood shortage and scarcity of other energy sources.

**References:**

1. Emerhi, E.A, (2011), Physical and Combustion Properties of Briquettes Produced from Sawdust of Three Hardwood Species and Different Organic Binders, Advances in Applied Sciences Research, 2(6): 236-246.
2. Granger and Gibson, (1981), Coal Utilization Technology Economics and Policy, Graham and Trotman Limited, pp 3-7.
3. Onuegbu T.U., Ogbu I.M., Ilochi N.O., Okafor I., Obumselu F., and Ekpunobi U.F., (2010), Enhancing the Efficiency of Coal Briquette in Rural Nigeria Using *Pennisetum purerum*, Advances in Natural and Applied Science (3): 299-304.
4. United States. Agency for International Development (USAID), (2010), Biomass Briquetting in Sudan: A Feasibility Study Women’s Refugee Commission, www.scribol.com/doc/.../USAID.
5. Ugwu, K.E, and Agbo K.E., (2010), Briquetting of Palm Kernel Shell, Journal of Applied Science and Environment Management, 15(3):447-460
6. Ndiemia, C.K.W., Manga N.P., and Ruttoh, C.R., (2002), Influence of Die Pressure on Relaxation Characteristics of Briquetted Biomass, Energy Conversion. Manage, 43:2157-2161
7. Wilaipon, P (2007), Physical Characteristics of Maize Cob Briquette under Moderate Die Pressures A.M.J. Applied Science, 4: 995-998.
8. Finell, M., Nilsson, C., Olsson R., Agnemo, R., and Svensson S., (2002), Briquetting of Fractioned Reed Canary-Grass for Pulp Production, Ind Crops Prod. 16:185-192.
9. Coates W, (2002), Using Cotton Plant Residue to Produce Briquettes. Biomass Bioenergy, 18:201-208.
10. Onyimonyi, A.E., and Okeke, G.C., (2007), Assessment of the Practical Potential of Bambaranut (Voandzeia Subterranean Thourars) Wastes for Weaner Pigs, Pakistan J.Nutr., 6(3): 264-266
11. Tembe E.T., Adetogun A.C., and Agbidye, F.S., (2014), Density Briquettes Produced from Bambaranut Groundnut Shells and Binary And Its Tertiary Combination With Rice Husk And Peanut Shells, Journal of Natural Sciences Research 4(24): 21-25.
12. ASTM Standard E711-87, (2004), Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorific Calorimeter. Annual Book of ASTM Standard, ASTM International, http//www.astm.info/standard/E711.htm.
13. Standard Organization of Nigeria, (2010), Compressive Strength and Hardness of Briquette, pp 1-6.
14. Onuegbu T.U., Ogbu I.M., Ilochi N.O., Ekpunobi U.E., and Ogbuagu A.S., (2010), Enhancing the Properties of Coal Briquette Using Spear Grass (*Impereta cylindrical*), Leonard’s Journal of Science (17): 47-58.
15. Sotannde O.A, Oluyeye A.O, and Abah G.B., (2010), Physical And Combustion Properties of Charcoal Briquettes from Neem Wood Residues, Int. Agrophysics, (24): 189-194.
16. Davies R.M and Abolude D.S., (2013), Ignition and Burning Rate of Water Hyacinth Briquettes, Journal of Scientific Research and Report, 2(1): 111-120
17. Kuti, O.A., (2009), Performance of Composite Sawdust Briquetted Fuel in A Biomass Stove Under Simulated Condition, Department of Mechanical Engineering, University of Hiroshima, Japan, pp 284-288.
18. Birwatker, V.R., Khandetod, V.P, Mohod A.G., and Dhande K.G, (2014), Physical and Thermal Properties of Biomass Briquetted Fuel. Ind J. Sci Research and Technology, pp 55-62.
19. Wilaipon P, (2010), Density Equation of Cassava- Stalk Briquettes Under Moderate Die, American Journal of Applied Sciences, 7 (5): 698-701.
20. Garivait G., Chaiyo U., Patumsawad S., and Deakhuntod J., (2006), The 2nd Joint International Conference on “Sustainable Energy and Environment (SEE 2006)”, Bangkok, Thailand
21. Mills, J.E, (1998), Binders for Coal Briquettes, US Geological Survey, Bulletin 343, pp 5-59
22. Loo, S.V., and Koppejan J., (2008), The Handbook of Biomass Combustion And Co-firing Earthscan London, pp 7-11.