GRAIN SIZE EFFECTS OF PALM KERNEL BRIQUETTES ON CALORIFIC VALUE

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Abstract

The need to convert agricultural wastes to useful and viable source of alternative energy for domestic and industrial purposes has been very rife in recent developments. Energy sustainability, suitability and affordability is required for human socio-economic growth and development for better standard of living. This study focused on effect of two different particle sizes of fine and coarse particulate of palm kernel shell agricultural-waste materials for producing briquettes on its calorific value. The synthetic adhesive (glue) an impure form of gelatine was adopted as binding agent for homogenous compatibility of the palm kernel shell to form the desired briquette. The calorific values of the dried briquettes made from fine and coarse particle sizes were determined by proximate and ultimate analyses of the raw palm kernel shells. The results of the calorific value of the two different particle sizes showed that the briquette made from coarse particle has higher calorific value than fine particle briquette. The calorific value of briquette from coarse particle size was 17.997 MJ/kg and that of fine particle size briquette was 12.186 MJ/kg.

Keywords: briquette; grain size; palm kernel shell; calorific value; energy content; binding agent

Introduction

Turning waste to wealth by reducing the nuisance that many agricultural waste materials pose to the environment. The need to convert the agricultural wastes to useful and viable source of alternative energy for domestic and industrial purposes. Wilaipon (2007) submitted that part of the promising solutions to the problem is the application of briquetting technology. Amanda et al. (2019); Oriaku et al. (2017) concurred that biomass is a well promising alternative energy source to develop as organic fuel for domestic and industrial purposes. Briquette is a small rectangular or cylindrical block of flammable compressed matter to be used as fuel maybe either solid or hollow in geometric shape (Encarta Premium, 2009; Legacy Foundation, 2003). Briquettes are common type of solid fuels, replacing solids of raw peat as a domestic fuel (Yaman et al., 2000; Demirbaş and Şahin, 1998). Jekayinfa and Omisakin (2005) observed that agricultural residues are neither utilized nor effectively managed in most developing countries but would play a vital role in substituting as alternative towards alleviating their insufficient energy demand. Fapetu (2000a) identified that farming activities result in production of various economic products from distinct types of residues that are biomass materials containing enormous amount of energy are left as waste materials after harvest. Meanwhile, Oladeji (2010) suggested that conversion processes should be involved to mitigate the problems. Fapetu (2000b) believed that civilization has brought enlightenment with ingenuity of human capabilities by increasing the efficient and extensive harnessing of various forms of energy for socio-economic improvement. Energy sustainability, suitability and affordability required for human continuity in term of development and economic growth would be achieved. Aransiola et al. (2019) concluded that provision of adequate energy is very essential to improve human living standard. Briquettes are made from various agricultural wastes compressed to form a smokeless, slow burning, easily stored and transported fuel (Olugbade and Ojo, 2020). The most popular briquettes are biomass, charcoal varieties whose sizes are related to their uses (Cassie, 2003).

Biomass physiochemical properties to be employed as fuel determine its choice from agricultural wastes to produce briquette for domestic and industrial usage (Richards and Kobus, 2007). As reported by Aransiola et al. (2019) that the compaction of these agricultural wastes would add more values to their bulk handling and storage properties. Olugbade and Ojo (2020) established that briquetting provides rare advantages such as consistent briquette size, shape for easy storage and transportation with the influence of binders which ensured good bonding and combustion performance. Helwani et al. (2018) argued that fuel crisis caused by the constantly increasing consumption of fossil energy can abate with use of alternative sources as replacement for fossil fuels. Briquettes are widely used as a renewable and alternative energy material for solving the problem of dependency on firewood as a source of energy for human use. Briquettes has shown positive characteristics such as low costs, high energy content and high durability (Olugbade et al., 2019; Demirbaş, 1999; Horne and Williams, 1996; Stevenson, 1993; Abasaeed, 1992)

Previous studies on palm kernel shell briquette either by homogenous or heterogeneous mixture of the materials with the binding agent especially starch which relied on information of the calorific value as well as the mechanical properties of briquettes. This study focuses on effect different particle sizes of palm kernel shell materials for producing briquettes on its calorific value. Synthetic adhesive (glue), an impure form of gelatine as binding agent for homogenous compatibility of the palm kernel shell to form the desired briquette.

Kpalo et al. (2020) conducted a study on the production and characterization of hybrid briquettes from corncobs and oil palm trunk bark under a low-pressure densification technique which used wastepaper pulp as binding agent. His results from the work showed that hybrid briquettes did better than the briquettes made from corncobs with calorific values ranging between 16.54-16.91 MJ/kg due to the varying ratios of corncob to oil palm trunk bark.

Aransiola et al. (2019) studied the effect of binder type, binder concentration and compacting pressure on some physical properties of carbonized corncob briquette. Three different concentrations of binders used were cassava starch, corn starch and gelatine to produce briquettes at predetermined compacting pressure levels with application of hydraulic press. The study showed that for all the three factors investigated, variables with cassava binder at concentration of 30 % and compaction pressure of 150kPa exhibited the most positive attributes than other variables. It affirmed that the higher the binder concentration and compacting pressure, the better the briquettes to be produced.

Olugbade et al. (2019) researched on influence of binders on combustion properties of biomass briquettes as a review which revealed that the higher compacting pressure of the binders and processing temperature would eventually lead to the higher density and energy content per unit volume of fuel briquettes.

Helwani et al. (2018) conducted research on the effect of process variables on the calorific value and compressive strength of the briquettes made from high moisture empty fruit bunches in which glycerol, a by-product of biodiesel, was the binding agent. He declared that the process conditions influence the calorific value significantly with heating value of 28.99 MJ/kg due to the binder composition ratio used.

Amanda et al. (2019) worked on the effect of binding types on the biomass briquette calorific value from cow manure as a solid energy source in which molasses and starch as binder. It was announced that the briquettes with 10 % sugar cane binding content produced the highest calorific value of 3907.5 cal/g at carbonization temperature of 400 °C.

Kabok et al. (2018) investigated the effect of shapes, binders, and densities of faecal matter-sawdust briquettes on ignition and burning times. The researchers conducted the study on three different geometric shapes such as spherical, triangular and cylindrical densities of 600 kg/m^3, 700 kg/m^3 and 800 kg/m^3 respectively using molasses and starch as binding agents respectively. The report showed that there was significant difference on ignition time on shapes and densities and not on burning times with shapes and binders.

Tanui et al. (2018) investigated the influence of processing conditions on the quality of briquettes produced by recycling charcoal dust in which they used molasses as binding agent. The report from the researchers' result revealed the optimized values of gross calorific value and shatter index were 29.031 MJ/kg and 80.363%, respectively.

Borowski et al. (2017) used wheat starch as binding agent for the bond of charcoal to form briquette and stated that the starch binder has no effect on toughness and ash content, but the combustion test had shown quite different burning properties.

Muraina et al. (2017) conducted a study on physical properties of biomass fuel briquette from oil palm residues in which they used
cassava peel as binder for the briquettes. The
results from their study showed that the fuel briquettes made from the palm kernel shell and mesocarp fibre with the ratio 70 to 30 mixture at 350 µm had the highest fixed carbon and calorific value of 19.90 % and 18.1063 kJ/g, respectively. The researchers announced that this could serve as alternative source of energy for domestic and industrial applications.

Oriaku et al. (2017) performed an experiment on conversion of sawdust to useful energy which used cassava starch as binding agent. The results from their study elucidated that the carbonized sawdust briquettes had higher calorific value of 28.614MJ/kg than briquette from charcoal and other agricultural waste either carbonized or un-carbonized at 500 °C. The researchers identified that the carbonized briquettes made from sawdust could be a reliable source of energy for industrial heating in boilers, furnaces, ovens and also for domestic applications.

Oke et al. (2016) worked on the analysis of the effect of varying palm kernel particle sizes on the calorific value of palm kernel briquette and used starch binding agent. The result from the study of the researchers showed that the calorific values of the three different particle sizes were 18.415, 18.412 and 17.342 MJ/kg respectively. The implication derived from the foregoing is that the calorific values clearly pointed to the probability that is drawn from their interdependent on binders used or the particle sizes of the briquetting materials.

The work of Ndubuisi et al. (2016) which studied the performance evaluation of suitability of carbonized palm kernel shell as veritable alternative to coal and charcoal in solid fuel fired furnace. It was reported by the researcher that higher heating value could be obtained from carbonized palm kernel shell compared with those from firewood, peat and lignin but less than bituminous and anthracite coals.

Ojaomo et al. (2015) reported that the starch was effective as binding agent for fastening the particles of briquettes made from waste materials such as maize husks, waste papers with fine shredded wood wastes (sawdust).

Olugbade and Mohammed (2015) examined fuel developed from rice bran briquettes and palm kernel shells in which they used cassava starch as binder. The researchers declared that the higher heating value obtained with mixing ratio of palm kernel shell to rice bran was 14.25 MJ/kg and thus increased with a decreasing palm kernel shell grain size.

Mohammed and Olugbade (2015) conducted a study to investigate the effect of parameters on burning rate of briquettes produced from rice bran and palm kernel shells with cassava starch used as binder. They found that increased in compaction pressure, binder ratio and decreased in particle size caused decrease in the burning rate of the briquettes.

Ogwn et al. (2014) conducted study on comparative analysis of calorific value of briquettes produced from sawdust particles of *daniella oliveri* and *afzelia africana* combination at binary and tertiary levels with rice husk. The researchers reported that 40% starch level content as binder gave the highest heating value of 4827.20 kcal/kg and least ash content of 4.30% among the three different percentage of starch binder levels used.

Davies and Davies (2013) investigated the physical and combustion characteristics of briquettes made from water hyacinth and phytoplankton scum as binder. The results from the study revealed that phytoplankton scum as binder improved the mechanical handling characteristics of the briquettes and also its durability become more improved with increased binder proportion.

Ugwu and Agbo (2013) studied the evaluation of binders in the production of briquettes from empty fruit bunches of elais guineensis in which starch and asphalt as binding agents for comparison. It was announced that the briquettes made with starch as binder had higher calorific value, higher burning rate, higher heat output with less smoke emission and ignited within a shorter time than the asphalt bonded briquettes.

Chin and Mohd (2012) evaluated an experimental investigation on the handling and storage properties of biomass fuel briquettes made from oil palm mill residues which used paper waste as binding agent. It was declared that the mixture of palm kernel shell with mesocarp fibre in ratio 60 to 40 gave best mechanical properties and retained its combustion properties.

Ugwu and Agbo (2011) worked on briquetting of palm kernel shell by using starch as binding agent. The result obtained affirmed that the palm kernel shell briquettes had higher calorific value than the others made from charcoal and sawdust with desirable combustion characteristics.

**Kuti (2007) conducted research on impact of charred palm kernel shell on the calorific value of composite sawdust briquette. It declared that the addition of palm kernel shell in various proportions increases the average calorific value to 23.57 MJ/kg when compared with the briquette produced from 100 % pure sawdust material. This researcher established that the application of charred palm kernel shell as a biomass additive in composite sawdust briquette increases the energy content of the solid fuel. It was also reported that it would be suitable for both domestic and industrial applications as high-grade biomass fuel.

Aris et al. (2005) conducted a study on development of fuel briquettes from oil palm wastes in which they used wastepaper and starch as binders. It was reported that the gross calorific value of 22.4 MJ/kg indicated good energy content of the briquettes made from the mixing ratio of fibre, shell and wastepaper with 36% increase compared with starch bonded briquettes.

The material for binding has key role to play in the making of briquettes which can be categorized into organic, inorganic and compound binders. These have influence on the compatibility, density, durability, and combustion characteristics of the briquettes produced with different binders (Zhao et al., 2001; Zhang et al., 2018).

Materials and Methods

The palm kernel shell used for this research was locally sourced from farm settlement which was later sun dried to minimum moisture content (constant dry weight). The sample preparation procedures consisted of grinding, milling, sieving, mixing of binder material and compacting. The pulverizing and ball mill grinding machines used to grind the kernels are shown in Figure 1 respectively. The pulverizing machine pre-grinded the palm kernel shell to large coarse particles. The ball mill grinding machine then milled the pre-grinded palm kernel shell into finely and powdered particles as shown in Figure 2. The milled palm kernel shell and sieved using a sieve diameter of 3.0mm – 5.0mm to get two different particle sizes using single mesh of small, tiny size. Synthetic adhesive (glue) as binding agent for the bond of finely and coarsely mill pulverized palm kernel shell particles gradually mixing them homogenously. Compaction of the different bonded particles of the palm kernel shell using fabricated manually operated screw compaction machine as shown in Figure 3. 400g of each sample (coarse and fine) were measure into the cylindrical shaped compaction machine for moulding to form the briquettes at optimum desirable pressure. The briquettes produced were dried under sunshine as shown in Figure. 4.

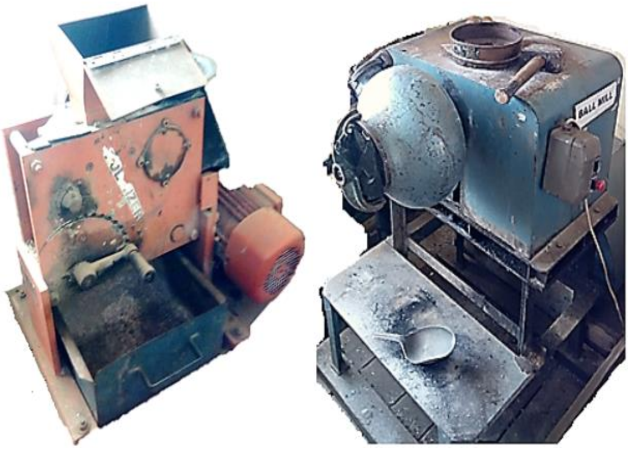

Figure 1: Pulverizing and Ball Mill Machines

Figure 2: Pulverized and Sieved milled shells

Figure. 3: Compacting Machine

Figure 4: Sun dried produced coarse and fine size briquettes

Determination of Parameters

The calorific or heating values for the dried briquettes were determined using e2k combustion bomb calorimeter as shown in Figure 5. Proximate and ultimate analyses of the palm kernel shell briquettes was conducted. This test was conducted at the Central Research Laboratory of Federal University of Technology, Akure, Nigeria and the laboratory results are shown in Appendix 1. American Society for Testing and Materials ASTM D3172-75, ASTM D5865 and American Public Health Association (APHA) standard test method rules were followed in carrying out the experimental test to determine proximate analysis and heating value for fixed carbon, ash content, volatile matter moisture content and calorific value respectively.

Figure 5: Combustion Bomb Calorimeter System

Results and Discussion

Table 1 presented the proximate and ultimate analyses of the palm kernel shell as revealed in the test result presented in Appendix1. It showed the trend of starch binder depicted no clear deviation in caloric values from the findings established by (Oke, 2016). Table 2 presents the effect of using glue binder for kernel compaction

Table 1: Proximate and Ultimate Analyses

Proximate Analysis (%)		Ultimate Analysis (%)	
Ash Content	37.49	Carbon	39.68
Fixed Carbon	28.05	Hydrogen	0.66
Moisture Content	5.88	Nitrogen	0.51
Volatile Matter	28.58	Oxygen	57.65
Total	**100**	Sulphur	1.50
		Total	**100**

The result of the calorific values of the two different particle sizes of the palm kernel shell were presented in table 2.

Table 2: Calorific Values of Fine and Coarse Aggregate in Glue

Fine Particle (MJ/kg)	Coarse Particle (MJ/kg)
12.186	17.997

Table 3: Calorific Values of Fine and Coarse Aggregate in Starch

Fine Particle (MJ/kg)	Coarse Particle (MJ/kg)
11.794	16.542

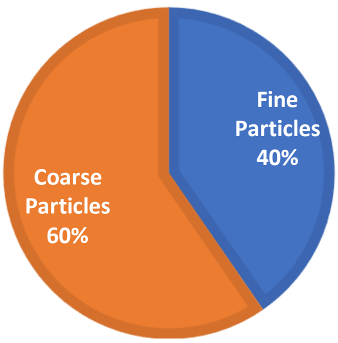

Figure 6: % Calorific Value in glue Binder

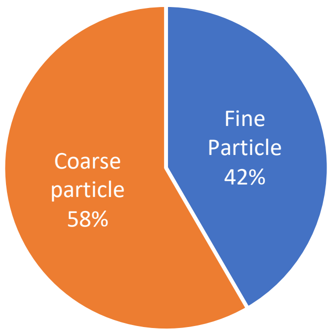

Figure 7: % Calorific Value in Starch Binder

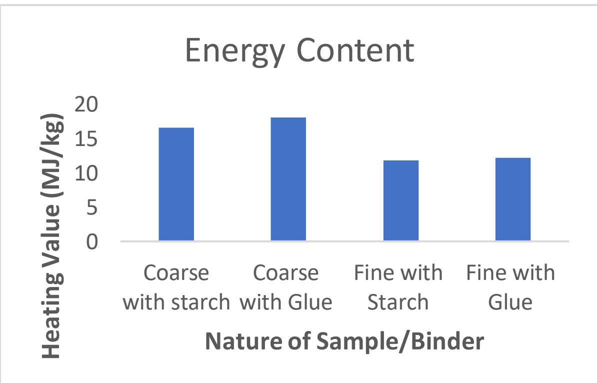

Figure 8: Energy content with nature of kernel

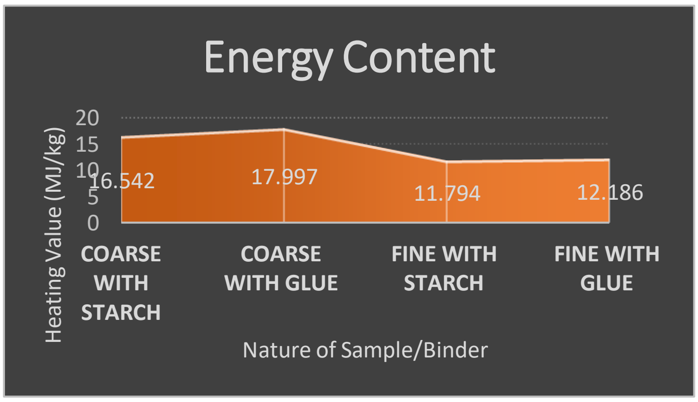

Figure 9: Energy content trend with size and binder

The calorific value of the raw palm kernel was determined to be 4.124 MJ/kg with the Dulong's empirical formula according to Rajput (2006) without the addition of binder to form the briquettes using the ultimate analysis parameters to affirm the effect of the binder on the energy content of the briquettes of the two different particle sizes of fine and coarse. Figure 6 and Figure 7 showed the closely related calorific values due to the binders used. This suggested that calorific value of palm kernel briquettes may be insignificantly dependent on the type of binders used. Rahaman and Salam (2017) stated that fine particle size enhances combustion characteristics due to its larger surface area which could eventually enhance the combustion rate. Figure 8 and Figure 9 Showed the relative effects of the particle size of the briquettes with the energy content. The bigger sized particles referred to as coarse suggested a significant difference in energy contents when compared with the fine particles. The results of the calorific value of the two different particle sizes showed that the briquette made from coarse particle has higher calorific value than fine particle briquette.

Conclusion

Briquettes of fine and coarse particles sizes aggregate were produced, and its energy content were also determined. Results from the analysis showed that the coarse particle size briquette contained more energy content than briquette made from fine particle size. The calorific value of briquette from coarse particle size was 17.997 MJ/kg and that of fine particle size briquette was 12.186 MJ/kg. It was also noted that the result of the calorific value ws slighted altered by the binding agent used. This observation concurred with Aransiola (2019) and Olugbade (2019). The 2% variation of calorific values in Figure 6 and Figure 7 is significant and this could be resonably adduces to the the different binders since the same compacting presure was applied for them.

Compliance with Ethical Standards

Conflict of Interest, the authors declare that there is no conflict of conflict of interest

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APPENDIX 1

Vice-Chancellor: Prof. Joseph Fuwape

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ONDO STATE, NIGERIA.
Tel: 07035897591
Cables & Telegrams: Fed UNITECH, Akure
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Our Ref:

Date: 22/10/2019

Name of Clients	MR INNOCENT
Request Form No	CRL/NUT/102010/002
Nature of Sample	

PROXIMATE ANALYSIS RESULTS

S/N	% MC	% Ash	% VM	% FC	Total %
1	5.88	37.49	28.58	28.05	100

Foot note:
MC: Moisture Content
VM: Volatile Matter
FC: Fixed Carbon
Ash: Ash Content

ULTIMATE ANALYSIS RESULTS

S/N	% Nitrogen	% Sulphur	% Hydrogen	% Carbon	% Oxygen	Total %
1	0.51	1.50	0.66	39.68	57.65	100

CALORIFIC VALUE or HEATING VALUE RESULTS

S/N	Nature of Sample/Binder	Energy Content or Heating Value (MJ/Kg)
1	Coarse Particle Palm Kernel with Starch	16.542
2	Coarse Particle Palm Kernel with Glue	17.997
3	Fine Particle Palm Kernel with Starch	11.794
4	Fine Particle Palm Kernel with Glue	12.186