Estimation of the Moisture Content, Volatile Matter, Ash Content, Fixed Carbon and Calorific Values of Rice Husk Briquettes

Francis Inegbedion and Emmanuel Ikpoza
Department of Production Engineering
University of Benin
Benin City, Nigeria
francis.inegbedion@uniben.edu, emmanuel.ikpoza@uniben.edu

Abstract

The study was undertaken to assess the calorific value of briquettes produced from rice husk bonded with cassava starch. Rice husk was mixed with the starch binder in a ratio of 100:15. Combustion related properties namely percentage volatile matter, percentage ash content, percentage fixed carbon and calorific value of the briquettes where determined. Results indicated that the average percentage moisture content, the average percentage volatile matter, the average percentage ash content, the average percentage fixed carbon and the average calorific value for the rice husk briquette produced were 5.87%, 14.35%, 5.34%, 74.45%, 14304.61KCal/Kg respectively. These results indicate that the briquettes made from rice husk have high heating value enough for domestic, small-scale industrial cottage applications. This research has established the potential of rice husk briquettes as alternative material for firewood, charcoals and fossil fuels.

Keywords
Briquettes, Rice Husk, Calorific Value, Moisture Content, Agro Waste.

1. Introduction
"The primary source of energy for such vital activities as cooking and space heating is burning wood and other agricultural products. An increasing population using dwindling resource of combustible biomass materials will eventually result in the shortage of those materials unless urgent steps are taken to reverse the trend. One way of making efficient use of existing resources is briquetting. Briquetting involves collecting combustible materials that are not usable due to lack of density, compressing them into solid fuels of convenient shape that can burn like wood or charcoal" (Khadatkar and Gangwani 2016).

Mordi (2007) "defined biomass briquetting as the densification of loose agro residues with or without binding agents to produce compact solid composites of different sizes with the application of pressure. A briquette is the product formed from the physio-mechanical conversion of dry, loose and tiny particle size material with or without the addition of an additive into a solid state characterized by a regular shape. Briquettes are mainly used for heat applications (steam generation, melting metals, space heating, brick kilns, tea curing, etc) and power generation through gasification of biomass briquettes and for domestic uses".

Biomass briquettes are a proven way of generating energy from waste. Different types of waste have been utilized in order to develop biomass briquettes. Recently, Romallosa and Kraft (2017) revealed that the simulated fabrication of biomass briquettes derived from the municipal waste stream could result in feasible on-site fuel production. In another report, Garrido et al. (2017) produced briquettes from sawdust, date palm trunk and different plastic wastes, lacking an external binding agent.

There is a rapid increase in the volume and types of wastes due to intense activities in the wake of population growth and improved living standards, which are now becoming a major problem as rotten waste biomass emits methane and leach-ate. Open burning of these wastes usually generates carbon dioxide (CO2) and other local pollutants (UNDP, 1982). Most solid wastes are generated by the rearing of animals, and harvesting and processing of crops.

These wastes take the form of residual stalks, straw, leaves, roots, husk, nut or seed shells, waste wood and animal husbandry waste.

These wastes are managed through the processes of collection, storage and disposal in form of biomass. If not managed properly, waste can pollute the environment and even degrade both surface and underground water as they contain a lot of nitrates which can reduce the ability of these resources to support aquatic life and serve for human and animal consumption (Agidi et al. 2015).

A major contribution to pollution is the use of fossil fuels; hence there is huge push to reducing the usage of fossil fuels for cooking and heating applications. Developing countries are faced with the problem of waste management and agro residues such as dry leaves, rice husk, coffee husk, sawdust, palm fruit shell, coconut fiber etc., are a major contributor to this problem. More often than not these agro residues are usually burnt, which poses a huge pollution problem. There is the need to finding a way of converting these wastes to useful fuels. These agro residues wastes are very difficult to transport, handle, store and if these residues are burnt directly it results in very poor thermal efficiency and create lot of pollution. These can be avoided by briquetting the agro residue waste in to usable energy generating fuel. If properly handled, biomass briquettes from agro residue wastes can become an alternative fuel for domestic and small-scale industrial cottage applications and to a greater extent help in waste management and reduced pollution.

1.1 Objectives

In this research work, we estimated the moisture content, volatile matter, ash content, fixed carbon and calorific values of rice husk briquettes in order to establish its potential as an alternative fuel for domestic and small-scale industrial cottage applications.

2. Literature Review

Agidi et al. (2015) “reported that developing countries are faced with the huge problem of waste management and agro residues. We usually see agro and sawmill residues burnt on roadside or dump yards, which results in pollution. There is a need to convert these residues into fuels they noted. However, these residues are very difficult to handle, store and if they are burnt directly results in very poor thermal efficiency and create lots of air pollution. They however concluded that these problems could be avoided by briquetting the waste biomass into a usable energy generating fuel. This will make biomass briquettes an alternative for fossil fuels, improve waste management and reduced air pollution”.

Akintaro et al. (2017) determined the potentials of using carbonized corncob to produced briquettes as an alternative to fuelwood. They selected properties of the carbonized corncobs and the briquettes produced namely moisture content, volatile matter, ash content, fixed carbon and calorific value that were determined. Their results indicated that moisture content, volatile matter, ash content, fixed carbon and calorific value increased with increase in binder concentration and compacting pressure. The average moisture content, volatile matter, ash content, fixed carbon and calorific value they obtained ranged from between 4.43 to 7.62%, 10.31 to 16.48%, 3.03 to 5.06%, 72.68 to 81.30% and 28.85 to 32.36 MJ/kg respectively. Their study established the potential of using carbonised corncob as alternative material for briquettes production. This will increase the sources of energy for domestic and industrial use in developing economy.

Bello (2005) carried out a research project in processing of agricultural residues into briquettes using gum Arabic as binder and evaluated their performance characteristics based on fuel efficiency, cooking efficiency, boiling time and fuel consumption rate respectively. for cooking purposes in the department of agricultural engineering, Ahmadu Bello University, Zaria in which she produced briquettes from agricultural residues using gum Arabic as her binder and evaluated their performance characteristics based on fuel efficiency, cooking efficiency, boiling time and fuel consumption rate respectively.. Also, a hand operated biomass briquetting mould, have been fabricated with locally available materials to prepare the charcoal briquettes for its ultimate analysis.

DahamShyamalee et al. (2015) prepared briquettes with binding agents like cow dung, wheat flour and paper pulp. These briquettes were tested for calorific value and compressive strength by varying percentage by volume of binders. They also calculated the minimum energy cost for production.

DahamShyamalee, et al. (2015) found that the Biomass briquettes are often used as an energy source for cooking purpose and in some industries like bricks and bakery. The briquettes are produced by densification of waste biomass using various processes. In this study manual densification of saw dust was tested with three different binding agents; dry cow dung, wheat flour, and paper pulp. The samples with cow dung as binding agent failed with mould detaching and minimum required binder percentage for other two binders for successful forming were found to be 30%.

Emerhi, E. A. (2011) have found that the calorific value of briquettes produced from mixed sawdust of three tropical hardwood species bonded with different binding agents (starch, cow dung and wood ash) are high. Sawdust from each of the species was mixed with the binder in ratio of 70:30 for cow dung and wood ash and 70:15 of starch. The sawdust where mixed in a ratio 50:50 for each briquette combination produced. The result shows that, the best briquette was produced when sawdust was mixed with starch.

Inegbedion (2021), prepared briquettes with palm fruit shell using cassava starch as binding agent in the ration 100:15 by weight. He estimated the average percentage moisture content, average percentage volatile matter, average percentage ash content, average percentage fixed carbon and calorific values of the briquettes produced. His results indicate that the briquettes made have high heating value enough for domestic, small-scale industrial cottage applications.

Kishan et al. (2016) designed and Fabricated a low cost briquetting machine and estimated the Calorific values of biomass briquettes made from sawdust, dry leaves and very small amount of wheat flour. Their results indicated that the briquettes made from sawdust, dry leaves and very small amount of wheat flour (binding agent) are compact, dry and have greater calorific value when compared to the briquettes made from sawdust, dry leaves and coffee husk (binding agent) are not strongly bonded and possesses slightly lower calorific value.
Kumar et al. (2016) reported the evaluation of calorific value of bio-briquette made from palm tree branches mixed with coconut coir, saw dust, screw pine, indian bdellium tree powder in different proportions. The briquettes were prepared in the different ratios of 100:0 with and without binder (P_{W100}, P_{WO100}), 100:50(P_{W50}), 100:20 with and without binder (P_{W20}, P_{WO20}), 0:100 by using only additives (A_{W100}). The proximate analysis was conducted and those are compared with the Indian coal. The moisture content is high for A_{W100} (8.53%), ash content is for A_{W100} (12.2%), volatile content is for P_{WB100} (86.9%), fixed carbon is for P_{W20}(17.38%) and calorific value KJ/KG is for P_{WO100}(19,351).

Obi et al. (2013) in their study, developed an appropriate commercial biomass briquetting machine suitable for use in rural communities and performance evaluations were carried out on the machine using sawdust. The physical and combustion properties of the briquette produced were determined at varying biomass-binder ratios of 100:15, 100:25, 100:35 and 100:45 using cassava starch as the binding agent. Both the physical and combustion properties of the briquette were significantly affected by the binder level ($P < 0.05$). The optimum biomass-binder ratio on the basis of the compressed density was attained at the 100:25 blending ratio having a compressed density of 0.7269g/cm^3 and a heating value of 27.17MJKg^{-1} while the optimum blending ratio on the basis of the heating value was attained at the 100:35 blending ratio with a compressed density of 0.7028g/cm3. They concluded that the heating values at the optimum biomass-binder ratios were sufficient to produce heat required for household cooking and small scale industrial cottage applications.

Ogwu, et al. (2014) have Compared performance in calorific value was determined from the binary and tertiary combination of briquettes produced from biomass materials (sawdust) of Afzeliaafricana, Daniella oliveri and Rice husk at 20% 30%, and 40% starch binder levels. From the proximate analysis of the samples, it was observed that there were significant differences ($p<0.05$) between the densities, Percentage Ash content, Percentage Volatile matter and Percentage Fixed carbon of the samples. A progressive increase in heating value was observed among briquettes produced as the starch level increased. Briquettes produced at the tertiary combination of Afzeliaafricana + Daniella oliveri + Rice husk biomass recorded the highest heating value of 4827.20kcal/kg at 40% starch level while Daniella oliveri + Rice husk briquettes at binary level recorded the least heating value of 4586.72kcal/kg at 20% starch level. Among the various starch levels the tertiary combination had the least Ash content of 4.30% at 40% starch level while Daniella oliveri + Rice husk briquettes at 20% starch level had the highest Ash content of 9.29%. It is therefore recommended that 40% starch level be used for briquettes production.
Olawale, et al. (2014) have tested effect of starch and gum arabic as binders in the combustion characteristics of briquette prepared from sawdust of different ratios were investigated. Briquettes of sawdust were produced by

mixing with different binders and agglomerate using starch paste and gum arabic. The mixture was compressed at 110kN using manually operated hydraulic briquette machine and sun dried. The calorific value, the volatile matter and flame temperature were determined. Results showed that the briquette formed using starch as a binder performed better in all aspect than the gum arabic.

Olorunnisola (2004) undertook a study to investigate the properties of fuel briquettes produced from a mixture of a municipal solid waste and an agricultural residue and observed that briquettes produced using the following 100 % waste paper and 5 : 95 waste paper - coconut husk ratio respectively exhibited the largest (though minimal) linear expansion on drying. While the equilibrium moisture content of the briquettes ranged between 5.4 % and 13.3 %, there was no clearly discernible pattern in equilibrium moisture content variation with increase in coconut husk content. A reciprocal relationship was observed between compressed/relaxed density and relaxation ratio of the briquettes, while the mean durability rating of all the briquettes exceeds 95 %. It was however concluded that stable briquettes could be formed from waste paper mixed with coconut husk particles.

Onuegbu et al. (2011) had prepared bio briquettes from elephant grass, spear grass and bio coal at moderate pressure and temperature. They did proximate analysis and compared the results with wood samples. Their efforts was to substitute firewood to briquettes in the rural households in Nigeria.Style et al. (2008) briquettes production provides a key technology for increasing biomass available for use in both electricity and heat generation.

3. Methods

Dry rice husks was homogeneously mixed with cassava starch in a ratio of 100:15 and fed into a designed briquette machine designed by Inegbedion and Francis-Akilaki (2022). The machine is a single extrusion die screw press that consists mainly of driving motor, speed reducer, feed screw, die, and the housing with a hopper. The motor transmits power directly to the screw through the speed reducer. As the machine is running raw materials are fed into the compaction chamber through the hopper; the raw materials are compressed in the barrel by the screw, and extruded through the die. The screw continuously forces the materials into the die. In an extrusion die screw press pressure is built up along the screw rather than in a single zone as in the piston type machines" (Figure 1).

Figure 1. Briquettes produced from rice husk bonded with cassava starch

3.1 Determination of Moisture Content of the Briquettes Produced

The percentage moisture content (PMC) determined by weighing 1.5g of the briquette sample put in a crucible of known mass and placed in an oven set at 105°C ± 5°C for 1 hour. The crucible and its content were removed from the oven allowed to cool to room temperature and reweighed. This process was repeated until the weight after cooling became constant and this was recorded as the final weight. The sample's moisture content was determined using equation (1).

$$PMC = \frac{W_1 - W_2}{W_2} \times 100\% \qquad (1)$$

Where, W_1 is the initial weight of briquette sample and W_2 is the final weight of briquette sample.

3.2 Determination of Volatile Matter of the Briquettes Produced

The percentage volatile matter (PVM) was determined by placing 1.5g of the briquettes sample in a crucible and kept in a furnace for 8 minutes, at temperature of 550ºC ± 5°C and weighted after cooling. The percentage volatile matter of the sample was determined using equation (2)

$$PVM = \frac{W_2 - W_3}{W_3} \times 100\% \qquad (2)$$

Where, W_2 is the weight of the oven-dried sample (g); W_3 is the weight of the sample after 8 min in the furnace at 550 °C (g)

3.3 Determination of Ash Content of the Briquettes Produced

1.5g of the briquettes samples are kept in a closed furnace and burnt completely. The weight of the residue was taken with an electronic balance. The percentage weight of residue gives the ash contained in the sample and its determined using equation (3).

$$PAC = \frac{W_4}{W_2} \times 100\% \qquad (3)$$

3.4 Determination of Fixed Carbon of the Briquettes Produced

Akowuah *et al.* (2012) gave the percentage fixed carbon (PFC) as equation (4).

$$PFC = 100\% - (PMC + PVM + PAC) \qquad (4)$$

3.5 Determination of Calorific Value of the Briquettes Produced

The calorific value of the briquettes were determined using a bomb calorimeter. 1.5g of the briquettes sample was burnt completely in oxides of oxygen. The liberated heat was absorbed by the water and calorimeter. The heat lost by burning briquette was the heat gained by water and calorimeter. The calorific value (CV) of the fuel was calculated from the measured data (Obi *et al.* 2013) using equation (5)

$$CV = \frac{BFx\ \Delta t - 2.3\ length\ of\ wire}{W} \qquad (5)$$

Where: BF = Burn Factor; Δt = Change of temperature ($t_2 - t_1$)ºC; t_2 = final temperature; t_1 = initial temperature; W = mass of the sample used and BF = constant = 13,257.32

4. Results and Discussion

The physico-chemical properties of the briquettes produced from Rice husk were limited to determination of the percentage moisture content, percentage volatile matter, percentage ash content, percentage fixed carbon and calorific value.

4.1 Numerical Results

Table 1. Percentage Values of Moisture Content for Rice Husk Briquettes

Sample	PMC (%)
1	5.59
2	6.17
3	5.84

Table 2. Percentage Values of Volatile Matter for Rice Husk Briquettes

Sample	PVM (%)
1	14.25
2	14.36
3	14.43

Table 3. Percentage Values of Ash Content for Rice Husk Briquettes

Sample	PAC (%)

1	5.06
2	5.62
3	5.34

Table 4. Percentage Values of Fixed Carbon for Rice Husk Briquettes

Sample	PFC (%)
1	75.10
2	73.85
3	74.39

Table 5. Calorific Values for Rice Husk Briquettes

Sample	CV (KCal/Kg)
1	14,199.78
2	14,207.40
3	14,506.65

4.2 Graphical Results

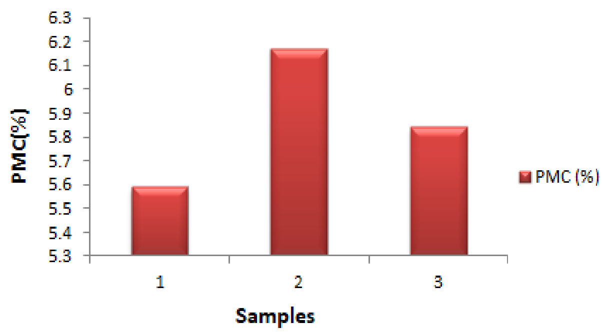

Figure 2. Percentage moisture content (PMC) for rice husk briquettes

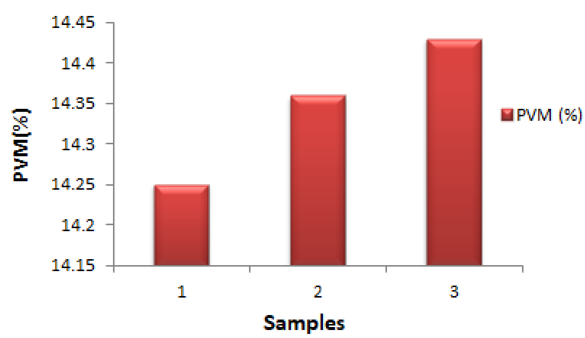

Figure 3. Percentage volatile matter (PVM) for rice husk briquettes

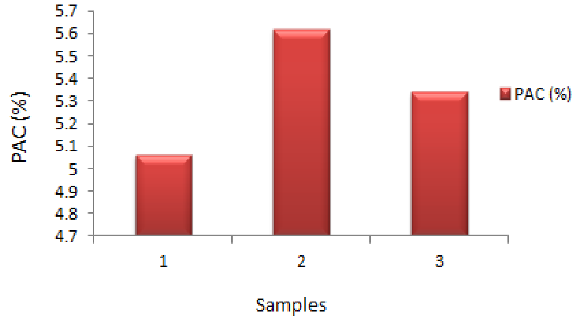

Figure 4. Percentage ash content (PAC) for rice husk briquettes

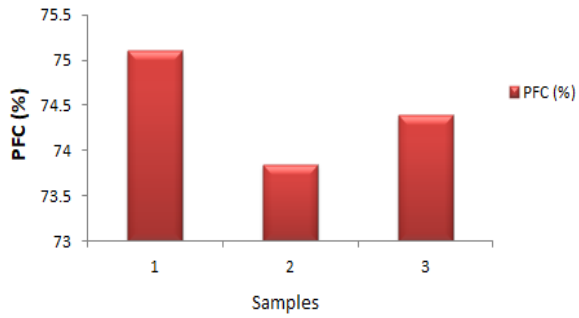

Figure 5. Percentage Fixed Carbon (PFC) for Rice Husk Briquettes

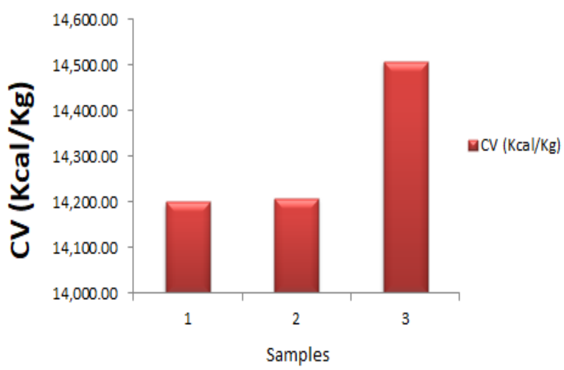

Figure 6. Calorific values (CV) for rice husk briquettes

4.3 Proposed Improvements

It was observed that the briquette samples produced has good combustion properties good enough for domestic use and small-scale industrial cottage applications.

4.4 Validation

Results from Table 1 and Figure 2, showed that the average percentage moisture content for the rice husk briquette produced is 5.87%. Moisture content of briquette increased with increase in binder concentration and decreased with increase in compaction pressure for all briquettes (Akintaro et al. 2017). Results obtained agreed with Pallavi *et al.* (2013) recommendation of 5 – 10% moisture content for quality briquettes. When moisture content is low, briquettes will easily ignite, and higher calorific values are expected from the briquette (Akowuah et al. 2012).

Results from Table 2 and Figure 3, showed that the average percentage volatile matter for the rice husk briquette produced is 14.35%. High volatile matter of a briquette indicates ease of ignition, rapid burning and proportionate increase in flame length but low heating values. The rice husk briquette produced has a percentage volatile matter that falls within the range 10 to 25% for good quality briquettes as reported by Akintaro et al. 2017.

Knowledge of the ash content tells the extent of clogging up of the burning medium. Results from Table 3 and Figure 4, showed that the average percentage ash content for the rice husk briquette produced is 5.34%. Low ash content offers higher heating value for briquettes but high ash content results in dust emissions that lead to air pollution. It affects the combustion volume and efficiency (Obi *et al*. 2013). High ash content results in lower calorific value and vice versa, because ash content influences burning rate as a result of minimization of heat transfer to fuel's interior parts and diffusion of oxygen to the briquette surface during char combustion (Chaney 2010).

Results from Table 4 and Figure 5, showed that the average percentage fixed carbon for the rice husk briquette produced is 74.45%. This result agrees with the result of Pallavi et al. (2013) who reported the suitability of briquettes with fixed carbon as 80.5% for domestic applications. Moore and Johnson, (1999) reported that, the higher the fixed carbon of a fuel, the greater the calorific value, the smaller the volatile matter, the lower the ash and moisture content and the better the quality of the fuel.

The calorific value determines the amount of heat energy present in a material. Results from Table 5 Figure 6, showed that the average percentage calorific value for the rice husk briquette produced is 14304.61KCal/Kg. "Ogwu et al. (2014) in their work obtained calorific values ranging from 4586.72kcal/kg to 4827.20 kcal/kg" and "Emerhi (2011) in his work obtained calorific values ranging from 33116kcal/kg to 23991kcal/kg" when compared with results obtained from this work showed that the briquette samples produced has good combustion properties good enough for domestic use and small-scale industrial cottage applications.

5. Conclusion

Fossil fuels and wood fuels are the major source for energy in Nigeria today. The excessive use of these fuels will lead to serious environmental issues like global warming, air pollution and deforestation. It is high time we convert biomass wastes to useful briquettes, which will be the substitute for these fuels. This work focused on estimating the heating values of rice husk briquettes to ascertain its suitability for domestic use and small-scale industrial cottage application. Results obtained indicate that the briquettes made from rice husk have high heating value enough for domestic use and small-scale industrial cottage applications.

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Biographies

Francis INEGBEDION is a Lecturer in the Department of Production Engineering, University of Benin, Benin City, Nigeria. He earned B.Eng. in Production Engineering, M. Eng. in Manufacturing Engineering and a PhD in Production Engineering from University of Benin, Benin City, Nigeria. Earlier he had obtained a National Diploma (ND) and Higher Nation Diploma in Mechanical Engineering Technology (Power Plant Option) from Auchi Polytechnic, Auchi. He has published several journal papers in both national and international journals. His research interests include engineering design and manufacturing, lean manufacturing, engineering materials, production and engineering management, simulation, optimization, and energy. He is a corporate member of COREN, NIProdE and NATE.

Emmanuel Ikpoza is a Lecturer at the Department of Production Engineering, in University of Benin, Benin City, Nigeria. He received his B.Eng. in Production Engineering and his M.Eng. and PhD degrees in Industrial Engineering from the University of Benin, Benin City, Nigeria. He has published a number of Journal Papers. Some of Emmanuel's major research interests are optimizations, applied materials science, lean manufacturing, reliability, computer application in production engineering etc. Emmanuel is a corporate member of the Nigerian Society of Engineers (NSE), Nigerian Institute of Production Engineers (NIProdE). He is a COREN Registered Engineer. More information about him is found on his LinkedIn and Google Scholar Profiles.