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A Comparative Analysis of Combustion Properties of Briquettes Produced From Sawdust Particles, Palm Fruit Shell And Rice Husk

Francis Inegbedion[1*] and Festus Inegbedion[2].
[1]Department of Production Engineering, University of Benin, Benin City, Edo State, Nigeria
[2]Department of Polymer Technology, Auchi Polytechnic, Auchi, Nigeria.
*Corresponding Author: francis.inegbedion@uniben.edu

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Abstract

Briquetting is one way to efficiently use existing resources. This involves collecting combustible waste and compressing it into a convenient form of solid fuel that can be burned like wood or charcoal. Biomass briquettes are one of the proven ways to get energy from waste. Excessive use of fossil fuels, firewood and natural gas is causing serious environmental problems and deforestation. This study focused on comparing the combustion properties of briquettes made from sawdust particles, coconut husks, and rice husks. Cassava starch was used as the binder in a weight ratio of 100:15 and the flammability of the obtained palm fruit briquettes was determined. The calorific value of the briquettes was measured using a bomb calorimeter. The average moisture content and average ash content of the sawdust briquettes were 5.04% and 3.85%, respectively. Coconut fruit shell briquettes have the highest average percentage of volatile substances at 17.45%. Sawdust briquettes had the highest average proportion of fixed carbon, with average calorific values of 80.95% and 26,918.02 kcal/kg, respectively. These results showed that the obtained briquettes had good combustion properties and were suitable for domestic use and small-scale industry, compared with the literature

1. Introduction

The main source of energy for many rural household activities such as cooking and heating is the combustion of wood, charcoal, and other agricultural products. As more and more people rely on dwindling sources of flammable materials (fossil fuels and wood) for cooking and heating, these materials will eventually become scarce unless urgent steps are taken to reverse this trend. Biomass charcoal briquettes are an efficient way to use existing resources. Briquetting involves collecting combustible waste that cannot be used because it is not dense enough and compressing it into a convenient form of solid fuel that can be burned like wood or charcoal [1].

Biomass briquette forming compresses large amounts of agricultural waste with or without binders to produce compact solids under pressure. Briquettes are products that are physically and mechanically transformed from dry, granular, fine-grained material into a solid state characterized by the correct shape, with or without the addition of additives. Briquettes are mainly used for thermal purposes (steam production, metal smelting, space heating, ovens, tea making, etc.) and for power generation through gasification of biomass briquettes, as well as for domestic and commercial applications [2].

Developing countries face major problems in the disposal of agricultural waste. Agricultural and sawmill wastes are typically burned on roadsides or in landfills, leading to environmental pollution. These residues are very low in thermal efficiency when faced, stored, or burned directly, and it is very difficult to cause air pollution. These problems are linked to this lighter one, linked to the use of fuel, and generate energy [3]. Biomass briquettes are a proven method of producing energy from waste. Different types of waste are used in the production of biomass briquettes.

Akintaro et al. (2017) [4] identified the possibility of using charred corncobs to produce briquettes as an alternative to firewood. They selected and measured the properties of the resulting charred corn cobs and briquettes: moisture content, volatile content, ash content, fixed carbon, and calorific value. The results showed that as the binder concentration and compaction pressure increased, the moisture content, volatile content, ash content, fixed carbon, and heating value increased. The average content and calorific value of moisture, volatile matter, ash, and fixed carbon obtained were 4.43-7.62%, 10.31-16.48%, 3.03-5.06%, 72.68-81.30% and 28.85-32.36 MJ/kg, respectively. . Their research established the possibility of using carbonized corn cobs as an alternative material for briquette production. This will increase energy sources for domestic and industrial use in developing countries.

In the study by Inegbedion and Erameh (2023) [2], Briquettes prepared from palm fruit peel using cassava starch as binder in a weight ratio of 100:15 was prepared. They evaluated the average percentage of moisture content, average percentage of volatile matter, average percentage of ash, average percentage of fixed carbon content and calorific value of the produced briquettes. The average combustion properties of the obtained palm briquettes were: average moisture content 7.56%, average volatile content 17.45%, average ash content 6.68%, average fixed carbon content 68.28%, and average calorific value 9,717.74 kcal//. kg. Their results showed that the obtained briquettes had a high calorific value and were sufficient for domestic use in industrial small-scale households.

Inegbedion (2022) [5],evaluated the moisture content, volatile content, ash content, fixed carbon and calorific value of briquettes prepared from sawdust particles using cassava starch as binder in a weight ratio of 100:15. The calorific value of the sawdust briquettes was: average moisture content 5.04%, average volatile fraction 10.80%, average ash content 3.85%, average fixed carbon rate 80.95%, and average calorific value rate 26918.02 Kcal. /kg. The results show that the obtained briquettes have a high calorific value and are sufficient for domestic use in small scale industrial households.

Inegbedion and Ikpoza (2022) [6],evaluated the moisture content, volatile content, ash content, fixed carbon, and calorific value of rice husk briquettes using cassava starch as a binder at a weight ratio of 100:15. As a result, the average moisture content, average volatile content, average ash content, average fixed carbon rate, and average calorific value of the produced rice husk briquettes were 5.87%, 14.35%, 5.34%, and 74.45%. %. , 14304.61 Kcal/kg, respectively. Their results show that the obtained briquettes have a high calorific value and are sufficient for domestic use in small industrial households.

Kishan et al. (2016) [7] designed and built a low-cost briquetting machine and evaluated the calorific value of biomass briquettes made from sawdust, dried leaves, and trace amounts of flour. As a result, briquettes made from sawdust, dried leaves, and a very small amount of flour (binder) are denser, drier, and have a lower calorific value than briquettes made from sawdust, dried leaves, and coffee husks (binder).

Kumar et al. (2016) [8] 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 (PW100, PWO100), 100:50(PW50), 100:20 with and without binder (PW20, PWO20), 0:100 by using only additives (AW100). The proximate analysis was conducted and those are compared with the Indian coal. The moisture content is high for AW100 (8.53%), ash content is for AW100 (12.2%), volatile content is for PWB100 (86.9%), fixed carbon is for PW20(17.38%) and calorific value KJ/KG is for PWO100(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/cm3 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) [9] Comparative performance in terms of calorific value was demonstrated for binary and ternary briquettes produced from Afzelia africana, Daniela oliveri, and rice husk biomass materials (sawdust) at starch binder levels of 20%, 30%, and 40%. determined from the combination. From the detailed analysis of the samples, it was observed that there were significant differences when mixing different binders and aggregates using starch paste and gum arabic. The mixture was compressed to 110 kN using a manual hydraulic briquette machine and dried in the sun. Calorific value, volatile content, and flame temperature were measured. The results showed that briquettes formed using starch as binder performed better than gum arabic in all respects.

In this research work we compared the combustion properties of briquettes produced from sawdust particles, palm fruit shell and rice husk.

2. Materials and Methods

Briquettes were homogeneously mixed with cassava starch at a mass ratio of 100:15 as described by Sotannde et al. [10], Martin et al. [11]. Each mixture was fed in different ways to a briquette machine designed and manufactured by Inegbedion and Francisco-Akilaki [12] to produce the different briquettes required. This machine is a single-screw extrusion press, which mainly consists of a drive motor, gearbox, feed screw, die and hopper housing. The drive motor transmits power directly to the auger via a gearbox. During the operation of the machine, the raw material is fed into the compression chamber through the hopper, and the raw material is compressed into the cylinder by the screw and forced out from the nozzle. The screw continuously pushes the materials into the die. In an extrusion die screw press, pressure builds up along the screw rather than in a single area as in piston machines. Figure 1 – 3 shows the different briquettes produced from sawdust particles, palm fruit shell and rice husk bound with cassava starch.


Figure 1: Briquettes produced from Sawdust Particles


Figure 2: Briquettes produced from Palm Fruits Shell


Figure 3: Briquettes produced from Rice Husk

2.1 Determination of Moisture Content of the Briquettes

The percentage moisture content (PMC) was determined by weighing 1.5g of each briquette sample 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 the value 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.

2.2 Determination of Volatile Matter of the Briquettes

The percentage volatile matter (PVM) for each briquette sample was determined by placing 1.5g of the briquettes sample in a crucible and kept in a furnace for 8 minutes, at temperature of 550°C ± 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)

2.3 Determination of Ash Content of the Briquettes

1.5g of each briquette sample was placed 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).

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

2.4 Determination of Fixed Carbon of the Briquettes

The expression for determing percentage fixed carbon (PFC) is equation (4) [13].

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

2.5 Determination of Calorific Value of the Briquettes

The calorific value of each briquette sample was determined using a bomb calorimeter. 1.5g of each briquette 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 [14] using equation (5)

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

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

3. Results and Dıscussıon

The physicochemical properties of charcoal briquettes obtained from sawdust, coconut husks, and rice husk particles were limited to the measurement of humidity percentage, volatile matter percentage, ash percentage, fixed carbon percentage, and calorific value.

Table 1: Percentage Values of Moisture Content of Briquette Samples

Sample	PMC (%)		
	Sawdust Particles	Palm Fruit Shell	Rice Husk
1	5.10	7.65	5.59
2	5.09	7.52	6.17
3	4.92	7.60	5.84

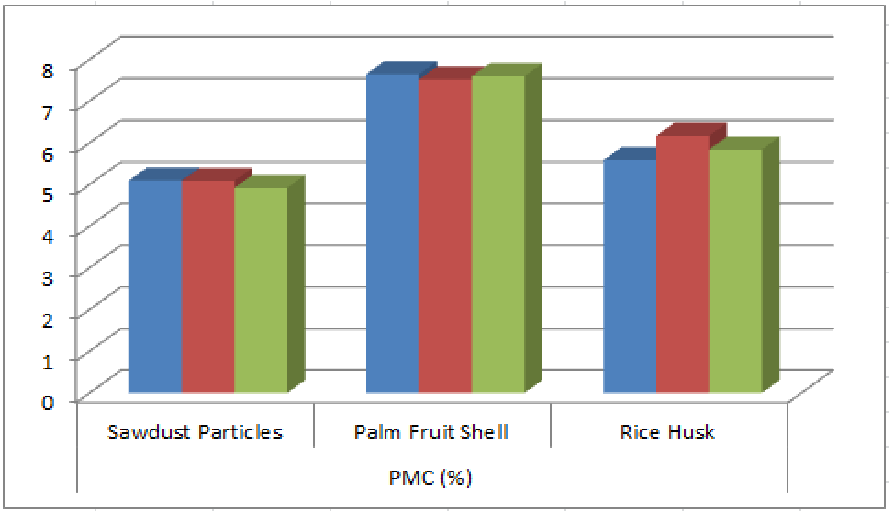


Figure 4: Graphs of Percentage Values of Moisture Content of Briquette Samples

The results in Table 1 and Figure 4 show that the average moisture content of sawdust particle briquettes is the lowest (5.04%) for all three samples. This means that briquettes made from sawdust particles will ignite faster than briquettes made from other samples. If the moisture content is low, the briquettes are more likely to ignite and a higher calorific value is expected [13]. The moisture content of briquettes increases with increasing binder concentration and decreases with increasing compaction pressure for all briquettes [4]. The results obtained for the produced briquettes are in agreement with the recommended value of a moisture content of 5–10% for high quality briquettes [15].

Table 2: Percentage Values of Volatile Matter of Briquette Samples

Sample	**PVM (%)**		
	Sawdust Particles	**Palm Fruit Shell**	**Rice Husk**
1	10.95	17.45	14.25
2	10.56	17.48	14.36
3	10.88	17.42	14.43

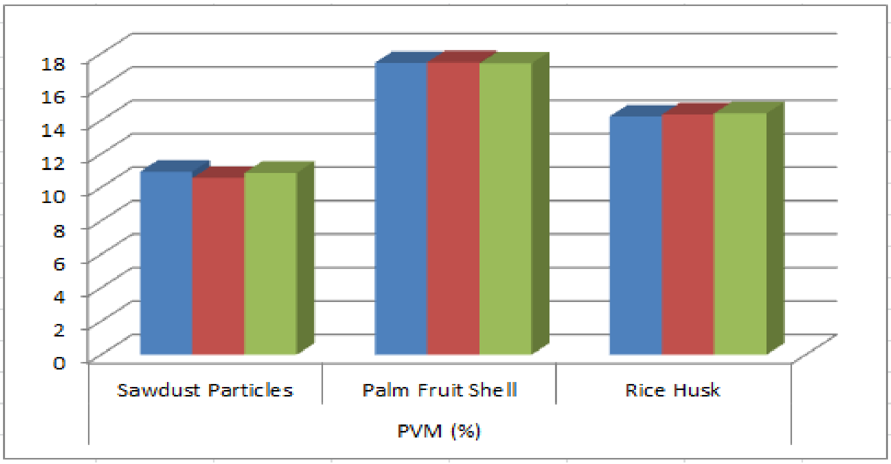


Figure 5: Graphs of Percentage Values of Volatile Matter of Briquette Samples

The results in Table 2 and Figure 5 show that the average percentage of volatile substances in palm shell briquettes is the highest (17.45%). The high content of volatile substances in briquettes indicates that they are easy to ignite, burn quickly, have a proportionately long flame length, but have a low calorific value. The proportion of volatile substances in the produced briquettes varies from 10% to 25% for high quality briquettes [4].

Table 3: Percentage Values of Ash Content of Briquette Samples

Sample	**PAC (%)**		
	Sawdust Particles	**Palm Fruit Shell**	**Rice Husk**
1	4.15	6.58	5.06
2	3.81	6.98	5.62
3	3.60	6.47	5.34

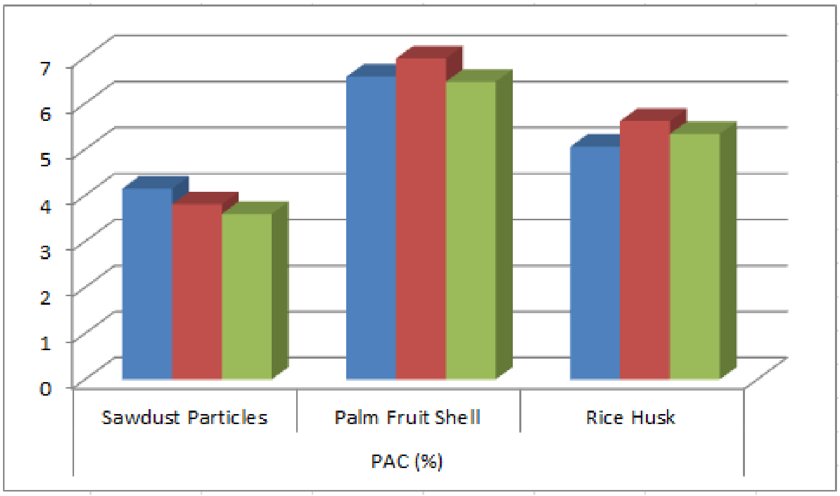


Figure 6: Graphs of Percentage Values of Ash Content of Briquette Samples

Knowledge of the ash content produced tells the extent of clogging up of the burning medium. Results from Table 3 and Figurs 6, revealed that the average percentage ash content for the sawdust briquette produced (3.85%) is the lowest. 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 [14]. 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 [7].

Table 4: Percentage Values of Fixed Carbon of Briquette Samples

Sample	**PFC (%)**		
	Sawdust Particles	**Palm Fruit Shell**	**Rice Husk**
1	80.50	68.32	75.10
2	81.24	68.02	73.85
3	81.10	68.51	74.39

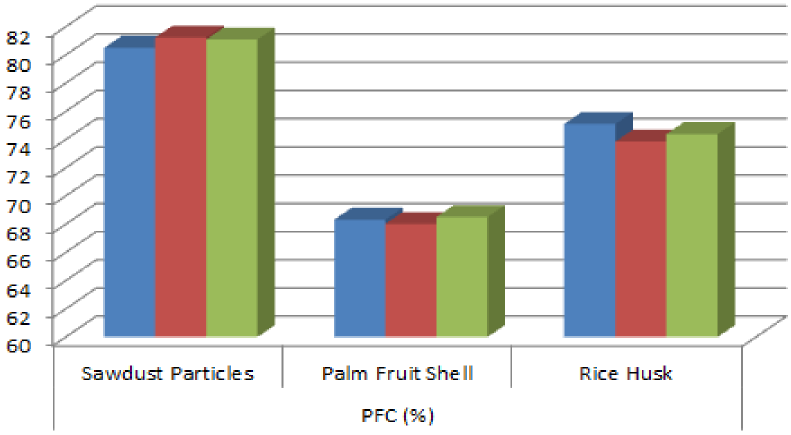
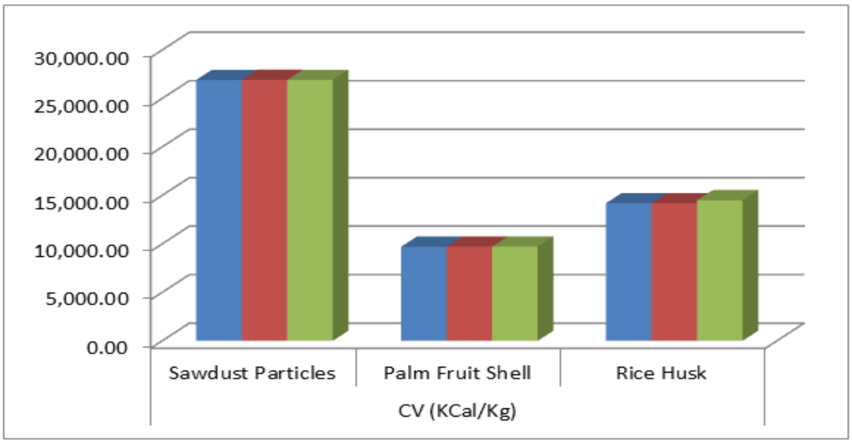


Figure 7: Graphs of Percentage Values of Fixed Carbon of Briquette Samples

Results from Table 4 and Figure 7, showed that the average percentage fixed carbon for the sawdust briquette produced (80.95%) is the highest. These results agrees with the reported suitability of briquettes with fixed carbon as 80.5% for domestic applications [15]. 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 [8].

Table 5: Calorific Values of Briquette Samples

Sample	**CV (KCal/Kg)**		
	Sawdust Particles	**Palm Fruit Shell**	**Rice Husk**
1	26,914.98	9,710.53	14,199.78
2	26,926.21	9,721.12	14,207.40
3	26,912.88	9,721.56	14,506.65



Figre 8: Graphs of Calorific Values of Briquette Samples

The calorific value determines the amount of heat energy present in a material. Results from Table 5 and Figure 8, revealed that the average percentage calorific value for the sawdust briquette produced (26918.02KCal/Kg) is the highest. The briquette samples produced were of high heating value enough for domestic use and small-scale industrial cottage applications.

4. Conclusion

This study focused on comparing the combustion properties of the obtained briquettes to evaluate sawdust, coconut husk, and rice husk particles. The combustion properties evaluated from the obtained briquettes confirm that the briquettes are suitable for domestic and small-scale industrial applications. The results obtained show that briquettes made from sawdust have the highest calorific value.

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