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Research Paper

Production of Fuel Briquettes from a Blend of Corncob and Rice Husk

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ABSTRACT

The main subjects of this study were the production of briquettes made from a mixture of corncob and rice husk. The calorific value of the manufactured briquettes and proximal and ultimate analyses were used to evaluate their combustion characteristics. The manufactured fuel briquette's ash, moisture, volatile matter, and fixed carbon content varied from 2.99 to 14.28, 4.24 to 14.99, 59.7 to 71.39, and 9.50 to 21.38, respectively. Its calorific value ranges from 11.98 to 15.55 MJ/kg. The maximum compressed density (2.1 g/cm3), relaxed density (0.82 g/cm3), shattering index (99.53%), and water resistance capacity (11.9 minutes) were found in maize cob briquettes with 0.2 mm particle size. Briquettes made from a mixture of rice husk and corn cob can be used as a source of cooking fuel and in small businesses like bakeries.

Keywords: Agricultural waste, fuel briquettes, corncob, rice husk

INTRODUCTION

The increase in urbanization and population expansion has caused a steady rise in the demand for traditional energy sources (Deac et al., 2016). Nearly 90% of the world's energy consumption comes from fossil fuels like oil, coal, and gas combined (NS Energy, 2015). However, significant issues are preventing the continued use of fossil fuels, including the inevitable depletion of the world's oil supplies, volatility in the petroleum market, and greenhouse gas emissions caused by the combustion of petroleum-based fuels (Oladeji, 2015). Therefore, a sustainable alternative energy source is necessary, especially in a developing nation like Nigeria (Stout and Best, 2001). When developed, biomass is a renewable energy source with a lot of potential and it provides significant environmental and economic benefits (FAO, 2010). A considerable amount of residue is produced during agricultural production, making collecting biomass simple. Nigeria is endowed with a wealth of biomass resources, particularly agroforestry waste and municipal solid waste, and its potential for energy production can be completely realized (Jekayinfa and Scholz, 2009). The country produces a lot of agricultural waste but doesn't do much with it. Most of it is burned or allowed to rot in the field, which degrades the environment (Jekayinfa and Omisakin, 2005). More research is being done on the possibility of using agricultural and agro-industrial waste as biomass fuel for power generation as an alternative to them. Agricultural leftovers could be gathered and processed in the home and industrial applications as a substitute energy source, either directly as solid fuel through combustion or by densification (Ajimotokan et al., 2018). However, due to their bulkiness, unevenness, and poor energy density, most agricultural wastes are not appropriate for direct use as fuel (Oladeji, 2010). They are challenging to handle, store, and transport due to their qualities. Therefore, a conversion process is required to turn these wastes for use as home and industrial energy. These residues can be turned into biomass energy by briquetting, a practical technology.

Briquettes made from agricultural waste are highly suitable for replacing fossil fuels currently in use and have considerable economic and environmental benefits (Yamaji et al., 2010). Solid material particles are compressed during the briquetting process to create blocks with a specific shape and size. This procedure enhances the biomass's handling properties while significantly increasing its calorific value (Ahmed et al., 2008). Paper trash (Chaney et al., 2010), rice husk (Saptoadi, 2008), sawdust (Mitchual et al., 2013), corn cob (Wilaipon, 2007), coal and corncob (Ikelle, 2014), and banana peel (Wilaipon, 2008) are just a few examples of the biomass briquettes that have been the subject of numerous studies. Therefore, this study aimed to produce briquettes using a mixture of corncob and rice husk. This is due to the country's abundant availability of both agro-residues. Making these wastes into a real source of energy that can be used for both home and industrial purposes will be a breakthrough.

Nigeria faces an environmental concern due to the rising pace of deforestation brought on by the cutting down of trees for charcoal in rural and some urban regions. A bill requiring manufacturers to obtain a license to generate charcoal legitimately has also been enacted into law by the Kwara State administration to lessen the harmful environmental effects of charcoal production. Since there are no other sources of revenue for many illicit producers, this approach has not truly been successful. Additionally, households now lack an affordable alternative energy source to charcoal. Therefore, it is crucial to quickly identify a suitable replacement that will require little upfront investment and be considerably more environmentally friendly. To reduce deforestation and environmental harm, this research looks for alternatives to firewood and charcoal.

The purpose of this research is the production of fuel briquettes from mixtures of carbonized corncob and rice husk. Given this, leftover corn cob and rice husk materials will be gathered and sorted; perform preliminary characterization of the biomass materials; pulverising the biomass and performing sieve analysis and densifying the biomass to make briquettes.

Overview of the Materials

Corncob

Corncob is a byproduct of agriculture made from maize and is still attached to the ear where the kernels develop. According to statistics on the production of corn worldwide, Nigeria produced 7.2 million metric tons of maize in 2016. For corn cobs, the crop to residue ratio is 0.273. (Alhassan et al., 2019). It is a biomass feedstock with direct potential as an energy source, making it appropriate for the production of biomass briquettes. Its density and uniformity, enhanced energy content, low sulfur and nitrogen contents, and other benefits make it superior to other biomass feedstocks (Extension Farm Energy, 2016).

Rice Husk

The tough protective layer that covers rice grains is called a husk. Throughout the growing season, it safeguards the rice. When rice is harvested, the husk makes up around 20% of the crop's volume, which makes it heavy, unwieldy, and possibly expensive to transport (Tatyana et al., 2016). When rice is processed at a rice processing facility, the membranes are separated, and the grain is crushed, ground, polished, and moved along elevators and conveyors, among other technological processes involved in the manufacture of rice. The agro-residues exhibit poor flow properties, higher potash content, and higher ash content than sawdust. But rice husk, as depicted in Figure 2.2, is unique biomass. It has good flowability, is often available with 10% moisture, and the high ash sintering temperature is caused by a lack of alkaline minerals in the ash. Despite having a lower calorific value than wood and other agro-residues, it makes an excellent fuel.

Biomass fuel briquettes

Briquettes made from biomass are a biofuel alternative to coal and charcoal. Briquettes are mostly utilized in developing countries with limited access to cooking fuel. They are created using various organic materials, including grass, leaves, sawdust, rice husks, corn cobs, banana peels, and other paper types. A briquette press is then used to compress these ingredients. Briquettes are more straightforward to create than fossil fuels because they come from a sustainable energy source (Shrestha, 2015).

Because they are compacted, biomass briquettes are preferable to lose biomass. They can burn for a more extended period, thanks to the compression. It is inexpensive and accessible to anyone.

Concept of briquetting

The process of compacting residues into a product with a higher density than the initial raw materials is known as briquetting, also known as densification (Kaliyan and Morey, 2008). By compressing these materials into a solid fuel with a practical shape that can be burned as solid fuel, briquetting aims to solve the issues these materials are known for, such as low thermal efficiency, complex handling, and transportation. Compared to the original garbage, briquettes have better physical and combustion properties. Rice straws, wheat straws, cotton stalks, rice husks, corn cobs, sugar cane waste (bagasse), fruit branches, and other materials make suitable raw materials for briquetting. Briquettes' appearance, burning properties, and compactness are all influenced by the type of feedstock, level of use, and mould (El-Saeidy, 2004; Wilaipon, 2009; Kaliyan and Morey, 2006).

Briquettes were a significant source of energy during the First and Second World Wars for heat and power generation (Yadong and Henry, 2000). Under the influence of fuel shortages, the briquetting of sawdust and other waste materials spread throughout several nations in Europe and America during this time. To make briquettes, various biomasses are being investigated. Kaliyan and Morey (2010) examined the properties of maize cob densification. The fuel characteristics of briquettes made from leftover rice husk and corncobs were assessed by Oladeji (2010). Chou et al. explored the manufacture and characterization of solid biomass fuel derived from rice bran and straw (2009). Yumak et al. (2010) created briquettes from soda weed (salsola tragus) to be used as a fuel source in rural areas. By Wilaipon and Acma (2013), the effects of briquetting pressure on banana-peel briquettes and banana trash in northern Thailand were studied, as well as the creation of bio-briquettes from carbonized brown seaweed (2009).

The handling and combustion attributes of agricultural leftovers are improved by briquetting. Studies have shown that after briquetting, the calorific value increases (El-Saeidy, 2004; Wilaipon, 2008). In comparison to raw agricultural residues and wastes, briquettes are simple to handle, inexpensive to store, and convenient to transport (Kaliyan and Morey, 2009). The briquetting process assists in resolving the issue of biomass leftovers being difficult to dispose of and sometimes causing pollution problems (Ndiema, et al., 2002). Briquetting raw materials are easily accessible everywhere in the world, particularly in less developed nations. Additionally, low-cost equipment can be utilized for densification. Briquette burning is potentially clean and smokeless, and it doesn't frequently cause eye and respiratory illnesses in women and children who are typically engaged in domestic tasks (Shakya, 2002). Briquetting fuel promotes and maintains a green environment. This is because most of these leftovers are gathered for briquetting, preventing the open-air burning of residues. By giving people an alternative to burning wood for fuel, the procedure also helps to stop deforestation. Because they are made from biomass waste, they have reduced overall fuel costs for users. Lastly, the briquetting process creates employment prospects (El-Saeidy, 2004).

There are several types of briquetting machines available for the densification of agricultural wastes. Examples are:

Screw Presses

In developing nations, screw presses are a standard densification tool that works well for small-scale applications. Japan is where the technology was created and invented in 1945. (Grover and Mishra, 1996). The machine feeds raw materials constantly through a screw that presses them into a cylindrical die. To get the temperature in this die high enough for lignin flow, it is frequently heated. The temperature may not rise enough to enable lignin flow if the die is not heated, in which case binding materials may need to be added (Tabil, 1997). Compared to piston presses, the screw press may create denser and stronger briquettes (Singh et al., 2007).

Piston Presses

Contrary to screw presses, the machine's cylindrical die is not continuously supplied with raw materials. A piston then forces the material into a die with a small taper. A piston press creates solid briquettes. There are essentially two types of piston presses. The piston presses mentioned here are mechanical and hydraulic (Grover and Mishra, 1996).

Mechanical Piston Press

This piston press uses an electric motor that has been geared down using a belt coupling as its main drive. Most materials can be turned into hard, dense briquettes using mechanical presses. In Switzerland, during World War II, the contemporary style of mechanical piston press was first developed.

Hydraulic Piston Presses

The principle of operation is the same as with a mechanical piston press. The main difference is that energy to the piston is transmitted from an electric motor via a high-pressure hydraulic system (Grover and Mishra, 1996).

Review of Related Studies

The project "Physico-Mechanical Characterization of Fuel Briquettes produced from Blends of Corncob and Rice Husk" was undertaken by Ajimotokan et al. in 2018. It was established that the investigated physicomechanical properties of the created briquettes were strongly influenced by variations in the particle size of the corncob and rice husk components, as well as the mixing ratio and compaction pressure. The study assessed a number of the physical and mechanical characteristics of fuel briquettes, including compressive strength, durability, and green and relaxed densities. The highest compressive strength of 111 kN/m^2 was achieved by the briquette made from an 80:20 mixture of corncob and rice husk with 0.25 mm particle size at 65 kPa compaction pressure. The briquette's lowest compressive strength of 39 kN/m2 was achieved. The study also demonstrates that briquette durability rises as particle sizes are decreased.

Production and Characterization of Biomass Briquettes from Tannery Solid Waste was the focus of Onukak et al. (2017)'s research. The study's subjects were the production and characterization of biomass briquettes from tannery solid wastes. The samples were subjected to proximate analysis and scanning electron microscopy. The six briquettes were shaped and given different proportions of hair, flesh, chrome shavings, and polishing dust. The six briquette formulations also investigated properties like compressive strength, thermal efficiency, and durability. The generated briquettes had calorific values ranging from 18.632 to 24.101 MJ/kg. The briquettes' levels of durability ranged from 98.12 to 99.77 per cent. In comparison to other fuel sources like sub-bituminous coal (20.00 - 24.73 MJ/kg), the energy values were in the range of 17.462-24.101 MJ/kg. This study demonstrates how solid waste from tanneries may be used to make fuel briquettes, a renewable energy source. It is more inexpensive, cost-effective, and environmentally benign than fossil fuel.

The "Characterization and Production of Banana Crop and Rice Processing Waste Briquettes" focus of Maia et al. (2017). Banana leaves, pseudostem, rice husk, High Heating Value (HHV), Thermo Gravimetric Analysis (TGA), and Differential Scanning Calorimetry were prepared and analyzed, according to the report (DSC). In a hydraulic press operating at 18 MPa for one second, samples were prepared and compressed into briquettes. The same studies employed in waste and mechanical compressive strength were utilized to characterize the final briquettes. Notably, the briquettes released the most energy when burned at temperatures lower than the garbage. The energy output from the rice husks and their briquettes was less than other garbage. The waste's HHV ranged between 15 and 18 MJ/kg. The rice husk's HHV increased due to the waste being compacted, and the briquettes had the maximum compressive strength, measuring 19 MPa. The banana leaves offered the finest features, qualities, and potential for producing energy as briquettes among the three waste samples that were examined.

A study on "Effects of operating variables on the durability of fuel briquettes from rice husks and maize cobs" was undertaken by Muazu and Stegemann in 2015. The study provided fresh evidence to demonstrate that mixing various types of biomass enhances the qualities of densified biomass briquettes. A factorial experiment was used to examine the effects of sample batch (biomass source), material ratio (rice husks to corn cobs), binder addition (starch and water mixture), and compaction pressure on briquette qualities. The briquettes were stronger than briquettes made from separate ingredients and had a unit density of up to 1.9 times that of loose biomass. An unconfined compressive strength of 176 kPa was obtained for a 3:7 blend of rice husks to maize cobs with 10% binder at a compaction pressure of 31 MPa by taking average values from two biomass sources into consideration. These briquettes were strong, with only 4% mass loss during abrasion testing and 10% mass loss during shattering tests. Compared to loose corn cobs, they only absorbed 36% as much water. A statistical examination of the study's findings revealed that adding flour and water was necessary for acceptable briquette strength but that doing so drastically decreased the green and relaxed densities. It was noted that the source of the biomass had a considerable impact on densification, highlighting the significance of comprehending the variables causing biomass variability.

The "Production and Characterization of Hybrid Briquettes from Biomass" was the focus of Imoisili et al. (2014). The study aimed to produce and characterize hybrid biomass briquettes utilizing sorghum dust, albiziazygia sawdust, and cassava starch as a binder. The physical and mechanical characteristics of the sawdust/sorghum dust hybrid briquette were assessed using tests for moisture content, compressive strength, ash content, calorific value, and burning efficiency. Five different compositions of the hybrid briquette were created. The study's test results revealed that the moisture content could range from 6.83 to 29.70%. The compressive load at break can be anywhere between 4.94 and 15.18 kN, the ash content can be anywhere between 2.85 and 17.14 per cent, and the calorific value can be anywhere between 3.83 and 10.43 MJ/kg. The burning efficiency can range from 1.57 to 6.63%.

Aia et al. (2014) worked on the Production and Characterization of Fuel Briquettes from Banana Leaves Waste. They pointed out that growing bananas produce a lot of trash, some of which can be utilized for briquetting. In their research, semi-dried banana leaf fragments were crushed between 2 and 5 mm in size, and their moisture content was calculated. The briquettes were made in a hydraulic press using two compressing times and a compaction pressure of 18 MPa. The briquettes were then tested for bulk and energy density, linear shrinkage, mechanical compressive strength, high heating value (HHV), thermogravimetric analysis (TGA), and differential thermal analysis (DTA).

They stated that the banana leaf briquettes had a moisture content of 7.2%, a high carbon (44.3%) and volatile matter (75.3%), a low amount of sulphur and nitrogen, and an HHV of 17.7 MJ/kg. These outcomes hold for other biomass that is used to make briquettes. The briquettes demonstrated considerable mass loss during combustion in TGA and DTA analyses, with maximal energy release occurring between 200 and 500 degrees Celsius. The banana leaf briquettes' thermal qualities and physicochemical traits show how useful they could be as a biomass fuel source.

"Production and Characterization of Briquette Charcoal from Carbonization of Agro-Waste" was the focus of Zubairu and Gana's (2014) research. Four distinct types of charcoal briquettes were made from corncobs carbonized in a metal kiln and bound with tapioca starch. The bulk density ranged from 425.6 to 358.3 kg/m2, the fixed carbon content was found to range from 72.776 to 81.884 per cent, the ash content for the briquette grades was 21.38 to 11.49 per cent, the moisture content was 5.88 to 6.63 per cent, and the fixed carbon content ranged from 72.776 to 81.884 per cent. The characteristics of the created briquette charcoal were then contrasted with those of wood charcoal and sugarcane bagasse. Due to its higher fixed carbon content and bulk density compared to both wood charcoal and sugarcane bagasse, briquette charcoal was determined to be a better fuel. The corncob briquettes' moisture level was higher than that of wood charcoal but lower than that of sugarcane bagasse. Additionally, it was discovered that compared to all five charcoal grades produced, sugarcane bagasse and wood charcoal had lower ash contents (4.33 per cent and 9.80 per cent, respectively). The mean calorific value of the briquette charcoal was 32.4 MJ/kg, which was significantly greater than the values for bagasse (23.4 MJ/kg) and wood charcoal (8.27 MJ/kg).

A study on "Use of Banana Culture Waste to Produce Briquettes" was done in 2013 by Selin et al. The preparation procedures and characterization of banana wastes (leaves and pseudostem) for briquette manufacture were provided in the study. Chemical analysis, high heating value (HHV), thermogravimetric analysis (TGA), and differential thermal analysis were used to analyze the wastes and briquettes (DTA). The briquettes' mechanical compressive strength was also assessed. The wastes for briquetting must have a moisture level of between 8 and 15%. The carbon levels of the pseudostem and banana leaves were 43.28 per cent and 38.92 per cent, respectively. The HHV of the pseudostem was about 13.70 MJ/kg, but the HHV of the leaves was roughly 17.10 MJ/kg. Under burning, the wastes released the most energy at around 580 °C, while briquettes did so at 300 °C. The compressive strengths of the pseudostem and leaf briquettes were 15 MPa and 5.3 MPa, respectively. These wastes are viable candidates for making briquettes for fuel in several applications based on their thermal properties and physicochemical traits.

The effects of some processing parameters on the physical and densification characteristics of corncob briquettes were studied by Oladeji and Enweremadu in 2012. The study looked at how corncob briquettes' physical and combustion properties were affected by processing variables such as compaction pressure, % binder ratio, and particle size. At a moisture level of 10.96 dry bases, corncobs were gathered from a farm dump, reduced, and sieved into S1, S2, and S3 particle sizes. The average moisture level of the corncob residue was 9.64 per cent, compared to 7.46 per cent for relaxed briquettes. It was discovered that the relaxed briquettes' bulk density, which is 315 kg/m3, is greater than the leftover materials, which is 50.32 kg/m3. This resulted in a volume reduction of 626 per cent. The range of the compaction ratio was 2.27 to 6.50. Binder ratio B1 (20%), particle size S3 (0.60 mm), and pressure P3 (6.6 MPa) showed the best results for the three processing parameters examined.

Material preparation

The systematic methodology used in this investigation included sample collection and sorting, preliminary sample characterization, sample pulverization, and sieve analysis, briquette manufacture, burning, and physicomechanical characterization.

Preliminary characterization of the raw samples

Both the University of Ilorin Central Research Laboratory and the Integrated Research Laboratory, Tanke, Oke-Odo, Ilorin, Kwara State, conducted preliminary characterization. The raw samples' volatile matter, moisture content, ash content, fixed carbon content, and higher heating value were all identified. The ASTM standard E871-82 (1998) was used to calculate the moisture content. The samples of crushed biomass were repeatedly oven-dried at 103 ±1 °C until a consistent mass was attained. The moisture content was then calculated using a change mas after 24 hours. The percentage of the volatile matter was calculated following ASTM standard D3175-11 (2013). It was calculated as the weight percentage of gas released from the sample following heating to 950°C in an atmosphere devoid of oxygen, after draining off the moisture content that turned to water vapour throughout the process. The ASTM standard D3174-12 (2013) was used to determine the percentage ash content (AC). The material was ground into a powder, weighed, and then burned for an hour at 500°C to 750°C. The percentage of ash content was calculated by comparing the weight of the sample after combustion to its initial weight. The amount of non-volatile carbon still present in the sample, as defined by ASTM standard D3172-07 (2013), was used to calculate the percentage of fixed carbon (FC). It is calculated as the percentage of the material that was lost during the testing of the moisture, volatile matter, and ash content. The sample's higher heating value (HHV) was determined according to ASTM standard D5865-10a (2013) to be the quantity of heat released from the sample during the test in a ballistic bomb calorimeter. A standard sample of Benzoic acid of known calorific value was used to calibrate the bomb calorimeter.

$$Q = \frac{\text{Galvanometer deflection} \times \text{calibration constant}}{\text{original weight of sample}} \qquad (1)$$

Pulverization and sieve analysis of biomass feedstock

The biomass samples were crushed using a locally grinding machine and screened to 0.2, 0.6, 1.0, and 1.4 mm particle sizes at the Soil Laboratory of the Department of Civil Engineering, University of Ilorin, Ilorin, Kwara State.

Briquette production

The materials were thoroughly mixed before being ground up to create blended briquettes. The ratios of corn cob to rice husk used to make the mixture were 80:20, 70:30, 60:40, and 50:50. A mixture of 130ml of starch and 180ml of distilled water was gelatinized by the addition of 270 ml of boiling water to create a starch gel, which was then employed as the binder (Ajimotakan et al., 2019). 15% of the weight of each mix was made up of the gelatinized binder. Afterwards, a mixer was used to combine the prepared corncob and rice husk mixtures with the starch gel binder. After that, the feedstock was placed into a ready mould. The feedstock was densified using a 40 MPa hydraulic jack machine (Patent No. NG/P/2022/194) at Ilorin, Nigeria. Each briquette had a 120-second dwell time., which was positioned between the machine's compressive plates, and the piston was manually lowered onto them to apply the proper amount of force to the aggregates. At compaction pressures of 5MPa, briquettes were created. After raising the piston, the briquette was finally discharged from the mould. The samples of briquettes were then exposed to the sun for 14 days to dry out any remaining moisture. The corncob feedstock, Rice husk feedstock, and the samples of fuel briquettes produced from a blend of corncob and rice husk are shown in Figures 1-3 respectively.

Figure 1: Corn cob feedstock

Figure 2: Rice husk feedstock

Figure 3: The samples of fuel briquettes produced from a blend of corncob and rice husk

Physico-mechanical analysis of the briquette samples

Density

A digital weighing scale and a Vernier calliper were used to measure the mass and dimensions of samples shortly after the briquettes were made to calculate the compacted density. After the briquettes had been sun-dried for two weeks, the relaxed density was calculated using ISO standard 3131. (1975).

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad (9)$$

$$\text{Volume} = \pi h R^2 \qquad (10)$$

where h is the height of the briquette,
R is the external radius of the briquette

Shattering index

This was measured by repeatedly dropping briquette samples onto a solid foundation from a specific height of 1.85 m (Odusote & Muraina, 2017). As a measure of briquette breakability, the percentage of the briquette that was retained was used. The ultimate weight of the created briquette after the drops is compared to the original weight to get the percentage shattering index.

$$\text{Shattering index} = \frac{\text{weight of briquette in plate after 4 drops}}{\text{the initial weight of sample}} \times 100\% \qquad (11)$$

Water Resistance Capacity

The amount of time it took for the briquettes to collapse after being submerged in a container was used to calculate their water resistance capacity.

$$\text{Water resistance capacity} = \text{Time taken in seconds for briquette to collapse in water} \quad (12)$$

Drop to fracture

By dropping a sample of the fuel briquettes from a height of 1.8 meters, the drop to fracture was calculated. Samples of briquettes were dropped repeatedly until they broke. The drop to fracture was the total number of drops necessary for the briquettes to break.

Compressive strength

The compressive strength is assessed using a Universal Testing Machine (Model: FS5080). Following the ASTM standard procedure, this test was carried out at the Mechanical Engineering Department of the University of Ilorin in Nigeria (ASTM D2166-85, 2008). Twenty-one days after drying, the compressive strength experiment was carried out. In doing so, the briquettes will be able to develop their full strength. The compressive strength of the briquettes was measured as the greatest stress for each trial. Three tests were conducted, and the average was then reported.

RESULTS AND DISCUSSION

Physicomechanical characteristics

Green density

The impact of the blending ratio and particle size on the green density of the resulting briquettes is depicted in Figure 4. The densities of the compressed materials ranged from 1.33 g/cm3 to 2.1 g/cm3. The crushed density of a briquette formed from 1.4 mm particle size was the lowest at 1.33 g/cm3, and the highest was 2.1 g/cm3 for a briquette made from 0.2 mm particle size. Figure 4 shows that an increase in the proportion of rice husk causes the compressed density to rise. This might be related to the different bulk densities of the raw materials used to make the briquettes; rice husk had the highest bulk density (Oladeji, 2015). Additionally, as the particle sizes of the briquette samples were reduced, the green density rose.

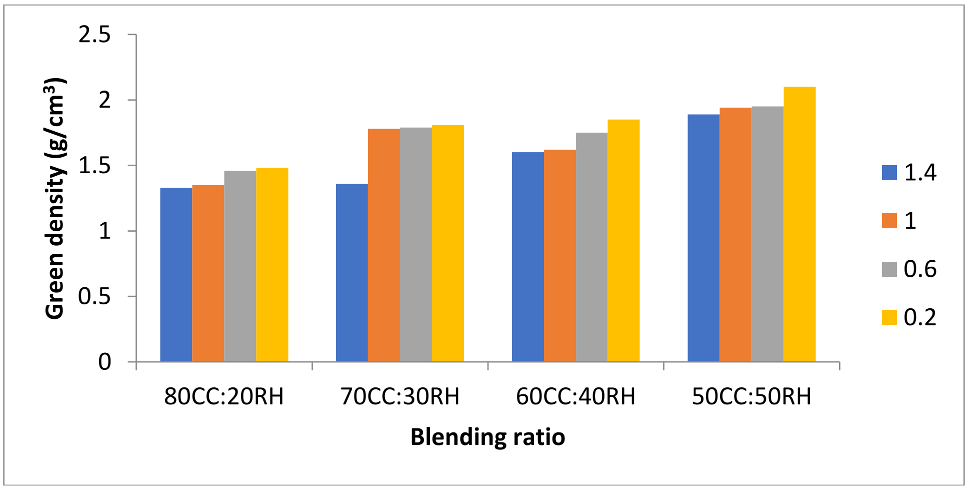

Figure 4: Effect of blending ratio and particle size on compressed

Relaxed density

According to Figure 5, relaxed density rises as the fraction of rice husk and particle sizes decrease. This finding was consistent with the study by Ajimotokan et al. (2019). The relaxed density was likewise found to be lower than the comparable green density. The loss of surface water during the drying process may explain this. Similar patterns may be seen in the fluctuations of the relaxed density and the green density.

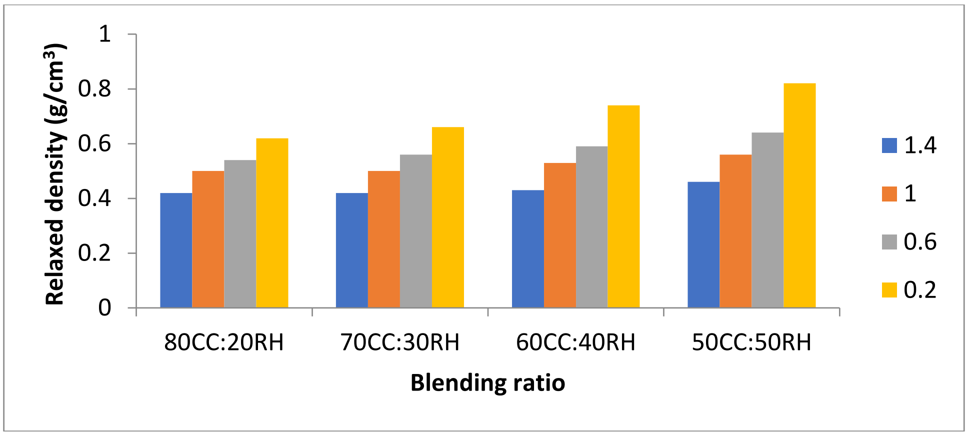

Figure 5: Effect of variations of mixing ratios and particle size on relaxed density

Shatter index

Figure 6 illustrates how particle size variation and blending ratio affect the briquettes' ability to fracture. Particle size was found to have a significant impact on the briquettes' shattering index, ranging from 44.51 to 99.85%. The shattering index increased when particle size decreased. This is caused by the cohesive forces and intermolecular bonds between the briquette's smaller particles. It was found that the shattering index fell as the proportion of rice husk in the blends rose. This suggests that a rice husk is less resilient than a corncob. This indicates that corncobs have a significant impact on enhancing the fuel briquettes' shatter index feature.

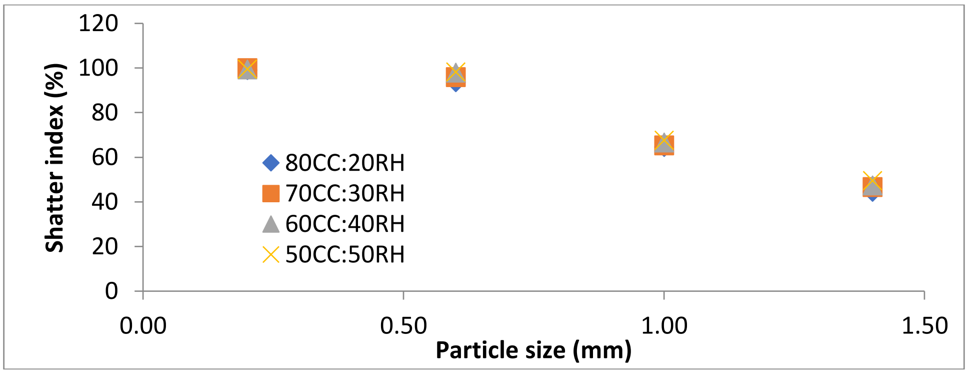

Figure 6: Effect of variations in compaction pressure on the shattering index of briquettes produced

Water resistance

The impact of the blending ratio and particle size on the ability of the resulting briquettes to resist water is depicted in Figure 7. The time underwater ranged from 11.9 to 4.9 minutes. The 50CC:50RH briquette with 0.2 mm particle size exhibited the most extended water resistance capability (11.9 minutes). The findings demonstrate that increasing the rice husk in the mix increases the blend's ability to repel water. Because the rice husk particles are entangled, there is less pore space between them, which limits water absorption and percolation.

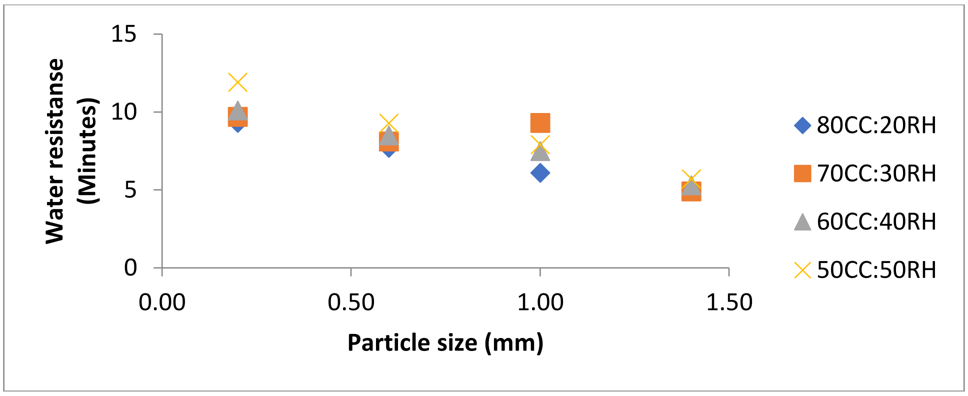

Figure 7: Effect of variations in compaction pressure on water resistance capacity of briquettes produced

Drop to fracture

The briquettes' capacity to withstand impact forces is measured by their drop to a fracture. Figure 8 illustrates how particle size and blending ratio change as a drop approaches fracture. The briquettes' drop to fracture rate ranges from 2 to 13 times. The percentage of rice rusk in the mix that causes the drop to fracture to increase also increases when the particle size of the briquettes decreases. Lesser pore gaps, stronger intermolecular bonding, and high interlocking and cohesive strength are characteristics of the smaller briquette particles. These are a reaction to the greater drop-to-fracture characteristics observed with the briquette output in this study.

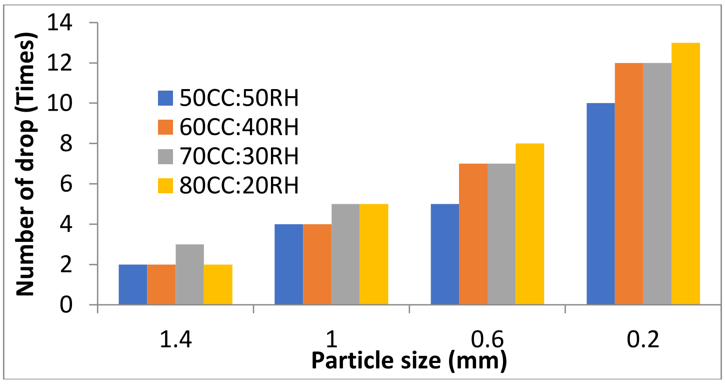

Figure 8: Variation of particle size and blending ratio with a drop to fracture

Compressive strength

Strength is a significant factor that enhances the longevity of briquettes. According to the findings in Figure 9, briquette blends with 0.2 mm particle size, 80:20 (corncob: rice husk) mixing ratio, and 82 kN/m^2 compressive strength had the most outstanding results. Compared to the results published by Ajimotokan et al., the current study exhibits poor compressive strength characteristics (2019) 111 kN/m^2 is used. The type of the material and the briquette-making process may be to blame for the variation. Additionally, as shown in Figure 4.8, sample grain size plays a significant role in the strength of blended briquettes. As the particle size decreases, the briquette's strength rises. This suggests that the finer the briquette particle, the smaller the pore spaces between the particles, and the more tightly the particles interlock, increasing the briquette's strength. Additionally, it was shown that as the amount of rice husk in the mixture increases, the strength of the briquette decreases. This demonstrates how the corncob was essential in increasing the compressive strength of the blended briquette.

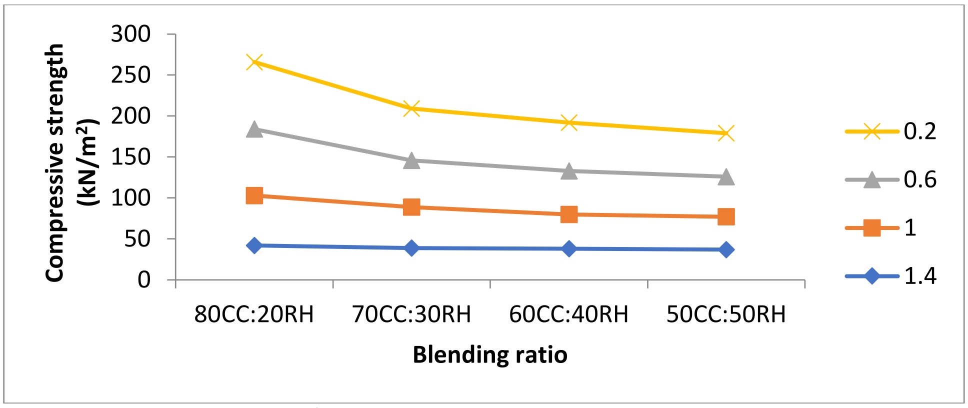

Figure 9: Variation of particle size and blending ratio with compressive strength

CONCLUSIONS

Rice husk and corncob residues, which are produced in large quantities and carelessly disposed of in Nigeria, can be used to make low-cost fuel briquettes that will satisfy the public's need for energy while reducing the harmful effects of charcoal production. The main subjects of this study were the creation and evaluation of briquettes made from a mixture of corncob and rice husk. A few physical and mechanical characteristics were determined, including compressed and relaxed densities, relaxation ratios, shattering indices, and water resistance capacities. The physicomechanical characteristics of the briquettes were shown to be affected by differences in particle size and compaction pressure, with samples with smaller particle sizes exhibiting the best characteristics. The maximum compressed density (2.1 g/cm3), relaxed density (0.82 g/cm3), shattering index (99.53%), and water resistance capacity (11.9 minutes) were found in maize cob briquettes with 0.2 mm particle size. Most of the combustion and physicomechanical properties of the briquettes generated were reduced as the amount of rice husk in the briquette blends increased. Briquettes made from a combination of corncob and rice husk can be used as a source of cooking fuel and in small businesses like bakeries.

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