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Fabrication and Characterization of Charcoal Briquettes Fuel from a Blend of Coconut Husk and Corncob

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Energy is very essential to human livelihood and makes significant help to economic, social, and environmental features of human development. Biomass is certainly a very significant source of renewable energy worldwide and abundant with high energy potential. This research aimed to characterize and produce briquette fuel from the combination of coconut husk and corncob using starch as a binder. The composite briquettes were produced by varying the mixture ratio of coconut husk to corncob (CH: CC), 80:20, 60:40, 50:50, 40:60, 20:80 using starch as a binding agent. The physical and combustion characteristics were analyzed according to the America Society of Testing of Materials Standard. It was observed that the moisture content decreased from 5.02% to 4.88%, fixed carbon increased from 74.20% to 75.13%, volatile matter increased from 20.20% to 21.70%, Ash content decreased from 5.60% to 3.17% and the calorific value increased from 20.35 MJ/kg to

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26.75 MJ/kg. The findings also show that the maximum density and durability indexes were 839 kg/m^3 and 98.58%.
The briquette at the ratio 20:80 of coconut husk to corncob has the highest calorific value and implies that it has more heating advantages and will therefore be suitable as an alternative solid fuel.

Keywords: Biomass; coconut husk; corncob; moisture content; volatile matter; calorific value; ash content.

1. INTRODUCTION

"The usage of wood is growing on a daily basis, particularly in developing countries. Globally biomass energy has continued to remain an important renewable energy component. It is an important component of the national energy mix both for developing and developed countries towards achieving sustainable energy for heating applications, reducing environmental impact, creating bio economies, reducing environmental dependence on fossil fuel, improving the quality of rural and urban life, and for the production of various biofuels. This frequently leads to indiscriminate cutting down of trees used as fuelwood and charcoal which leads to deforestation" [1].

"Due to its availability, local consumers of fuels in developing countries are frequently tied to charcoal, particularly in urban area" [2]. "Notwithstanding forest management systems employed in some countries, wood is usually obtained from natural forests and very regularly harvested illegally, defeating the laws in place for biodiversity preservation, ecosystem conservation, and the country's Intended Nationally Determined Contribution to emission reduction. Traditional charcoal-making processes typically lead to the highest emissions of CH4 and carbon dioxide. Moreover, they commonly require 6 kg of wood per kg of charcoal produced" [3-5] "In the year 2000, indoor air pollution from burning solid fuels was to blame for 2.7% of the world's disease burden and more than 1.6 million annual deaths" [6]. Despite being aware of the negative effects on health and the environment, there is still a clear dependence on wood and charcoal [7-9]. Making briquettes from agricultural waste can help the environment and prevent further deforestation [10]. Biomass-derived briquette made from agricultural waste adds to the mix of energy sources. Researchers are now interested in the benefit of turning biomass, which has a high moisture content, low calorific value, and low density in its raw form, into highly effective fuel briquettes [11].

"A perennial fruit such as the coconut grows well on sandy soils and does best on islands and coastal regions in tropical and rainforest climates, especially along coastlines where it receives both water and sun irradiation" [12]. "Globally, several million tonnes of coconut are produced annually in Asia, Latin America, and Africa. As of the year 2018, the total world production of coconut was 250–300 million tonnes" [13]. "Every part of the coconut plant is useful with a wide range of products being obtained from it" [14–17]. "Fresh coconut fruit is appreciated for its juice, food, and animal feed; coconut husks are used as raw material supply [18–23] and for wall hangings; fibers are used for clothing and bags, among other uses" [24]. "The shell normally takes a long time to decompose and often becomes a nuisance. Coconut husks with the shells attached and other biomaterials including straw, rice husks, corn stalks, sawdust, cereal husks, sugarcane bagasse, and nutshells are a potential bioresource that can be used as domestic fuel [25] in energy-poor communities, such as those found in Ghana where about 73% of households depend on firewood for cooking and water heating" [26].

Coconut husk and corncob as a form of renewable energy have not been adequately investigated: This project looks at the suitability of blending coconut husk and corncob to produce clean affordable and capable of giving better combustion.

2. MATERIALS AND METHODS

The method used in this research is an experimental method implemented in the laboratory.

2.1 Materials

The materials used include coconut husk, corncob, cassava starch as a binder and water. The tools used include a metallic container serving as a kiln, oven, 60 mesh sieve, crucible briquette compressor, muffle furnace, desiccator, bomb calorimeter, digital weighing scale, Vanier caliper, and manual briquette molding tool fabricated at the mechanical work of academic city university college was used.

2.2 Methods

The production of the coconut husk and corncob briquettes involved the following steps collection of raw materials, pyrolysis, briquette preparation, and test analysis of briquette samples using different ASTM standard methods.

2.2.1 Pyrolysis of coconut husk and corncob

The pyrolysis of the CH and CC was done following the experiments conducted by Gregory & Romo (2015) and Amy (2009). The CH and CC were sun-dried in the open air at an ambient temperature of 32 C for 7days before experimentation to reduce the moisture content. The collected sun-dried CH and CC weighing 10000 g were divided into two sections, 5000 g each, and then packed into two (2) metallic containers serving as a kiln. The pyrolysis was carried out within the metallic bucket. A metallic bucket measuring 20 cm in width on the top and bottom, with a height of 2 cm was employed. A hole of diameter 15 cm was created at the side of the metal container's cover (Fig. 1b) with the aid of a knife. A two-way open cylindrical pipe container measuring 29 cm (length), and 14.9mm (diameter) was inserted through the created hole within the cover (Fig. 1b) to act as a chimney. A hand full of biomass was used in the firing portion to ignite the CH within the metallic container. The initial smoke, from the ignition, was allowed to set out after which the sides of the metallic container were covered with sand to ensure enclosure. After loading the biomass into the container, the top was closed with the cover and attached conical chimney. The metallic combustion container and coconut husk are now ready for pyrolysis. In the initial stage of combustion, the color of the initial smoke observed from the pyrolysis process of the coconut was creamy brown, as seen in Figure. The CH and CC were left to burn entirely for 2 h into biochar. The percentage of recovery for the char was recorded 23%.

2.2.2 Briquette samples preparation

The coconut husk and corncob char were grounded using a mortar and pestle and screened through a 60-mesh sieve to create homogeneity. The process flow of the husks briquette is shown in Fig. 1. Twenty grams (25 g) of cassava starch was dissolved in a bowl containing 40 ml of cold water and mixed initially to obtain a cassava paste. A Hundred (100) ml of water was put to boil in a pot after which, it was added to the cassava paste and mixed properly with a stirrer to form starch. The grounded biochar of CH and CC fine particle size were blended at mixing ratios of 80:20, 60:40,50:50,40:60, and 20:80 was gradually added to the 10% of the starch gel and mixed using a stirring stick until a thick, black compound was formed. The compaction of the briquette was carried out manually with a briquette machine (Fig. 1e) for every 160 g of powdered samples. The total quantity of biochar used as well as the number of briquettes produced were 2345 g and 23 briquettes respectively. The essence of using this type of pressure was to make the briquettes, as it would be in the absence of expensive briquette machines. This method is targeted at the rural population who may not have access to briquette machines. After the briquette stage, the molded thick paste was sun-dried for one week. Proximate, combustion tests were further conducted on the briquette after a week of sun drying.

2.2.3 Determine the characteristics of briquettes

Analysis of briquettes quality includes the density, the durability index, the proximate test (moisture content, ash content, fixed carbon, volatile content), and the heating value (calorific value) were further conducted on the briquette after a week of sun drying using different ASTM standard methods.

a) Waste Coconut husk & Corncob

b) Pyrolysis process

c) Grounded biochar

d) Mass measurement

e) Briquette machines

f) Briquettes

Fig. 1. Shows the briquette fabrication process

3. RESULTS AND DISCUSSION

3.1 Mass Density Test of the Briquettes

Density is an important characteristic of fuel. It is an indication of energy density. The results (Table 1) show the density of briquettes at varying mixture ratios. From the results, the density of mix ratios of CH: CC increased to 839.8 Kg/m3 for 20:80 mix ratios. This could be attributed to characteristics of the original materials which were the coconut husk and corn cob. This shows that the density of corn cob is higher than that of coconut husk, and agrees with the findings of [27] who found that varying ratios of materials have a direct impact on densities.

3.2 Durability Index

The briquette's durability index is measured as a percentage of the initial mass of the material left on the metal plate. It shows how the particles joined throughout the briquette manufacturing process. The durability index ranged from 96.67% to 99.96% based on the results. The mix ratios did not affect the durability index. This means that the composition ratios had no meaningful effect on the bonding effect of the adjacent particle. The impacts of mix ratios on the durability index are shown in Table 1 and Fig. 3. Briquette strength affects briquette durability because as strength increases, air humidity absorption decreases. [28] discovered that increasing the amount of binder and the type of binder has a substantial impact on the briquettes' durability index. The durability index of 98.74% obtained in gum Arabic bonded briquettes was higher than 83.26% obtained in starch bonded briquettes, and the values were statistically significant at the 5% probability level, which concurs with the findings of this study. The study's average durability index was 98.43%, which is comparable to that of the Gum Arabic binder. This indicates that the starch binder has strong adhesive properties.

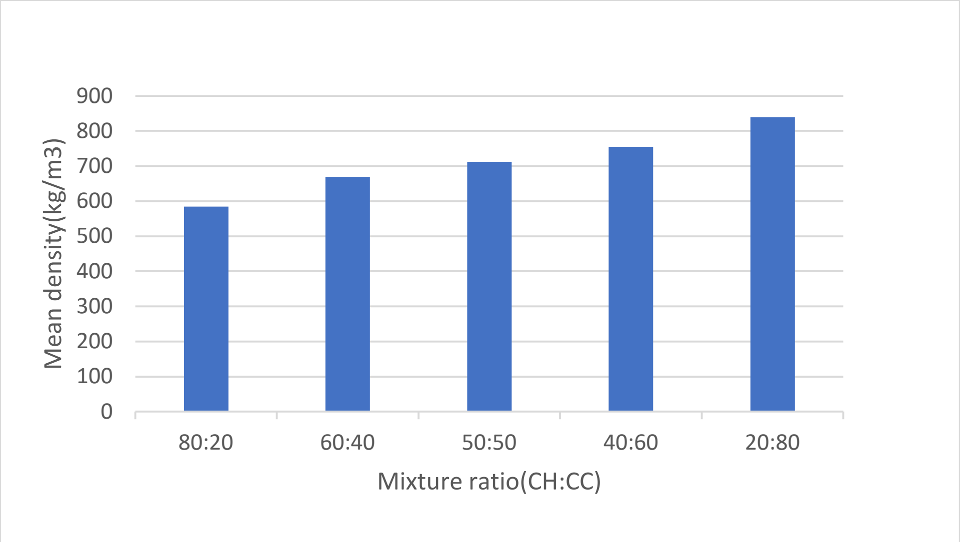

Fig. 2. Effect of mix ratios on the density

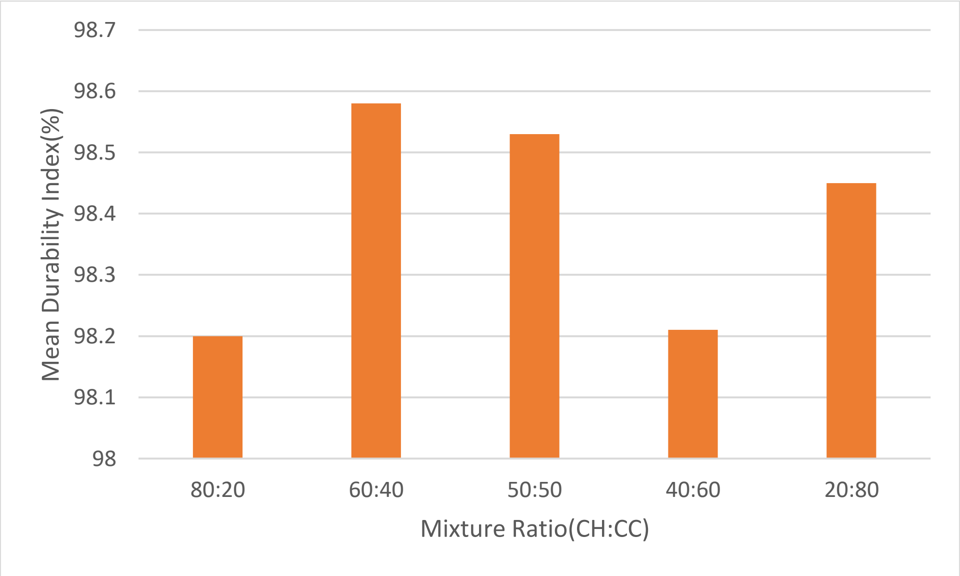

Fig. 3. Effect of mix ratios on mean durability index (%)

Table 1. Density (Kg/m3) and durability index (%) of briquette at different mix ratios

Mixture Ratio (CNH: CC)	Mean density (kg/m3)	Mean durability index (%)
80:20	584.2	98.20
60:40	669.4	98.58
50:50	712	98.53
40:60	754.6	98.21
20:80	839.8	98.45
Average	712	98.39

3.3 The Proximate Test

To know the quality of briquettes produced it is necessary to do the proximate test which includes moisture content, ash content volatile matter content, and fixed carbon content.

3.3.1 Moisture content

Moisture content has an impact on the fuel's combustion properties. High moisture content is undesirable since it requires more heat to dry the fuel. The moisture content was 5.05% at the CH: CC 80:20 mix ratio, but decreased to 4.88% at the 20:80 ratio, according to the data. When the optimal mechanical qualities of briquettes were achieved, the moisture percentage of the input raw material should be between 4 and 10%. Briquet moisture is mostly determined by the starting moisture of the raw material, and it varies during the briquetting process, as some moisture escapes when the temperature rises due to compression. Briquettes with a high moisture level have a more consistent bed, more crumbles, a lower energy value, and thus a lower price [29].

The moisture content varied significantly with the mix ratios, as shown in Table 2 and Fig. 5. The briquettes had an average moisture level of 4.96%.

3.3.2 Ash content

The low ash content as observed in 20:80 in this study (Fig. 5) is a reflection of the high calorific value (Fig. 7) which is a suggestion that the briquette does not contain high mineral (non-combustible) matters. As suggested by Sotannde et al. [30], "ash content usually causes a rise in the combustion remnant, thus lowering the heating effect". The ash content as recorded in this study is lower than ash content reported by Emerhi [31], Ogbuagu et al. [32], Ikelle and Anyigor [33], and Ige et. In this study the ash content ranges from (5.60%) as shown in the Fig. 5. "Lower ash content is an indication of good quality briquette, as the ash content of briquettes produced" [34]. "Higher ash content in a fuel usually leads to higher dust emissions, air pollution, and affects the combustion volume and efficiency of combustion" [35].

3.3.3 Volatile matter

The results of the percentage of volatile matter show that as the percentage of a cocoa pod in the mixture increases the volatile matter increases. The mixture ratio of 20:80 has the highest volatile matter (63.71%) due increase in cocoa pod husk. The volatile matter in this study is an indication of easy ignition, fast burning, and proportionate increase in flame length.

3.3.4 Fixed carbon

"Fixed carbon gives an indication of the proportion of char that remains after volatile matter is extracted. It gives a rough estimate of the heating value of a fuel and acts as the main heat generator during burning" [36]. The fixed carbon as reported in this study 74.20% to 75.13% is relatively higher than obtained by Adegoke et al. [37] 5.75% to 8.28% stated by Emerhi [31], 16.80–20.90% quantified by Adetogun et al. [38], and 15% fixed carbon estimated by Ige et al. [39] who all worked on briquettes produced from same particles. "A good quality and efficient fuel briquette are dependent on lower volatile matter and ash content with a higher fixed carbon content [40] in collaboration with result of findings of this study". "The percentage of fixed carbon content in briquettes is a critical factor that influences the calorific value of fuel" [41]. As the composition of CC increase in the mixture ratio, the percentage fixed carbon is increased. This is in agreement to the assertion of Onukak et al. [42] who posited that "high fixed carbon implies high calorific value. The change to this observation might be attributed to the blending of the CH and CC wastes with varying inherent volatile matter, which principally describes the reason for lower ash content and lower specific heat of combustion".

Table 2. Moisture content (%), ash content (%), volatile matter, fixed carbon and calorific value of briquette at different mix ratios

Mix ratio CNH:CC	Mean moisture content (%)	Mean ash content (%)	Mean volatile matter (%)	Mean fixed carbon (%)	Mean calorific value (MJ/kg)
80:20	5.05	5.60	20.20	74.20	21.45
60:40	4.99	5.16	20.62	74.22	22.75
50:50	4.96	4.89	20.89	74.23	24.15
40:60	4.94	3.81	21.18	75.01	25.55
20:80	4.88	3.17	21.70	75.13	26.75
Average	4.96	4.53	20.92	74.56	24.13

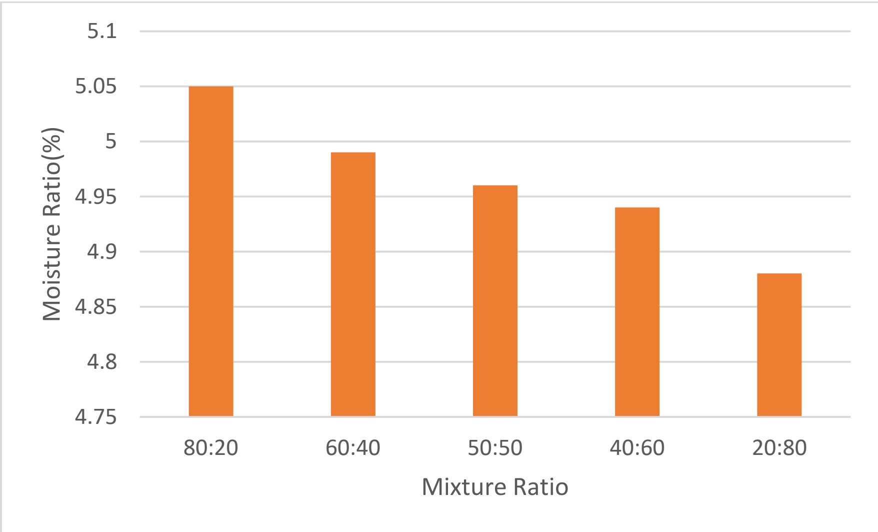

Fig. 4. Effect of mix Ratios on the moisture content

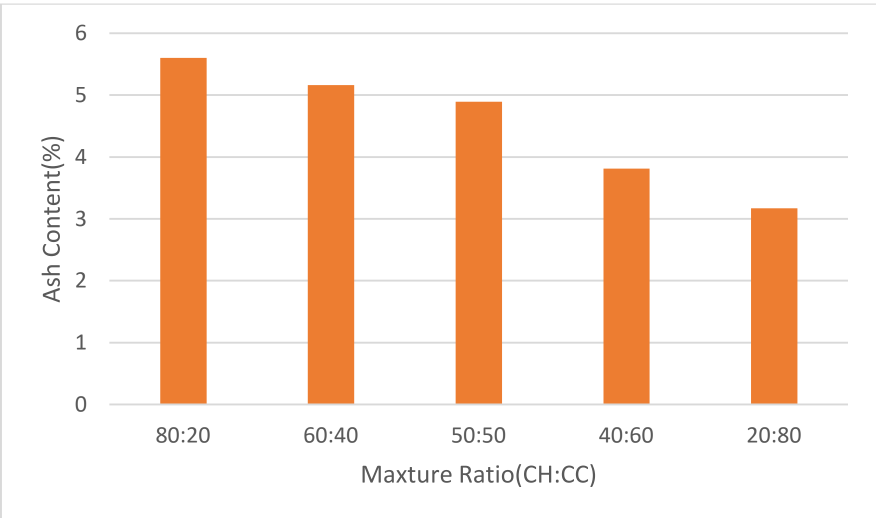

Fig. 5. Effect of mix ratios on the ash content

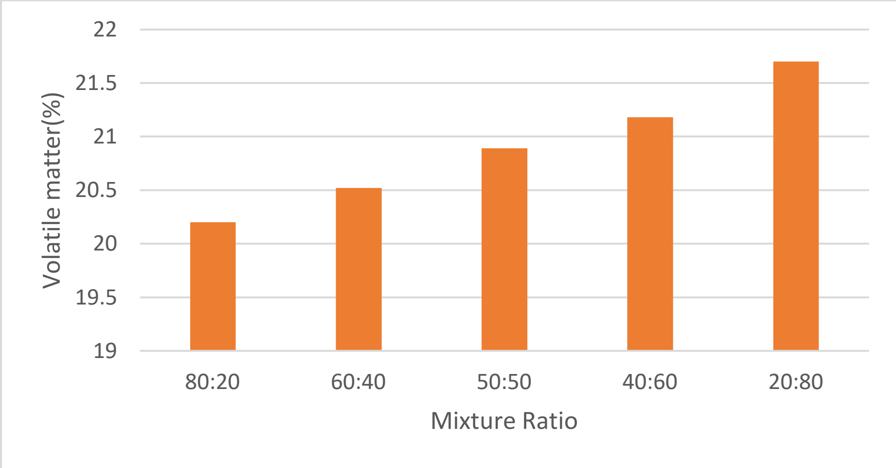

Fig. 6. Effect of mix ratios on the volatile matter

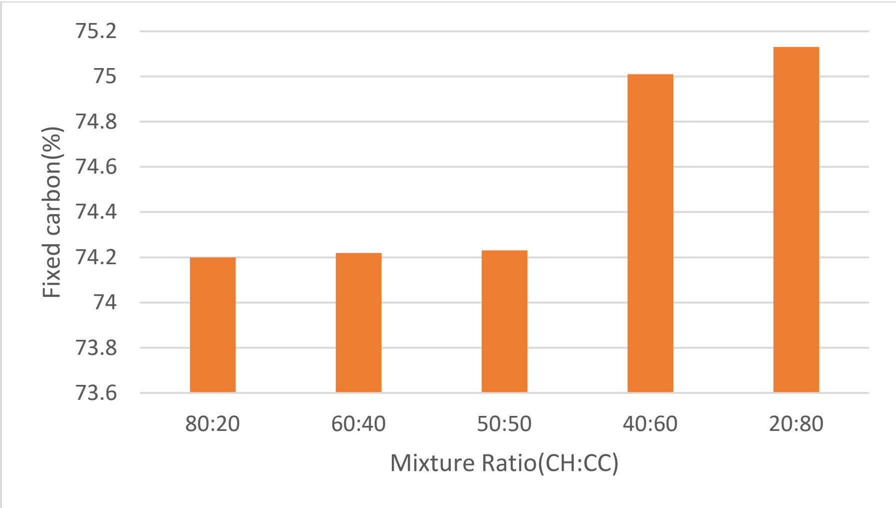

Fig. 7. Effect of mix ratios on the fixed carbon

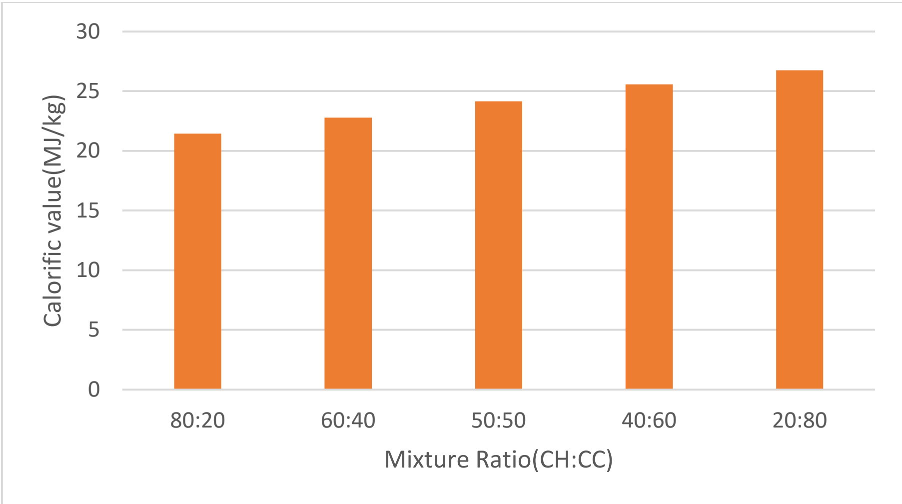

Fig. 8. Effect of mix ratios on the calorific value

3.3.5 The heating value (calorific value)

The calorific value is a standard measurement of a fuel's energy content. A high calorific value of 26.75 MJ/kg and high fixed carbon content of 75.13% was recorded for a briquette with a mixture ratio of 20:80. A low calorific value was recorded for a mixture ratio of 80:20 with fixed carbon of 74.20%, high fixed carbon results in high calorific value. It determines the property of fuel and depends on the chemical composition and moisture content of the material. The calorific value increased with increasing the composition of the corncob in the mixture ratio. The calorific value ranges from 21.45 MJ/kg to 26.75 MJ/kg.

4. CONCLUSION

A blend of mixture ratios of coconut husk and corncob briquettes were studied. It was observed that the best mixture ratio was CH: CC 20:80, which had the highest calorific value, good moisture and ash content, good density, and durability index. The density of the briquettes surged within the range of 584.20 Kg/m^3 to 839.80 Kg/m^3 at the ratios of 80:20, 60:40, 50:50, 60:40, 20:80 (CH: CC); respectively as the corncob was increased. As the corncob mixture ratio was increased, moisture decreased from 5.05% to 4.88%, ash content decreased from 5.60% to 3.17% and calorific value increased from 20.35 MJ/kg to 26.75 MJ/kg, respectively. Also, the fixed carbon content increased as the corncob pod in the mixture ratio increased that is from 74.20% to 75.13%, and volatile matter increased as the corncob in the mixture ratio increased from 20.20% to 21.70%. From the result of this research, it was obvious that briquettes can be satisfactorily produced from a blend of coconut husk and corncob. Thus, the usage of briquettes should be encouraged especially in developing countries to minimize pressure on fuel wood for energy generation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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