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Production and Characterization of Bio-Briquette Produced from Rice Husk, Corn Cob and Charcoal Dust

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Abstract: ***Bio-briquette is a renewable energy source that is produced from biomass materials such as rice husk (carbonized and uncarbonized), corn cob (carbonized and uncarbonized) and charcoal dust. The carbonized sample was obtained by controlled burning of feed stock in a kiln. In this study, the physical and chemical characteristics of bio-briquette produced from these materials were investigated. The objective of the study was to determine the suitability of the biomass materials for the production of bio-briquette and to evaluate the properties of the briquette with respect to their energy content and use. The characterization included measuring the proximate analysis, bulk density and calorific value of the briquettes. The results indicated that the rice husk, corn cob and charcoal dust were suitable biomass materials for the production of bio-briquette. The elemental analysis showed that the biomass materials had a high carbon content, indicating their potential as a fuel source. The physical characterization results showed that the bulk density of the briquettes produced was higher than that of the raw materials. The calorific value of the briquettes increased with the increase in the carbon content of the biomass materials, and this was reflected in the increase in the compressive strength of the briquettes with increasing carbon content. Overall, the study demonstrated that the rice husk, corn cob, and charcoal dust could be converted into a high-quality renewable energy solid fuel with carbonized rice husk having characteristics relatively close to that of charcoal dust fuel, with calorific value of 22.1924 MJ/kg, and 28.246 MJ/kg respectively. All the bio-briquette produced had desirable physical and chemical properties, making it a suitable alternative to traditional fossil fuels. The use of BIO-briquette can contribute to the reduction of greenhouse gas emissions and improve the energy security of rural communities.***

Keywords: about four key words separated by commas

1. Introduction

The decreasing availability of fuel wood, coupled with the ever-rising prices of kerosene and cooking gas in Nigeria, has stimulated the need to consider alternative sources of energy for domestic and cottage level industrial use in the country. Such energy sources should be renewable and should be accessible to poor. A transition to a sustainable energy system is urgently needed in the developing countries such as Nigeria. This should, of necessity, be characterized by a departure from the present subsistence level energy usage levels based on decreasing firewood resources, to a situation where human and farming activities would be based on sustainable and diversified energy forms. Patomsok (2008), explained that biomass, particularly agricultural residues seem to be one of the most promising energy resources for developing countries. Rural households and minority of urban dwellers depend solely on fuel woods (charcoal, firewood and sawdust) as their primary sources of energy for the past decade. Onuegbu (2006), emphasized that of all the available energy resources in Nigeria, coal and coal derivatives such as smokeless coal briquettes, bio-coal briquettes, and biomass briquettes have been shown to have the highest potential for use as suitable alternative. Briquetting process converts low bulk density biomass materials into high density fuel briquettes. In the briquetting plant ground charcoal burned from sawdust and other wood by-products are compressed into briquettes along with a binder and other additives that helps the briquette to burn. The selection of binder and additives is related to the quality and cost of the briquettes.

Energy is very essential to human livelihood and makes significant contributions to economic, social, and environmental features of human development (Fikremariam et al, 2020). Nonrenewable energy sources such as fossil fuel, coal, and kerosene cannot be renewed and resulted in emissions of greenhouse gases (GHG), CO2, SOx, NOx, etc (Sisay et al ,2020). Renewable energy sources are so alternate and sustainable that is considered to be a preferable and better option than nonrenewable energy sources. Among the renewable energy sources, biomass fuels such as fuel wood, wood charcoal, agricultural residues and animal dung are commonly utilized for household cooking purposes. However, the extensive and improper utilization of biomass fuel for household cooking resulted in deforestation, indoor air pollution, acute lower respiratory infections in women and children and emission of greenhouse gases, which can be considered as a great challenge to the world, particularly in developing countries (Fakunle et al, 2017). Biomass fuels consist of firewood, forest waste, animal dung, vegetable matter, and other agricultural residues that are highly utilized by many rural and urban households for domestic use (FAO UN, 2010). Several Researchers have been researching on the potential, production, combustion properties, and quality of briquettes produced from different biomass wastes and binding materials with heavy-duty densified machines.

The global demand for sustainable energy is increasing due to urbanization, industrialization, population, and developmental growth. Transforming the large quantities of biomass resources such as agro-residues/wastes could raise the energy supply and promote energy mix. Residues of biomass available in the rural and industrial centers are enormous, and poor management of these residues results in several environmental threats. The energy potential of these residues can provide job opportunities and income for the nation. The generation and utilization of dissimilar biomass as feedstock for energy production via densification could advance the diversity of energy crops. An increase in generation of agricultural biomass and the continuous open burning and dumping of such waste creates a serious environmental threat through the release of CO into the atmosphere hence causing ozone layer depletion.

2. Materials and Methods

2.1 Materials

Some materials/equipment involved in the production of the briquettes includes:
1) Sieve.
2) Kiln.
3) Stirrer.
4) Briquette machine.
5) Containers.
6) Weighing scale.

General materials involve the various feedstock used, additives, binders and testing material. These include corn cob, rice husk, charcoal dust, gelatin, cassava starch and molasses.

2.2 Methods

The briquetting process primarily involves drying, grinding, sieving, compacting, and cooling.

2.3 Material Preparation

The corn cob for this project was obtained from harvested corn that is hand shelled. It was dried in the sun. The rice husk was gotten from milled long and short grain rice in station market. The charcoal dust was obtained from a neighbor that sells charcoal.

The carbonized corn cob and rice husk was obtained using a kiln fabricated by the department’s project student. The uncarbonized corn cob was grounded using grinding machine at station market, Kaduna, Nigeria, to obtain the char. The char was screened using a 16 mm sieve to obtain a uniform char. They were all measured using a digital electronic weighing scale of varying percentages (500g to represent 100%).

The binder used is cassava starch obtained from Parking Dogo market, Kaduna, Nigeria, and molasses obtained from veterinary market located at club 69, Kaduna, Nigeria. The binder was prepared using hot water to obtain a paste and it was allowed to cool. It was further dissolved with cold water to lighten its viscosity and enable easy adhesion. The materials were mixed by proportions and compressed using a fabricated briquette press enclosed at one end.

2.4 Briquette production

The rice husk and corn cob were carbonized using a kiln. Fire wood was loaded at the base of the kiln which is the heating chamber and the wood was ignited. The kiln was preheated for about 30 minutes and the feedstock was then loaded at the upper chamber of the kiln. The kiln was then covered so as to reduce excess oxygen during combustion and allow for proper char production. After 3 hours, it was opened slightly and the feedstock was stirred with a shovel and allowed to burn for another 3 hours until a complete black char was obtained. The carbonized feedstock was poured out on a flat surface and allowed to cool.

500 g of each feedstock was measured using a digital weighing scale, these represent 100 % (control samples) of the feedstock. Various proportions, by weight, of the carbonized and the uncarbonized feedstock were then measured to make up the 500 g. Each sample of the feedstock was then homogeneously mixed with the binder until uniform mixing is achieved. The mixtures were then loaded unto the briquetting press and a hydraulic jack was used to compress the loaded feedstock for one minute. The briquettes were then brought out and sun dried for 3 days.

2.3 Characterization

The produced briquettes were characterized by obtaining the following properties;
i) Determination of Moisture content: The percentage moisture content (PMC) determined by weighing the briquette sample 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.

$$PMC = (W_1 - W_2) \times 100\%$$

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

ii) Determination of Volatile Matter: The percentage of volatile matter (PVM) was determined by placing 1.5g of the briquettes sample 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:

$PVM = (W_2 - W_3) \times 100\%$

Where, W_2 is the weight of the oven-dried sample in (g);

W_3 is the weight of the sample after 8 min in the furnace at 550 °C (g).

iii) Determination of Ash Content: 1.5g of the briquette 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.

$PAC = (W_4 / W_2) \times 100\%$

Where, W_2 is the weight of the oven-dried sample in (g);

W_4 is the weight of the burnt sample (g).

iv) Determination of Fixed Carbon: Akowuah et al. (2012) gave the percentage fixed carbon (PFC) as in equation below.

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

Where, PMC is the percentage moisture content,

PVM is the percentage volatile matter, and

PAC is the percentage ash content.

v) Determination of Calorific Value: The calorific value of the briquettes was determined using a bomb calorimeter. 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:

$CV = (BF \times \Delta t - 2.3 \text{ length of wire}) / W$

Where: BF = Burn Factor;

Δt = Change of temperature $(t_2 - t_1)$ °C;

t_2 = final temperature; t_1 = initial temperature;

W = mass of the sample used and

BF = constant = 13,257.32.

vi) Bulk density: The density of the briquette was calculated using the mathematical expression:

B.D (g/cm^3) = Mass of the briquette (g)/ Volume of the briquette (cm^3).

The mass of the briquette was calculated using an electronic digital weighing scale (g).

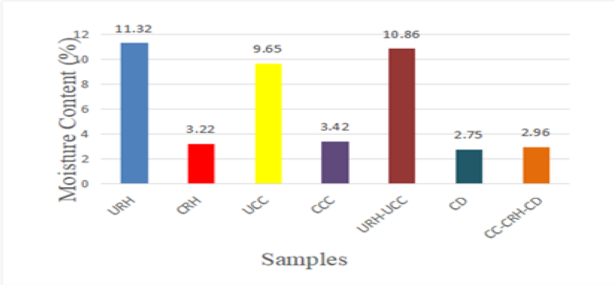
The volume of the briquette was calculated using the formula since the mould was cylindrical:

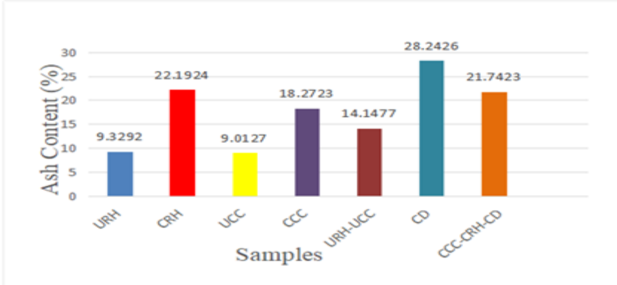
Vol. of a cylinder (cm^3) = (π/4) × (diameter of cylinder) × height.

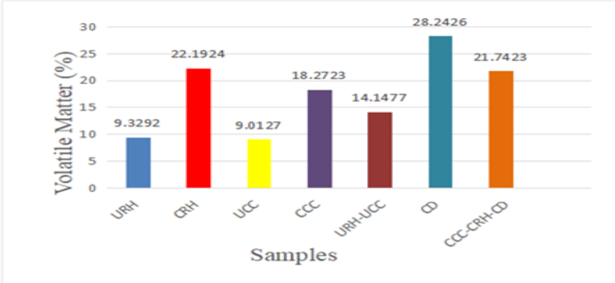
3. Results and Discussion

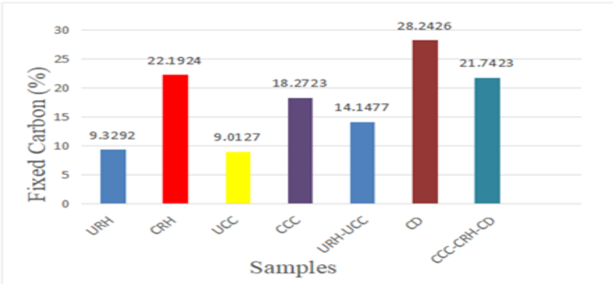
3.1 Results

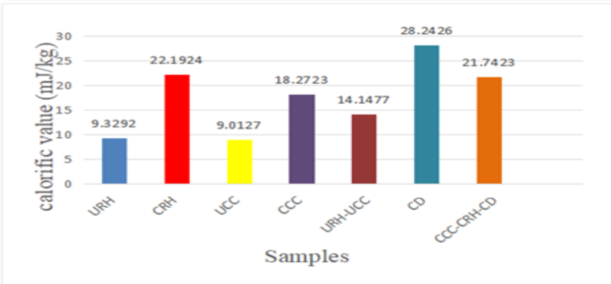
The results are presented in the figures below:

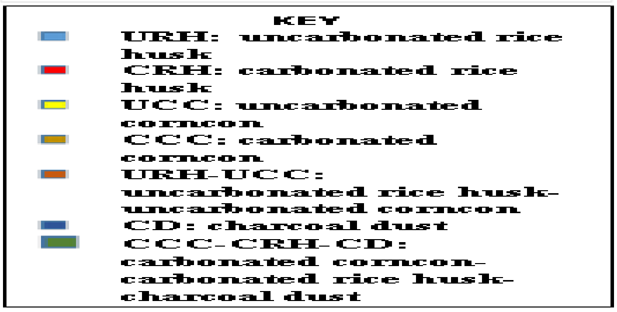












3.2 Discussion

From the results, it is clearly indicated that the charcoal dust briquette has higher calorific value (28.246 MJ/kg), fixed carbon (81.06 %) than the other briquettes but has lower ash content (3.22 %) and moisture content (2.75 %), the calorific value of charcoal dust indicates that it will release more heat during combustion than the carbonize rice husk which has its calorific value as (22.1924 MJ/kg), fixed carbon (22.18 %), moisture content (3.22 %), and ash content (19.63 %), followed by carbonized rice husk + corncob + charcoal dust with calorific value (21.7423 MJ/kg), fixed carbon (24.03 %), moisture content (2.96 %), and ash content (12.46 %).

The results of the uncarbonized samples also indicates that, the uncarbonized rice husk + corn cob has a higher calorific value (14.1477 MJ/kg), fixed carbon (11.42 %), moisture content (10.86 %) and ash content (22.95 %), as compared to that of the uncarbonized rice husk having calorific value (9.3292 MJ/kg), fixed carbon (15.28 %), moisture content (11.32 %), and ash content (27.18 %), followed by uncarbonized corn cob having calorific value (9.0127 MJ/kg), fixed carbon (9.65 %), moisture content (2.09 %) and ash content (8.93 %).

4. Conclusion

The conclusion drawn from the project shows that good quality and highly renewable briquettes can be produced from charcoal dust, rice husk and corn cob. The material (carbonized and uncarbonized) of the corncob and rice husk was found to have feasible effects on the physical properties of the briquettes produced. The briquette from carbonized corncob and rice husk had a better result in terms of moisture content compare with briquette from uncarbonized corncob and rice husk while briquette from uncarbonized corncob and rice husk had higher density briquette from carbonized corncob and rice husk.

Cassava starch among other binders produced the best physical properties of briquette from carbonized corncob, rice husk and charcoal dust. The higher the binder concentration, the more the positive attributes of physical properties of briquette from the feedstocks.

Finally, the study shows that corncobs, rice husk and charcoal dust were suitable materials for briquettes production that are well suited for domestic and industrial applications.

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