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The Effect of Binder Type on the Physico-Chemical and Calorific Compositions of Fuel Briquette Produced from Maize Cob, Sugarcane Bagasse and Discarded Polyethene Composite

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ABSTRACT

Briquette from wastes solves the problem of pollution and is a source of renewable energy. This study investigated the effect of using different binder type on the physico-chemical and calorific properties of briquettes made from maize cob, sugarcane bagasse and polyethene waste using cassava starch and plantain peel binders. The maize cob, sugarcane bagasse and polyethene waste were mixed at ratio 50 g:50 g:3 g. By using American Standard Testing Methods (ASTM), the study indicated that the two briquettes (having cassava starch or plantain peel binder) have low moisture content required for handling and storage. The briquette with cassava starch (CSB) has the range of volatile matter being 10.74-18.1%, while the one with plantain peel binder (PPB) had the range 14.56-23.08%. Increase in binder concentration (4-20%) resulted to increased volatile matter of the briquettes; though within the range of 9.0-25.8% recommended for carbonizate briquette. CSB has the highest fixed carbon content being 76.39%, ash content of 14.0% and the highest calorific value of 28.14 MJ/kg, compared to PPB with fixed carbon content of 68.20%, ash content 21.08%, calorific value of 15.91 MJ/kg. The result reveals that briquette produced using 4% cassava starch binder has the best properties required for biomass fuel compared to the briquette using plantain peel binder. Fuel briquette can help to minimize the pollution resulting from agricultural and polymeric wastes.

Keywords: Agricultural, Binders, Calorific value, Fuel, Polymeric, Wastes.

Introduction

Waste generation has generally increased in the world due to population growth. Utilizing agricultural wastes for primary or secondary energy source is attractive due to their availability, being indigenous and environmental friendliness.[1,2] Limitations ascribed to the use of waste residue generated from maize cob,[1] coconut husk,[2] and sugarcane waste[3] for primary or secondary energy sources are low energy value, low handling and high storage cost.

So, in developing countries like Nigeria today, these wastes are burnt off; so emitting various gases into the atmosphere constituting a major cause of greenhouse effect. These emissions which are carcinogenic include formal aldehyde, nitrogen (IV) oxide and polycyclic compound such as benzo(pyrene).[4,5] According to World Health Organization (WHO), the burning of raw biomass contributes to 3% of the total cause of diseases which results in premature death of about 1.6 million individuals.[6]

Presently, owing to the depletion of fossil fuel due to overdependence, research work has shifted from conventional processing of coal, biomass and wastes into more convenient environmentally friendly solid fuel known as briquettes using binding agents such as plantain peel,[7] starch[8] and clay.[9] Binder selection is a major factor in biomass briquetting because the type of binder used also affects the physico-chemical properties of briquette. Research has been carried out to determine the moisture content, volatile matter, ash content and calorific value of fuel briquette produced from mixed municipal waste composting char and sawdust char.[10] Also, characterization of char obtained from co-pyrolysis of waste mixture of plastics, tires and pine biomass used as a fuel was carried out.[11]

The objective of this work was to investigate the impact of binder type on the moisture content, volatile matter, fixed carbon content and calorific value of briquettes produced from maize cobs, sugarcane bagasse waste and discarded polyethene composite. This is relevant in the emerging trend that has positioned and raised the profile of today biomass as a renewable and profitable energy carrier; coupled with the call to action for all to "beat plastic pollution".

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Materials and Methods

Sample collection

The materials used for the fuel briquette were maize cob, sugarcane waste, discarded polyethene waste and binders (cassava starch and plantain peel). All these were obtained from Zaria, Kaduna State, Nigeria.

Preparation of Sample

The collected maize cobs and sugarcane waste (100 kg each) were each cleaned thoroughly to remove sand particles. Each was carbonized in a 200 litre metal drum at $100^{o}C$. The collected polyethene waste was reduced into smaller size using a pair of scissors. The carbonized maize cob and sugarcane waste was ground into smaller particles of mesh size 10 mm using a hammer mill. This was sieved using a mesh of size 5 mm in order to remove impurities and to achieve uniform sized particles.

Preparation of binder

Cassava starch was prepared by weighing 20 g, 60 g and 100 g of the purchased starch into three different labeled plastic bowls. Then 500 mL of water was measured using a measuring cylinder out of which 100 mL was used to dissolve the semi-solid cassava starch in a plastic bowl. The remaining 400 mL was poured into an electric kettle and allowed to boil at 100ºC. The hot water was gradually poured into the starch mixture and stirred to form cassava starch paste. This resulted to 4%, 12% and 20% cassava starch binder.

Also, the fresh collected plantain peels (5 kg) had the moisture content determined. These were cut into smaller sizes with a knife and sun-dried; after which the moisture content was determined again, until it was within the 15% moisture content recommended by Kaliyan.[10] The dried peels were then ground using a mechanical mill of mesh size 20 mm. After which it was sieved to particle size of 2 mm. The plantain peel powder was used to prepare 4%, 12% and 20% starch mixture.

Briquette Preparation

The carbonized maize cob, sugarcane waste and shredded polyethene waste were mixed with cassava starch binder in the ratio of 50 g: 50 g: 3 g of maize cobs: sugarcane: polyethene. To this 500 mL cassava starch binder of concentration 4%, 12% or 20% were added. To the other sets of 50 g: 50 g: 3 g of maize cobs: sugarcane: polyethene; 500 mL of plantain peel binder of concentration 4%, 12% or 20% were added.

Then fuel briquettes from each of the six sets of composition were formed in a fabricated briquetting press, which consists of cylinder with internal diameter of 60 mm and 100 mm length. Compaction was done using a hydraulic jack. The briquettes obtained for each set were sun-dried for two days. Thereafter, the briquettes produced are as shown in Plate I.

Plate I: Produced fuel briquettes from biomass waste

Analysis of Fuel briquette

The moisture content, ash content, volatile matter and fixed carbon contents of the prepared briquettes were determined according to ASTM D-3173.[13,14] The calorific value was determined using an oxygen bomb calorimeter (Model P6100, Switzerland) at Department of Chemical Engineering, Ahmadu Bello University, Zaria, Nigeria.

Statistical Analysis

Students t-test was used to assess the significant difference in the physico-chemical and calorific compositions of the produced briquettes as a function of binder type and binder concentration, with significance taken at $P < 0.05$.

Results and Discussion

The fresh plantain peels had the moisture content being 46.0%; while the sun-dried plantain peels had moisture content of 9.85% which was within the 15% moisture content recommended by Kaliyan for plantain peel production.[10]

As depicted in Figure 1 the briquette produced using cassava starch as binder (CSB) has the moisture content in the range of 5.71 to 7.52%, while the counterpart that had plantain peel binder (PPB) has moisture content in the range of 5.39 to 7.33%. Also, as the binder concentration increases from 4-20%, the moisture content of the produced briquette increases. The highest moisture content of 7.52% was obtained by using 20% of cassava starch. However, there was no significant difference in the moisture content obtained as a function of binder type and binder concentration (Students t-test, $P < 0.05$**).**

The moisture content values obtained for the briquettes in this study, agree with literature recommendation of 5-12% moisture content for good quality briquettes.[15] As high percentage moisture content of biomass briquette prevents application for thermo-chemical conversion processes including combustion.

On the other hand, following from Figure 2, use of cassava starch as binder led to volatile matter being in the range of 10.74 to 18.10% compared to the briquette made up of plantain peel binder, having the range of 14.56 to 23.08%. Generally, increased binder concentration resulted to increased volatile matter of the briquettes, except for PPB made with 4% binder. For CSB the range of volatile matter was 10.74-18.1%, while for PPB the range was 14.56-23.08%. This conforms within that expected for a good quality briquette, stated to be in the range of 10 to 25%. The report in this study falls within the range of 9.0-25.8% volatile matter obtained for carbonizate briquette.[16] There was no significant difference in the volatile matter of the briquette types.

Figure 3 indicated that the briquette with cassava starch (CSB) recorded the highest fixed carbon content of 76.39% with 4% of the binder, while PPB had the highest fixed carbon content of 68.2% by the use of 12% of plantain peel binder. The higher the fixed carbon content of a fuel, the greater the calorific value and the smaller the volatile matter.[17]

The ash content of CSB gradually increased from 12.87 - 14.0% with increased binder amount. On the other hand, the ash content of the briquette decreased from 21.08% with 4% binder to 15.93% with 20% binder (Figure 4). The use of cassava starch led to lower ash content of the briquette compared to plantain peel binder. Therefore, the lower ash content recorded by using cassava starch binder is of significance because low ash content value for briquettes is associated with higher calorific value.[18]

The result of the calorific values of the two briquettes indicated the effect of type of binder (Figure 5). Cassava starch has the highest calorific value of 28.14 MJ/kg by using 4% starch. The use of plantain peel binder recorded the highest value of 15.91 MJ/kg by using 20% of the binder Calorific value decreased with increased concentration of the binder. The use of cassava starch as binder at lower concentration (4-12%) significantly elevated the calorific value of the fuel briquettes ($P < 0.05$).

Calorific value is the most important combustion property for determining the suitability of briquette material as fuel. High heating value 28.14 MJ/kg obtained for briquette using cassava starch was found to be higher than 18.89 MJ/kg reported by using banana peel briquette and 14.1 MJ/kg obtained for maize cob briquette.[17] Therefore, the composite briquette produced in this study using cassava starch as binder have good potential as fuel source.

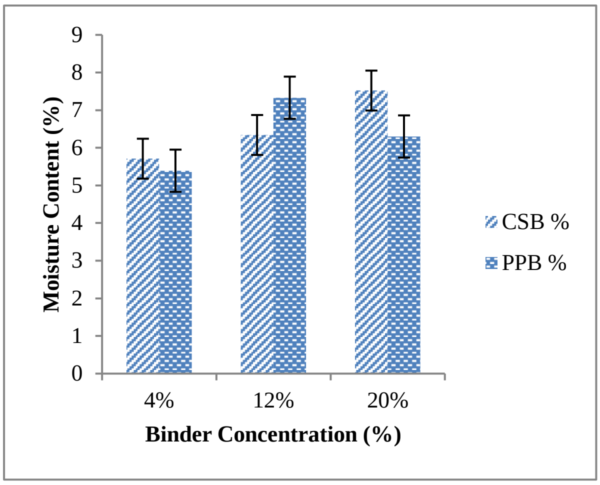

Figure 1: Effect of binder type on moisture content of fuel briquette.

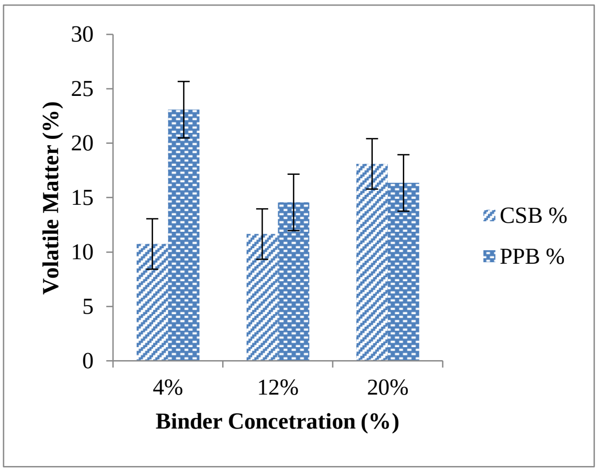

Figure 2: Effect of binder type on volatile matter of fuel briquette.

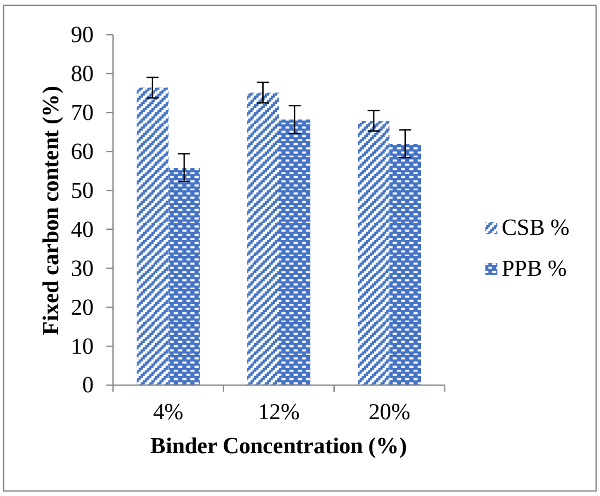

Figure 3: Effect of binder type on fixed carbon content of fuel briquette.

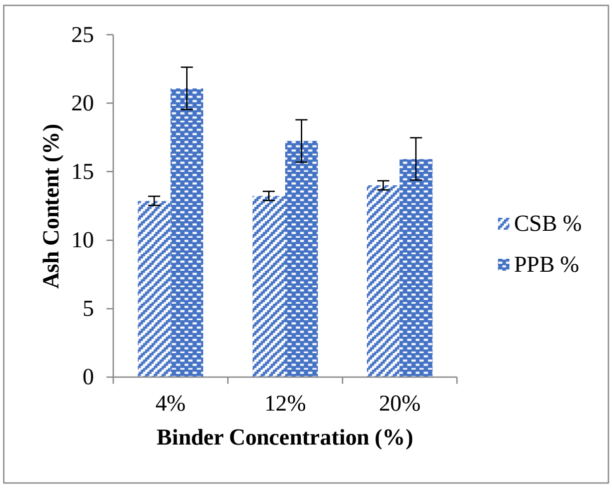

Figure 4: Effect of binder type on ash content of fuel briquette.

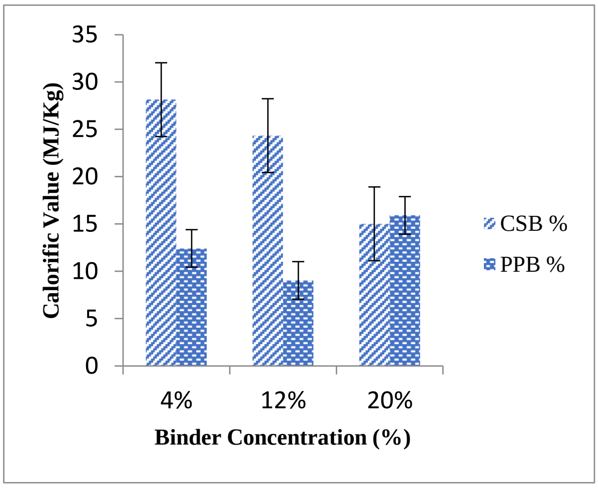

Figure 5: Effect of binder type on calorific value of fuel briquette.

Conclusion

The preliminary study on the production of fuel briquettes from maize cob, sugarcane bagasse and polyethene indicated that binder type is a key factor in the production of efficient fuel briquette. The use of cassava starch as binder resulted to the production of briquettes of lower ash content and significantly elevated calorific value than the briquettes produced by using plantain peel as binder. Therefore, cassava starch demonstrates better performance as a binder.

In addition, the fixed carbon contents, volatile matter and calorific values of the two briquette types produced in this study has positioned the briquette as efficient like some reported in literature. So, further studies to ascertain their suitable and sustainable utilization is on-going. Also, in order to minimize the competition arising from using cassava starch as binder due to food security and the bridging of energy deficit. Other alternative binders of less economic benefits are to be studied.

Conflict of interest

The authors declare no conflict of interest.

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Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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