EVALUATING THE EFFECT OF BINDER RATIO ON THE COMBUSTION CHARACTERISTICS OF COCONUT SHELL BRIUQETTES.

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Abstract

The paper evaluated the effect of binder ratio (%) on the combustion characteristics of coconut shell briquettes. The combustion characteristics evaluatated in the study were % volatile matter, % fixed carbon, % ash content and heating values of the briquettes. The briquettes were formed with the aid of a fabricated briquetting machine at compaction pressure of 4.5Mpa, binder ratios of 10%, 20%, and 30% respectively and particle size of 2.2mm. A dwell time of 120 seconds was observed during the briquettes formation. The results obtained showed that the binder ratio (%) had a positive effect on the combustion characteristics investigated and the values obtained compared well with the work of previous researchers. Moreover, the % volatile matter and heating value remained constant with slight increase in the binder ratio and dropped with further increase in the binder ratio (%). On the other hand, the % fixed carbon and % ash content remained constant with slight increase in binder ratio and increased with further increase in binder ratio (%). Recommendations were put forward for further research.

KEYWORDS: *briquettes, combustion, fixed carbon, volatile matter, heating value, binder ratio*

Introduction

One of the principal sources of energy is fossil fuels. According to El-Saeidy (2004) and Kaliyan and Morey (2009), 86% of energy being consumed all over the world is from fossil fuels. It must be admitted that, the use of fossil fuels is very convenient. However, many problems are associated with their applications. One of such problems is the issue of global warming, the seriousness of which was underscored by United Nation sponsored conference on climate change held at Copenhagen in Sweden in early December, 2009, where notable world leaders rubbed mind on how best to reduce global warming (Oladeji, 2011). Therefore, there is the need to gradually shift attention from fossil fuels and in this regard agricultural residues can play a significant role in alternative energy generation on a renewable basis.

One of the processes through which these residues could be converted to biomass energy is briquetting. Olorunnisola (2007) and Wilaipon (2007) described briquetting as a process of compaction of residues into a product of higher density than the original material, while Kaliyan and Morey 2009 defined briquetting as a densification process.

Fuel briquettes under different conditions have been reported to have different handling characteristics. These characteristic are also found to be strongly affected by the raw material properties. If biomass or agro-waste briquettes are to be used efficiently and rationally as fuel, they must be characterized to determine parameters such as the moisture content, ash content, density, volatile matter, and heating values among others. The result of these determinations indicates the positive and negative attributes of agro-waste briquettes (Oladeji, 2010).

Controlling densification system variables can be important to achieving the desired density, durability and quality. The quality of pellets or briquettes can be managed by proper control of manufacturing conditions, such as control of the manufacturing process, change of formulation and the use of additives (Tumurulu et. al, 2011). Shaw (2008), in his studies on densification of biomass, demonstrates how process variables (die temperature, pressure, and die geometry) feedstock variables (moisture content, particle size, and shape) and biomass composition (protein, fat, cellulose, hemi cellulose, and lignin) play a major role in the quality of the densified biomass.

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Combustion or burning is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. The release of heat can produce light in the form of either glowing or a flame. The combustion characteristics considered in this paper were fixed carbon, volatile matter, ash content and heating values of the briquettes. Binders are normally used to reduce the wear on production equipment and to increase the abrasion resistance of the fuel. Binders also improve the binding characteristic of the biomass and produce more durable pellets/briquettes (Sokhansanj, 2002). The aim of this work was to evaluate the effect of binder ratio (%) on the combustion characteristics (fixed carbon, volatile matter, ash content and heating value) of coconut shell briquettes.

Materials and Methods

Coconut shell residues were obtained from Gwallameji village and the premisis of Federal Polytechnic Bauchi. The residues were sun-dried for about two weeks until stable moisture content was obtained, thereafter subjected to size reduction process through the use of mortar and pestle. The medium particle size of 2.2mm was selected for this work. Cassava starch was bought from Gwallameji market in Bauchi and mixed with hot water and stirred properly in order to form a starch gel. Thereafter the residues were thoroughly mixed with the starch gel at the ratio of 10, 20 and 30% by weight of residues and formed into briquettes with the aid of a fabricated briquetting machine at compaction pressure of 4.5Mpa. A dwell time of 120 seconds was observed for the briquettes during formation. The relaxed densities were obtained using ASAE S269.4 (1998) standard methods for determining densities.

Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal/briquettes. Thus the volatile matter is an index of the gaseous fuels present. A typical range of volatile matter is 20 to 35%.

Percentage volatile matter was determined in accordance to ASTM D5373-02, (2003).About 2g of ground residue was selected. The sample was placed in crucible and heated in a muffle furnace at 250°C for 7 minutes. The crucible was retrieved and kept to cool in desiccators to room temperature. The final weight was determined. The loss in weight

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was expressed as a percentage of the original weight to obtain the percentage volatile matter as in Equation (3).

$$\%Vm = \frac{100(W_1 - W_2)}{W_1}$$

Where W_1 is the initial weight of the oven-dried sample and W_2 is the final weight of the sample after being subjected to 250°C for 7 minutes.

Ash is an impurity that will not burn. Typical range is 5% to 40%. Ash reduces handling and burning capacity, increases handling costs, affects combustion efficiency and boiler efficiency and causes clinkering and slagging.

The ash content was determined according to ASTM Standard D5373-02, (2003). About 2g of finely ground sample of the briquette was placed in a crucible and heated in a muffle furnace at 2500C for 10 minutes. After cooling it in desiccators, the final weight was measured. The ratio of the initial weight to the final weight was expressed as a percentage to obtain percentage ash content of the residue samples using Equation (4).

$$\%Ash = \frac{100W_3}{W_4}$$

Where W_3 is the initial weight of the oven-dried residue sample and W_4 is the final weight.

Fixed carbon is the solid fuel left in the furnace after volatile matter is distilled off. It consists mostly of carbon but also contains some hydrogen, oxygen, sulphur and nitrogen not driven off with the gases. Fixed carbon gives a rough estimate of the heating value of coal/briquettes.

ASTM Standard D5373-02, (2003) was used for determination of the fixed carbon. The fixed carbon was obtained by assuming that, the sulphur content is negligible as found by Emerchi (2011). The amount of fixed carbon in the combusted oven-dried sample was obtained using Equation (5).

$$\%FC = 100\% - \left(\%Ash + \%V_m + \%M_c\right)$$

Where %FC is the amount of fixed carbon (%), %Ash is the oven-dried residue sample, V_m is the volatile matter content of the oven dried residue sample (%) and $\%M_c$ is the % moisture content (dry-basis).

The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value. The difference is determined by the latent heat of condensation of the water vapour produced during the combustion process. Gross calorific value (GCV) assumes all vapour produced during the combustion process is fully condensed. Net calorific value (NCV) assumes the water leaves with the combustion products without fully being condensed. Fuels should be compared based on the net calorific value.

Heating value also known as the potential energy value of the produced briquettes was determined by the use of Gallen-Kamp Bomb calorimeter and the procedure as highlighted in accordance with ASTM Standard E711-87 (2004) was adopted. The heating value was determined in the following sequence.

1g of the sample was placed in a crucible located inside the bomb calorimeter. Ensuring that there was no weight loss, the sample was carefully pressed down with a spatula to form it into a smooth level layer suitable for combustion. The bomb closing ring was screwed such that the metal to metal contact is achieved between the bomb body and the base. The bomb was filled with oxygen from the steel gas cylinder to a pressure of about 25 bars. The time-firing button was pressed. The reading of the maximum deflection of the galvanometer was closely monitored.

The heating value of the biomass residue was computed based on the following expression given by Emerchi (2011).

$$Cv = \frac{(M_w - M_c)C\Delta T}{M_F} \tag{6}$$

Where; C_v is the higher heating value of the fuel (residue), M_W is the mass of water, M_c is mass of water equivalent of calorimeter, C specific heat capacity of water, M_F is the mass of fuel (residue) tested and ΔT is the corrected temperature rise of water.

Results and Discussion

The results of the effect of binder ratio; 10, 20 and 30 percents (%) at a compaction pressure of 4.5MPa and particle size of 2.2mm on the combustion characteristics briquettes is shown in Table 1 below.

The values of the % volatile matter (Table 1.) varied from 23 to 36%. These values are in accordance with the work of Emerchi (2011) who obtained values of 60.39 to 89.47% for % volatile matter from sawdust of three hardwood species with different organic binders. The volatile matter (%) remained constant with slight increase in % binder ratio but dropped with further increase in the binder ratio.

Table 1. The Effect of Binder Ratio on the Combustion Characteristics of Coconut Shell Briquettes.

Binder Ratio (%)	Briquette Characteristics			
	Volatile Matter (%)	Fixed Carbon (%)	Ash Content (%)	Heating Value (KJ/Kg)
5	25	23.13	98.12	11307.40
10	16.67	14.65	97.98	6943.70
15	25	22.08	97.08	10947.80

(Author, 2015)

Also, the values of the (%) fixed carbon (Table 1.) varied from 16 to 17% which is in line with the work of Garivait et al (2006) that obtained 15.54, 16.03 and 13.14% for rice straw, maize stalk and sugarcane briquettes respectively. The % fixed carbon remained constant with slight increase in % binder ratio and increased with further increase in the binder ratio.

Moreover, the values of the % ash content (Table 1.) varied from 30 to 36%. These values are also in conformity with the values of 14.89 to 28.13% obtained by Emerchi (2011) for % ash content from sawdust of three hardwood species with different organic binders. The ash content % remained constant with slight increase in binder ratio % and increase with further increase in the binder ratio. These values of % fixed carbon, ash content and volatile matter are good and acceptable. This is because higher percentage of the briquettes would be made available for combustion.

Furthermore, the values of the calorific value (Table 1.) varied from 13631.60 to 17773.15KJ/Kg. These values compare well with the results of the heating value of most biomass briquettes including almond shell briquettes (19,490KJ/Kg), corncob briquettes (20,890KJ/Kg), cowpea (14,372.93KJ/Kg) and soybeans (12,953KJ/Kg) (Emerchi, 2011). The heating value remained constant with slight increase in binder ratio and dropped with further increase in the binder ratio. These values of energy value are sufficient enough to produce the heat required for household and cottage applications.

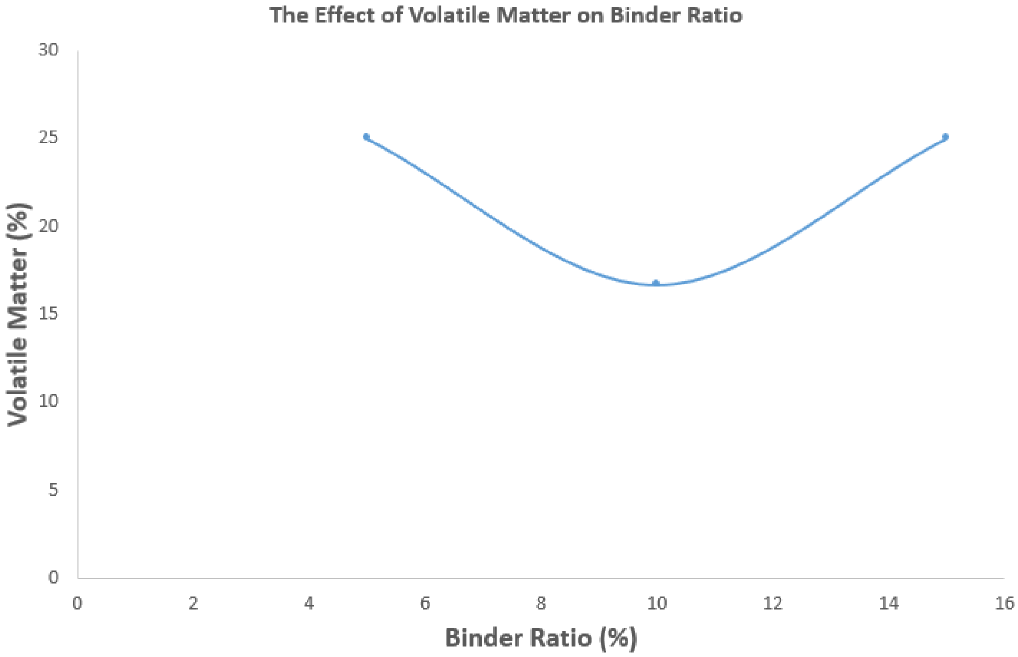

Fig 1. The Effect of Binder Ratio on the Volatile Matter of Coconut Briquettes

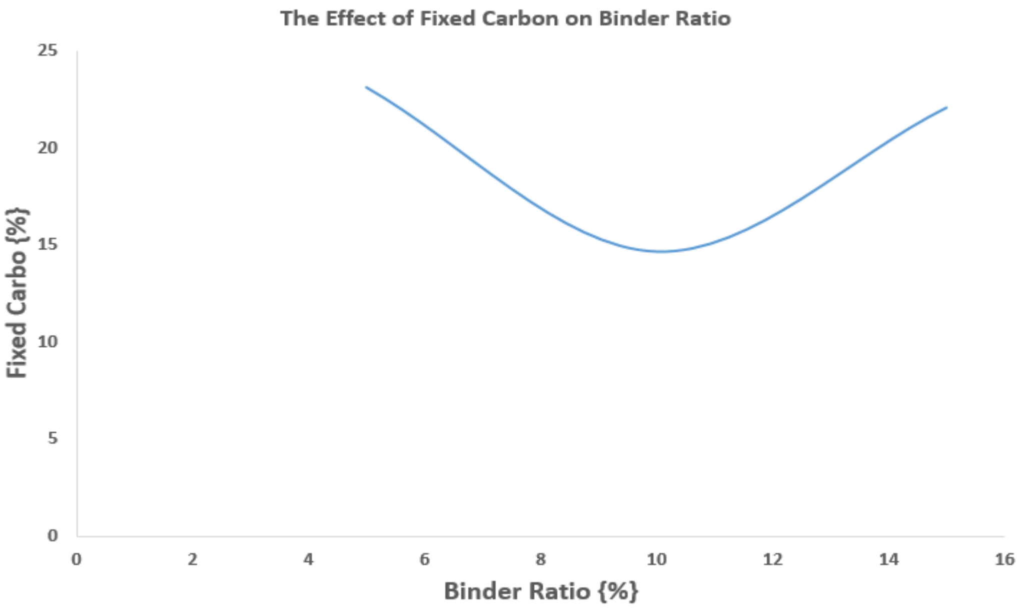

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Fig 2. The Effect of Binder Ratio on the Fixed Carbon of Coconut Briquettes

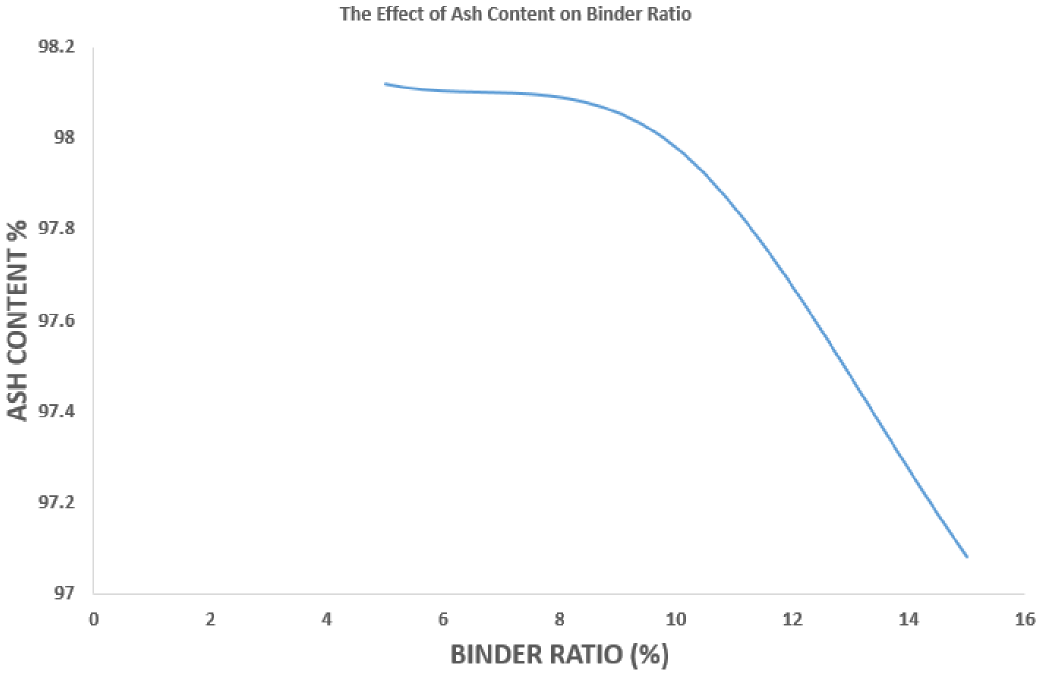

Fig 3. The Effect of Binder Ratio on the Ash Content of Coconut Briquettes

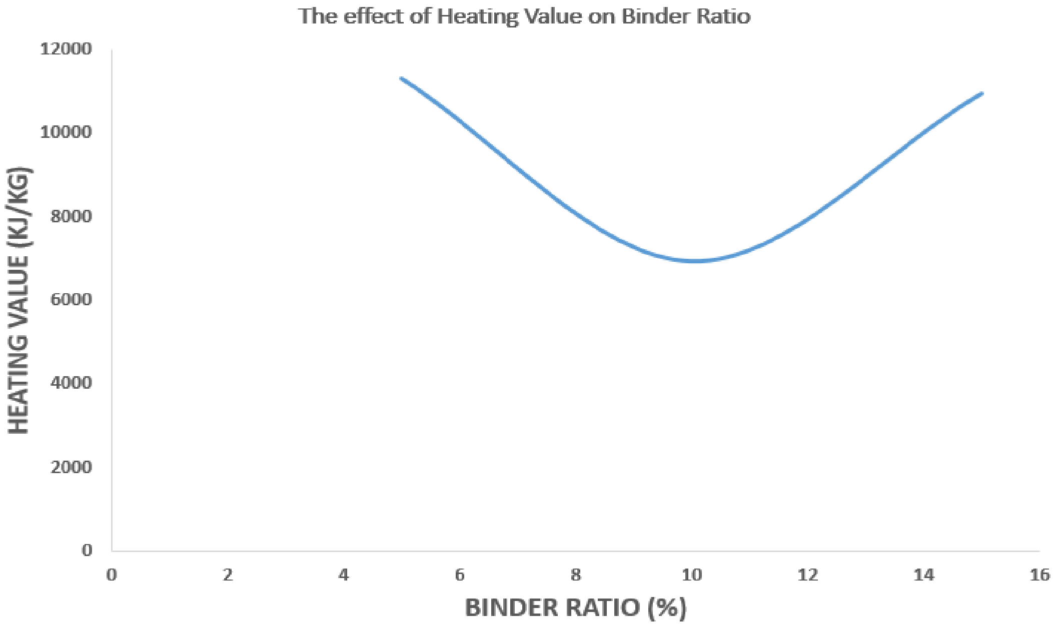

Fig 4. The Effect of Binder Ratio on the Heading Value of Coconut Briquettes

Conclusion and Recommendations

The paper evaluated the effect of % binder ratio on the combustion characteristics of Coconut briquettes. The results showed that the binder ratio (%) had a positive effect on the briquettes. From the results of the findings the following conclusions can be made:

1. The % volatile matter and heating values remained constant with slight increase in binder ratio (%) and dropped with further increase in the binder ratio (%).
2. The % fixed carbon and % ash content remained constant with slight increase in binder ratio (%) and increased with further increase in binder ratio (%).

It is recommended that higher binder ratio (%) be investigated to broaden the scope of the research. Also, other agro residues should be investigated to discover the effect of binder ratio (%) on their combustion characteristics.

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