BRIQUETTING OF PALM KERNEL SHELL BIOCHAR OBTAINED VIA MILD PYROLYTIC PROCESS

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ABSTRACT
The production of Palm kernel shell (PKS) fuel briquette via mild pyrolysis is the focus of this paper. The operating temperature was kept constant at 280 ^{0}C during carbonization at 30, 60, and 90 minute residence time. Proximate analyses and elemental composition of the char were determined, and also the calorific value of the briquette was obtained to be 20.27 MJ/kg. The briquette specific fuel consumption and the burning rate determined during the water boil test were 0.021kg/l and 1.18g/min respectively. The use of PKS briquette as high grade solid fuel can reduce considerably both environmental pollution emanating from wastes as well the energy crises in most developing countries.

Keywords: Palm kernel shell, briquette, pyrolysis, biochar, proximate, ultimate

INTRODUCTION

Deforestation and wood fuel shortages have become pressing problems in many developing countries which has necessitated the search for other types of biomass fuel. One of the ways of limiting the deforestation and protecting the environment is by briquetting of the flammable materials. With the rapid advances in biotechnology and bioengineering, some resources, which could have been classified as waste, now form the centre for energy creation (Mc Kendry, 2002). Briquetting of agro-residues is one of the numerous ways which has been developed to utilise huge volume of wastes from agriculture and agro-processing industries. Briquetting of biomass as an alternative fuel play a significant role to reduce the effects of global warming majorly arising from the combustion of fossil fuels (Deng*et al.*, 2009; Husan*et al*., 2002).
Biomass briquetting is the conversion of agricultural waste into uniform shapes which are easy to use, convey and store. It is a process of binding together pulverized carbonaceous matter, often with aid of binder (Felfi, 2005). Briquetting is a high pressure process which can be done at elevated temperature, or at ambient temperature depending on the technology applied. In some briquette techniques, the materials are compressed without addition of adhesive (binder less briquette) while in some adhesive materials are added to assist in holding the particles of the material together (Chin *et al.*, 2013; Adegoke and Mohammed, 1999).
According to Chin *et al*, (2013), palm kernel shell is among the numerous biomass feed stocks including rice straws, maize cobs, sugarcane bagasse, sawdust, melon and groundnut shells suitable for briquetting. The palm oil plants are mostly found in the southern parts of Nigeria. In the palm oil processing operations, the solid wastes are the empty fruit bunches (EFBs), palm fibre and palm kernel shell (PKS). PKS are carbonaceous solids, gotten from the processing of the oil palm fruit. It contains high proportion of carbon element and may be converted to a heat energy source by thermal reaction of the carbon content (Husan*et al*., 2002).

The palm kernel shell briquette can be used in domestic and cottage industries application, it is used to power boilers to generate steam as being utilized in some far eastern countries. Palm kernel shells are lit and the flame used in cooking in rural community levels. However, it burns with a lot of smoke owing to its organic content and the negative effects of such smoke to health cannot be over emphasized. For instance, the smoke from the wood releases pollutants, mainly in the form of particles and toxic gases which results in pollution in the atmosphere (greenhouse gas) and high potential for causing damage to the ozone layer. Also, numerousre searches has shown that mild pyrolysis has the potential of reducing the smoke producing compounds in the biomass (Chen and Kuo, 2010; Agbontalor, 2007; Attun et al., 2003; Bridge water, 2003, 1996; Akinbami, 2001).

Thus, the need for briquetting process to focus on the production of smokeless solid fuels from a palm kernel shell bio-char obtained via mild pyrolysis capable of giving better combustion performance and reduces pollutant emission has become paramount in this study.

Experimental

MATERIALS AND METHODS

Palm kernel shells were collected from the vicinity of Oro, Kwara state of Nigeria. Starch was processed from cassava obtained from the local market while manual briquetting machine fabricated at the department of agricultural and bio-resources engineering of the Federal University of Technology Minna, Niger state of Nigeria was employed.

Samples Preparation

The palm kernel shells collected were air - dried for ten days to reduce the moisture content of the materials. The materials were crushed and grounded using local pestle and mortar and subsequently passed through standard sieve to obtain uniform particles. Preparation of starch was also carried out as follows; Cassava tubers were washed, peeled, ground and pressed to extract the liquid content. The liquid was filtered and the filtrate was allowed to stay for 2 hours so that the starch would separate from the mixture. After that the upper liquid layer was carefully decanted and the starch was sun dried for five days to reduce the moisture content.

Mild pyrolysis process

The operating conditions were set at a constant torrefaction temperature of 280^{o}C and varying residence times of 30, 60 and 90 minutes respectively. The PKS residue was weighed and placed inside the reactor and the door kept closed. Pure N_2 gas was supplied continuously in order to create an inert atmosphere inside the reactor. Then, the residence time was set by a timer and the required torrefaction temperature was set by adjusting the digital temperature controller button. A T-type thermocouple placed inside the reactor was connected with the temperature controller. After the setting time, the timer switch cut out the electricity and left to cool to room temperature. The sample was then weighed and stored in airtight containers for subsequent analysis.

Preparation of the Briquette Samples

The PKS was pulverised using mortar and pestle and screened through sieve to a particle size of 2mm. Cassava starch was used as binder. 20 g of the cassava flour was dissolved in 40ml cold water. 100ml of water was put to boil in a container after which it was added into the cassava paste and then mixed properly with a stirrer.135 g of the pulverized Palm kernel shell charcoal were gradually added into the gel and mixed using a stirring stick until a thick, black compound was formed. Part of the thick paste was manually pressed into cylindrical moulds. The moulded thick paste was sun dried for 7 days to reduce its moisture content and compactness. The following tests were conducted on the briquette after one week of sun drying:

Proximate Analysis

The Moisture Content, Ash Content, Volatile Matter and the Fixed Carbon of the carbonized PKS were determined at the three different residence time in line with the ASTM D-3173 specification.

Ultimate Analysis

This analysis includes the testing for hydrogen, carbon, nitrogen, sulphur, and oxygen contents. All of which are in weight percent of the organic material. The Carbon (C), Hydrogen (H), Oxygen (O), Sulphur(S) and Nitrogen (N) determination in biomass represents is the elementary analysis carried out.

Calorific Value: The values of Carbon and Hydrogen, gotten from the ultimate analysis was used to determine the calorific value using the HHV formula (Yin, 2011; Sheng and Azevedo, 2005).

Ignition Test: The briquette sample was ignited at the base; the time taken for the flame to ignite the briquette was recorded as the ignition time using a stop watch.

Combustion Test: The sample briquette was ignited on a domestic stove, 100ml of water at room temperature was measured into an iron container and covered after which it was placed on the stove. Using a stop watch, the time it takes for the water to boil was noted. And also, the mass of the briquette fuel used during the test was recorded. During the course of the test fuel properties such as specific fuel consumption and burning rate were also determined (Kuti, 2009). Figure 1 show the moulded PKS briquette obtained.

Figure 1 Moulded Palm Kernel Shell Briquette

RESULTS AND DISCUSSION

The results are presented in Tables 1-3 and Figure 1 to 3. From Table 1, the values of fixed carbon (FC) increases as the residence time increases from 30 min to 90 min with a percentage increase from 23.49% to 28.61%. Result also show that PKS at 280^{o}C and 90 min having the highest fixed carbon composition of 28.61 % compared to the fixed carbon of 23.49 % and 27.56 % respectively at other residence times would provide a better char for making solid fuel. Furthermore, volatile matter (VM) and the moisture contents (MCs) of the torrefied PKS decreases with increase in residence time from 73.15 to 64.56 % and 0.83 to 0.33 wt% respectively. However, the ash content increases with increase in residence time from 2.44 % to 6.50 %., this findings of the moisture, volatile, fixed, and ash contents results is similar to the ones reported in literatures (Chen and Kuo, 2010; Agbontalor, 2007; Attun et al., 2003; Bridgwater, 2003, 1996; Akinbami, 2001).

Table 1.Proximate analysis of PKS at the same temperature and varying residence time

Temp.^{0}C	Residence time (min)	FC	Proximate (wt.%) MC	ASH	VM
280	30	23.49	0.83	2.44	73.15
280	60	27.56	0.67	3.75	66.02
280	90	28.61	0.33	6.50	64.56

Table 2. Ultimate analysis and calorific value of the torrefied PKS

Temp.^{0}C	Residence time (min)	C	Ultimate (wt.%) N	H	S	O	Calorific value HHV (MJ/kg
280	30	48.90	1.02	4.10	0.22	45.76	18.99
280	60	50.82	1.06	4.02	0.16	43.94	19.61
280	90	52.06	1.11	3.91	0.09	42.83	19.98

Result shows that carbon (C), nitrogen (N) and sulphur (S) contents of the PKS biochar increases with increase in residence time with 48.90 to 52.06 wt.%, 1.02 to 1.11 wt.% and0.22 to 0.09 wt.% respectively. Meanwhile, the percentage of oxygen decreases with increase in residence time from 45.76 wt.% to 42.83 wt.%. It was also noticed from the results that the percent composition of the sulphur was below 1 wt.% with increase in residence time, which makes the PKS biochar an environmental friendly fuel. Also, the higher heating value (HHV) of the biochar increases with increase in residence time with 18.99 MJ/Kg, 19.61 MJ/Kg, and 19.98 MJ/Kg respectively.

Figures 1-3 show the effect of moisture content, volatile matter and fixed carbon on the PKS biochar.

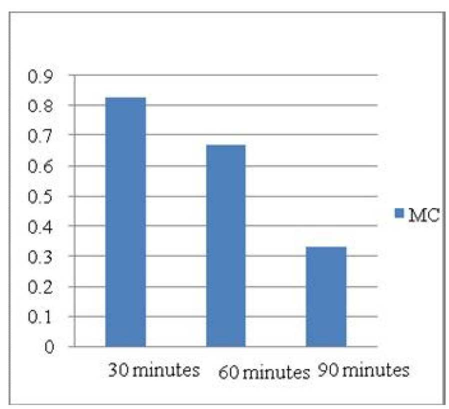

Figure1. Effect of Residence Time on Moisture Content

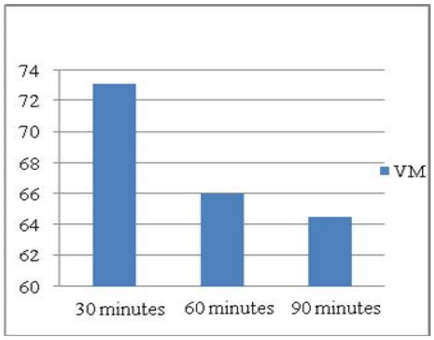

Figure2. Effect of Residence Time on Volatile Matter

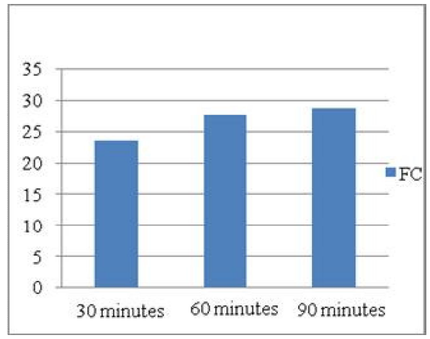

Figure3. Effect of Residence Time on Fixed Carbon

Table 3. Test result on PKS briquette

Tests	Data
The total weight of briquettes used	154.2g
Number of briquettes at the beginning of analysis	4
The average(dried) weight of each briquette	38.55g
The average weight of briquettes after water boil test	35.90g
Initial volume of water before water boil test	100ml
The final volume of water after boil test	91ml
Density of briquette	1.27g/cm^3
Average moisture content of briquette	5.58%
Carbon content	53.1%
Hydrogen content	3.8%
Nitrogen content	0.92%
Ignition time	1min 12secs
Calorific value	20.268 kJ/kg
Burning rate	1.18g/min
The specific fuel consumption	0.021kg/litre

From the ignition test result, the ignition time was observed to be 1min 12secs which gives a lesser value to the one obtained by (Kuti, 2007) as the time it took for the briquette to ignite. The results of the water boil test were used to calculate the burning rate and specific fuel consumption of the briquette. From the result, the burning rate was 1.18g/min which means that 1.18g of the briquette fuel was burnt per minute after ignition. This means that PKS briquette burns for a longer time. The value of the specific fuel consumption was also calculated to be 0.021 kg/litre which means 21g of the briquette fuel will be consumed to boil 1.0 litres of water.

The calorific value of the PKS briquette from the ultimate test shows a value of 20.268kJ/kg which gives a higher value when compared to the calorific value of sawdust briquette 18.936kJ/kg (Nasrin*et al*., 2008) and Palm Empty Fruit Bunches of 18.838kJ/kg. The calorific value also falls within the ASTM standard range for briquetting which is from 18 MJ/kg to 23 MJ/kg.It was observed that briquetting raises the calorific value of PKS from 18.72MJ/kg to 20.268MJ/kg.

Conclusion

Effective use of PKS waste into value added briquettes shows that PKS is a promising type of alternate fuel and will go a long way in creating an opportunity to build a bio economy which will in turn give rise to sustainable economic growth and job creation as the major outcomes. The project is economically viable since the materials and methods employed in making the briquette could easily be adopted at the local communities, with minimal training requirement. At 280^{0}C during carbonization of 30, 60, and 90 minute residence time. The calorific value of the briquette was obtained to be 20.27 MJ/kg. The briquette specific fuel consumption and the burning rate determined during the water boil test were 0.021 kg/l and 1.18 g/min respectively.

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