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The calorific value and compressive strength properties of composite briquettes from agro waste

J.O. Osarenmwinda, O.I. Ihenyen

Department of Production Engineering, University of Benin, Benin City, Nigeria

Abstract

The calorific value and compressive strength properties of composite briquettes from agro waste (palm kernel shell and groundnut shell) using starch as a binder have been investigated. The briquettes were produced with various composition of agro waste (palm kernel shell and groundnut shell) particle size of 100μm and starch binder concentration of 5% of the oven dry weight of agro waste. The briquette producing machine of 10 tonnnes capacity was used to produce various composition of briquette and the composite briquettes produced were evaluated for calorific value, ash content, compressive strength, density and moisture content properties. The results showed that calorific value and compressive strength increased as the palm kernel shell composition in the briquette increased. The optimum briquette calorific value and compressive strength was 16.65 Mj/Kg and of 2587.96 N/m^2 respectively.

Keywords: Briquette; starch; palm kernel shell; groundnut shell; calorific value; compressive strength

Introduction

Briquetting is defined as the densification (agglomeration) of an aggregate of loose particles into a rigid monolith. (Mordi, 2007).A briquette can thus be defined as a product formed from the physico-mechanical conversion of dry, loose and tiny particle size material with or without the addition of an additive into a solid state characterized by a regular shape.
Briquetting was first proposed in Russia by a Russian inventor F.P Veshniakov (Prokhorov, 1982). Veshniakov developed a method of producing briquettes from waste wood, charcoal and hard coal. During briquetting, a material is compressed under pressure to form a product of higher bulk density, lower moisture content and uniform size and shape. The most important advantages of briquette are its low sulphur content, relative freedom from dust, ease of handling and high calorific value (Osarenmwinda and Imoebe, 2006).

In Nigeria, briquetting technology has been applied to charcoal, saw dust and coal (Adegoke and Ajueyisti, 2003).The conversion of agricultural waste to produce high energy briquettes for domestic cooking have been investigated and found feasible (Adegoke, 1999). One major advantage of utilizing briquettes from agricultural waste is the appreciable reduction in environmental pollution. Musa (2007), compared briquettes made from rice husk and groundnut shell and observed that the latter was better. He obtained the calorific value of 11.9 Mj/Kg and 12.66 Mj/Kg for rice husk and groundnut shell briquette respectively, while the crushing strength was 1065.6 N/mm^2 and 2322.5 N/mm^2 respectively. He concluded that the briquette ultimate Analysis indicated that briquettes from Groundnut Shells have a higher carbon and hydrogen content and thus a better combustibility index. Osarenmwinda and Imoebe, (2006) produced composite briquettes from Sawdust (wood-dust), silica sand and kerosene using starch as a binder and obtained optimum calorific value of 12.68Mj/Kg) and concluded that the relative increase in calorific value was attributed to heat retaining ability of silica sand.

In developing countries like Nigeria, the direct burning of loose agro waste residues like rice husk, palm kernel shells, and groundnut shells in a conventional manner is associated with very low thermal efficiency, loss of fuel and widespread air pollution. When they are made into briquettes, these problems are mitigated, transportation and storage cost are reduced and energy production by improving their net calorific values per unit is enhanced (Grover et al, 1996).The focus of this work therefore was to investigate the calorific value and compressive strength properties of composite briquettes from agro waste (palm kernel shell and groundnut shell). This it is hoped will lead to wealth generation, creation of employment, reduction in environmental pollution and provide a cheap and efficient source of energy for domestic and industrial use.

2. Materials and method

2.1. Materials

Palm kernel shell (PKS) and Groundnut shell (GS) was obtained from oil mill in Benin city, Nigeria. While the cassava starch used as binder was obtained from Ediaken Market,Benin City, Nigeria. The major reason for choosing starch as a binder is it is smokeless when burnt, and it is relatively cheap and abundant. (Brown and Poon, 2005).Also the twin properties of gelatinization and retrogradation confer unique binding properties on starch (Morton, 2005).

2.2. Method

The Palm kernel shells and Groundnut shells were separately crushed into granules particles with a hammer mill and then separately sieved to a particle size of 100μm using the vibrating sieve. The Palm Kernel Shells and Groundnut shells particles were then mixed by weight using the various percentage ratios shown in table 1.Starch binder concentration of 5% of the oven dry weight of agro waste (Palm Kernel Shells and Groundnut shells) was used to produce starch gel (Musa,2007). The starch gel was then mixed with the appropriate proportion of the agro waste (Palm Kernel Shells and Groundnut shells) as shown in table 1 to form a homogenous mixture. The mix was then fed into the 20 dies of the 10 tonnnes capacity manual briquetting press (Ihenyen, 2009). The mixture was allowed to set for a period of about five minutes after which the lid was opened and the briquettes are ejected from briquette producing machine. The briquettes were then placed on a flat surface to dry. Each briquettes produced were cylindrical and had a 28mm diameter, while the height varied between 50 mm and 46 mm the produced briquette are shown in fig. 1.

Table 1
Produced Briquette Composition

Sample	%PKS	%GS
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50
7	40	60
8	30	70
9	20	80
10	10	90
11	0	100

Key:
%PKS = Percentage Composition of Palm Kernel Shell
%GS = Percentage Composition of Groundnut Shell

Fig. 1. Some Produced briquettes

2.2.1. Evaluation of produced briquette

Produced briquette samples were evaluated to determine the characteristics of the produced samples. The determination of density, ash content and moisture content of the produced briquettes was carried out using ASTM D 2974 – 87.

2.2.2. Determination of compressive strength

The individual samples were compressed in a manual compression testing machine. Individual briquette specimen is first oven dried before testing. A hydraulically controlled hand pump is used to drive the vertical spindle and thus moved the moveable block towards the direction of the stationary block where the oven dried briquette sample is clamped. The applied load is gradually increased with the aid of the hand pump until the oven dried briquette clamped on the fixed block fails. The applied force on briquette is read from an indicator attached to the vertical spindle of the machine and recorded. The compressive strength is then calculated using the Eqn. 1.

$$\sigma = \frac{P}{A} \quad (1)$$

Where σ =Stress in compression, P = Applied load or force in N, and A = cross sectional area of the briquette sample in m^2 and A is calculated using Eqn. 2.

$$A = \frac{\pi d^2}{4} \quad (2)$$

2.2.3. Determination of calorific value

The calorific value was determined with for each briquette sample with the aid of an Oxygen Bomb calorimeter. The oxygen bomb calorimeter was pressurized with excess pure oxygen at a pressure of 30 Pascal and a briquette sample of known mass 1 (gram) and some quantity of water (to absorb produced acid gases), is submerged under a known mass of water. With the aid of an automatic firing button, electrical energy is used to ignite the briquette sample. As the briquettes sample burns, it heats up the surrounding air, which expands and escapes through a copper tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. After about 30 seconds a temperature change is recorded on a Beckman thermometer graduated in Kelvin and read to one decimal place. The charge inside the calorimeter is then reignited by the automatic firing button until all organic matter is burned and oxidized. The temperature change in the water was then recorded again by the Beckman thermometer. This temperature rise, along with a bomb factor (which is dependent on the heat capacity of the metal bomb parts) is used to calculate the calorific value of the briquette sample. After the temperature rise has been measured, the excess pressure in the bomb was then released. The mass of water used for this test was recorded to be 0.25kg and the mass of the water equivalent of the calorimeter was given as 0.055kg. While a constant briquette sample size of 1g (0.001kg) was used. As an important safety precaution, the bomb assembly was allowed to cool before another test was conducted on the next sample.

The calorific value was calculated using the equation (3)

$$C_V = \left[\frac{M_W + M_C}{(M_f)^{-1}}\right] C.\Delta T \quad (3)$$

Where C_v = Calorific value of the Briquette sample in kj/kg

M_w = mass of water used in calorimeter, M_c = Mass of water equivalent of the calorimeter
C = specific heat capacity of water, C = 4200j/kg/k, M_f = mass of briquette tested
ΔT = corrected temperature rise of water (in k)

3. Results and Discussion

The Briquette Properties (density, moisture content, Ash content, compressive strength and calorific value) are shown in Table 2.The density of agro waste palm kernel shell and groundnut shell was determined to be 881.6kg/m^3 and 655.5kg/m^3 respectively. A summary of the result obtained from test carried out on different briquette compositions are shown in Table 2. From Table 2, it can be deduced that the density of produced briquette ranged from 670 kg/m^3 to 1068 kg/m^3. Density of the composite briquettes increased as the percentage of the palm kernel shell in the briquette composite increased. This can attributed to the fact that palm kernel shells with a density of 881.6 kg/m^3, have a higher density than groundnut shells which is 655.5kg/m^3 (Ihenyen,2009).

Table 2
Produced briquette properties

Briquettes Composition			Density kg/m^3	Moisture Content	Ash Content %	Compressive Strength N/m^2	Calorific Value Mj/kg
Samples	%PKS	%GS					
1	100	0	1, 068	9.7%	5.7	2587.96	16.65
2	90	10	1, 068	9.7%	5.4	2572.73	16.27
3	80	20	974.3	6.7%	5.0	2552.44	15.88
4	70	30	974.3	16.7%	5.6	2537.21	15.63
5	60	40	947.2	10.9%	5.2	2521.99	15.37
6	50	50	913.4	11.1%	4.58	2471.25	14.99
7	40	60	879.6	7.7%	4.58	2435.72	14.48
8	30	70	882.8	16.0%	5.2	2410.35	14.09
9	20	80	811.9	17.4%	5.3	2334.24	13.19
10	10	90	706.0	10%	5.5	2232.75	12.68
11	0	100	670.0	31.5%	7.69	2182.00	11.91

Key: %PKS = Percentage composition of palm kernel shell, %GS = Percentage composition of groundnut shell

The compressive strength of the produced briquette ranged from 2182.00 N/m^2 to 2587.96N/m^2 (Table 2). It was also observed from table 2, that there was a steady increase in the compressive strength of the briquette samples as the percentage of palm kernel shell in the briquette composition increased. This increase may have been experienced due to fact that the palm kernel had a greater density than groundnut shell (Ihenyen, 2009) and so as the percentage of palm kernel shell in the briquette increased the briquette compressive strength increased. Briquette with 100% palm kernel shell and 0% groundnut shell gave the optimum compressive strength of 2587.96N/m^2. The higher the briqueete compressive strength,the better the ability for it to withstand the stress usually experienced during its handling and transportation.

The range of calorific value from 11.19Mj/kg to 16.65Mj/kg (table 2) .The calorific value of produced briquette was observed in table 2 to increase as the palm kernel shell composition increased in the briquette. This may be attributed to the oil content of the palm kernel shell. The optimum calorific value of produced briquette was 16.65Mj/kg (table 2).This is higher than the briquette produced with rice husk and groundnut shell briquette with a calorific value of 11.9Mj/kg and 12.6Mj/kg respectively(Musa,2007). The calorific value obtained in this work was also higher than the one obtained by Osarenmwinda and Imoebe, 2006 who used sawdust and silica, to produce a briquette which calorific value was 12.32Mj/kg .The determined calorific value(16.65Mj/kg) of produced briquette compares favourably with the calorific value of hard wood which varies from 16 – 20Mj/kg (www.woodheat.org/firewood, 2009).

4. Conclusion

Briquettes have been produced using a combination of palm kernel shell and groundnut shell and starch as a binder in this study. The briquette calorific value and compressive strength ranged from 11.91Mj/kg to 16.65Mj/kg and 2182.00 N/m^2 to 2587.96N/m^2 respectively. We can conclude that agro waste (palm kernel shell and groundnut shell) can be used to produce high quality briquettes which can be used for domestic and industrial applications.

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