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Effects of Particle Size on the Thermal Properties of Sawdust, Corncobs and *Prosopis Africana* Charcoal Briquettes.

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ABSTRACT: *The thermal properties of Sawdust, Corncobs and Prosopis Africana Charcoal briquettes were studied as a function of particle size. The particle sizes were 300, 425, 600, 1180 and 2000µm. The sieved materials were compressed into briquettes and pellets. The pellets were 12.5mm diameter and 13mm in length. The properties determined were moisture content, ash content and calorific value. The calorific value for Sawdust particle were 300µm =16.04MJ/kg and 2000µm = 17.82MJ/kg which indicates an increased with increase in particle size. For Corncobs the calorific value also rises from 16.63MJ/kg to 17.51MJ/kg for 300 µm and 2000 µm respectively. In the same vain Prosopis Africana charcoal gives 24.94MJ/kg for 300µm size and 29.67MJ/kg for 2000µm. It was observed that for all the materials investigated, an increase in particle size was accompanied by higher energy output.*

Keywords: *Briquette, Moisture, Ash, Calorific value*

I. INTRODUCTION

The Nigerian energy industry is probably one of the most inefficient in meeting the needs of its customers. The use of kerosene and gas for cooking and domestic heating on the other hand is very expensive and the common man in Nigeria cannot afford. Even though Nigeria is said to be endowed with many natural resources, (Sambo, 1992 and Adenikinju, 2005), there is problem of energy scarcity. More than 70% of the populace has no access to national grid and those who have are facing the problem of low and epileptic supply coupled with high cost as reported by Jekayinfa and Scholz, (2009) and Oladeji (2013a).

Renewable source of energy is the fastest growing source of world energy, with consumption increasing by 3% per year. This is due to its environmental friendliness as against the rising concern about the environmental impact of fossil fuel use and also strong government incentives for increasing renewable penetration in most countries around the world EIA, (2009). Globally, biomass currently provides around 46 EJ of bioenergy in the form of combustible biomass and wastes, liquid biofuels, solid biomass/charcoal and gaseous fuels. According to FAO, (1990) this share is estimated to be over 10% of global primary energy, with over two-thirds consumed in developing countries as traditional biomass for household use.

Currently there is a tremendous interest in using biomass materials in many countries for the production of liquid transportation fuels, combine heat and power, chemical and bio- products Abdullahi *et al*, (2011). The use of wood is increasing on daily basis especially in the less technologically developed countries of the world as stated by Aremu and Agarry (2013). But complete reliance on wood for domestic cooking would not solve the present energy crisis; rather it would lead to deforestation or desertification resulting in further scarcity of this resource (Salunkhe, *et al*, 2012).

To address the various energy challenges associated with non-renewable fuels, many countries have indicated commitment to Biofuels production that are renewable, sustainable, cheap and safe and geographically diversified. Fabian (2003). For example, Agricultural biomass residues have the potential for the sustainable production of bio-fuels and to offset greenhouse gas emissions Campbell *et al* (2002). According to Liu, (2005), straw from crop production and agricultural residues existing in the waste streams from commercial crop processing plants have little inherent value and have traditionally constituted a disposal problem. Oladeji, (2011) further stated that these residues represent an abundant, inexpensive and readily available source of renewable lignocelluloses biomass. Agriculture offers much potential for renewable energy sources in the form of biomass. With advances in biotechnology and bioengineering, some resources, which could have been classified as waste, now form the basis for energy production Oladeji, (2010). The large quantities of agricultural residues produced in Nigeria can play a significant role in meeting her energy demand. Unfortunately, the abundant quantities of agricultural wastes and forest residues are neither managed effectively, nor utilized efficiently in all developing countries. The common practice is to burn these residues or they are left to decompose .This burning itself contributes to atmospheric pollution, but more than that; the burning or decomposition is a waste of available energy Wanukanya (1995). However, these problems can be handled through densification of biomass materials into pellets, briquettes and cubes.

A briquette is a block of combustible matter which is used to start and maintain a fire. Henry ford have been credited with the invention of charcoal briquettes from the wood scraps and saw dust from his car factory. Worthless fine coals were compressed into briquettes in the late 1800s allowing for stable transportable products to be made. www.virtualbilled.com. Charcoal briquetting have been used in emerging economies as cooking fuel in rural areas. The process of manufacture usually employs a devitalizing step whereby gas or volatile matter is driven prior to briquetting to produce a smokeless domestic fuel. Biomass briquettes produced through densification of Sawdust and other agro residues has been practiced for many years in several countries. The binding mechanisms of densification encompass the suitability of biomass based on its physical and chemical properties. Physical properties are most important in the description of the binding mechanism of biomass densification. Densification of biomass at high pressure brings about mechanical interlocking and increased adhesion between particles, forming interlocking bonds in contact areas Grover, (1996).

The densification of biomass into briquettes, logs, bales, chips, pellets, etc has become an important source of energy even in the rural communities. The main advantage of the Biofuel briquettes are its domestic origin, potential for reducing total dependence on oil and gas economy, jobs creation to the rural dwellers and help in the waste management by changing waste to wealth. Biofuels briquettes for utilization as energy source for domestic and industrial heating processes can significantly reduce emissions of air pollutants Fabian, (2003).

This work investigated the effects of particle size on the calorific values, moisture and ash content of Sawdust, Corncobs and *Prosopis Africana* charcoal briquettes.

II. MATERIALS AND METHODS

2.1. Raw Material Procurement

The raw materials used include Sawdust, Corncobs and *Prosopis Africana* charcoal. The Sawdust and Corncobs was obtained from a saw mill in Muda Lawan timber market. The Corncobs were obtained at the University farm while the charcoal was bought from local charcoal producers at the Galambi cattle ranch. The Sawdust and Corncobs samples were sundried. All the samples were hand crushed and grounded using a hammer mill at the Center for Industrial Studies, Abubakar Tafawa Balewa University, Bauchi. The grounded samples were sieved into five different particle sizes using (300, 425, 600, 1189 and 2000µm) sieves for all samples. The briquettes were then air dried then sieved

2.2. Briquettes Production

A wood/Agric waste briquetting machine shown in plate I is a device used to produce solid briquettes from wood and agricultural waste. It is manually operated based on the principle of piston cylinder arrangement. Basically, the briquettes were produced in cylinders when a mixture of raw materials and suitable binders were compacted by the piston. The machine consist of the following components: the compaction and ejection lever, Pillar caps, cylinder cover assembly, table, cylinder, connecting rods and piston assembly, pillars, lever for operating the cover, the base and the auto feed unit.

2.3. Briquetting Process

Binding agents were made into paste using hot water and the sieved waste material was added in the ratio of 1:5, 1:7, 1:10 (binder : waste) following the method of Akpabio and Illalu (1997). The paste and the waste were thoroughly mixed and loaded into the cylinders of the Briquetting machine shown in Plate I which is manually operated to achieve compaction.

Plate I: Manually operated Briquetting Machine

Plate II: Briquettes produced using the Briquetting Machine

The briquettes (Plate II) were extruded from the mould with the aid of the extruding ram. The procedure was repeated for all samples. The briquettes were then air-dried for two weeks.

2.4. Determination of Moisture Content

The procedure suggested by Dara (1999) was adopted. The weighed briquettes were put into an oven whose temperature has been adjusted to between 105^oC to 110^oC and left for 24 hours. They were then removed from the oven, allowed to cool and weighed. The procedure was repeated two times and the average taken. The moisture content of each sample was expressed as a percentage of its dry mass and was computed using equation (2):

$$\text{Moisture content } Mc = \frac{\text{loss of moisture}}{\text{dry mass}} \text{x}100, \% \qquad (1)$$

Let m_1 = mass of empty container

m_2 = mass of container and wet sample.

m_3 = mass of container and dry sample (after heating).

Then

$$M_C = \frac{m_2 - m_3}{m_3 - m_1} x100 \qquad (2)$$

2.5. Determination of Ash Content

The procedure suggested by Dara (1999) was adopted. Each sample was placed in a crucible weighed and burnt in a furnace at 350^{o}C and left to cooled overnight in the furnace. Thereafter, the ash was later weighed. The ash content was then determined on dry basis using equation (3):

$$\text{Ash Content } A_C = \frac{m_a - m_1}{m_2 - m_1} x100 \qquad (3)$$

where m_2 = weight of sample and container

m_a = weight of container and ash.

m_1 = weight of container

2.6. Determination of Calorific Value

The bomb calorimeter was used to determine the calorific value of the briquettes and results obtained. The result of the calorific value was calculated using equation (4) as suggested by Dara, (1999) and the result tabulated in Table 7.

$$\text{Calorific value} = \frac{(W + w)x\Delta T}{X}, kcal \; / \; kg \qquad (4)$$

where: W = weight of water in calorimeter, (kg)
w = water equivalent of apparatus (kg)
ΔT = temperature rise ^0C
X = weight of fuel sample taken (kg)

III. RESULTS AND DISCUSSION.

3.1. Results.

The results of the experiments carried out on the moisture, ash and calorific values on saw test, corncobs and Prosopis Africana charcoal are presented on tables 1 to 7.

Table 1: Results of Moisture Content of Sawdust

Sample size		300µm	425 µm	600 µm	1180 µm	2000 µm
Container label		A	B	C	D	E
Container and wet sample (g)	m_2	8,00	8.00	8.10	8.00	8.00
Container and dry sample (g)	m_3	7.90	7.90	8.00	7.90	7.90
Empty Container(g)	m_1	7.00	7.00	7.00	7.00	7.00
Dry Sample(g)	m_3-m_1	0.90	0.90	1.00	0.90	0.90
Moisture Loss (g)	m_2-m_3	0.10	0.10	0.10	0.10	0.10
Moisture Content (%)	w	11.11	11.11	10.00	11.11	11.11

Table 2: Results of Moisture Content of Corncobs

Sample size		300µm	425 µm	600 µm	1180 µm	2000 µm
Container label		A	B	C	D	E
Container and wet sample (g)	m_2	9.00	9.00	9.10	9.00	9.10
Container and dry sample (g)	m_3	8.80	8.70	8.90	8.70	8.90
Empty Container(g)	m_1	7.00	7.00	7.00	7.00	7.00
Dry Sample(g)	m_3-m_1	1.8	1.70	1.90	1.70	1.90
Moisture Loss (g)	m_2-m_3	0.20	0.30	0.20	0.30	0.20
Moisture Content (%)	w	11.11	17.65	10.52	17.65	10.53

Table 3: Results of Moisture Content of Prosopis Africana Charcoal

Sample size		300 µm	425 µm	1180 µm	2000 µm
Container label		A	B	C	D
Container and wet sample (g)	m_3	8.00	8.10	8.00	8.00
Container and dry sample (g)	m_3	7.90	8.00	7.90	7.90
Empty Container(g)	m_1	7.00	7.00	7.00	7.00
Dry Sample(g)	m_3-m_1	0.90	1.00	0.90	0.90
Moisture Loss (g)	m_2-m_3	0.10	0.10	0.10	0.10
Moisture Content (%)	w	11.11	10.00	11.11	11.11

Table 4: Results of Ash Content of Sawdust.

Sample Size	300µm	425 µm	600 µm	1180 µm	2000 µm
m_a (g)	7.50	7.30	7.20	7.20	7.10
m_1 (g)	7.00	7.00	7.00	7.00	7.00
m_2 (g)	8.10	8.20	7.90	8.00	8.30
m_a- m_1	0.50	0.30	0.20	0.20	0.10
m_2 –m_1	1.10	1,20	0.90	1.00	1.30
A_c (%)	45.45	25.00	22.22	20.00	7.69

Table 5: Results of Ash Content of Corncobs.

Sample size	300µm	425 µm	600 µm	1180 µm	2000 µm
m_a (g)	7.40	7.30	7.30	7.20	7.10
m_1 (g)	7.00	7.00	7.00	7.00	7.00
m_2 (g)	8.10	8.10	8.10	8.10	8.10S
m_a- m_1	0.40	0.30	0.30	0.20	0.10
m_2 –m_1	1.10	1.10	1.10	1.10	1.10
A_c (%)	36.36	27.27	27.27	18.18	9.09

Table 6: Results of The Ash Content of Prosopis Africana Charcoal

Sample size	300 µm	425 µm	1180 µm	2000 µm
m_a (g)	7.30	7.20	7.20	7.10
m_1 (g)	7.00	7.00	7.00	7.00
m_2 (g)	8.10	8.10	8.00	8.00
m_a- m_1	0.30	0.20	0.20	0.10
m_2 –m_1	1.10	1.10	1.00	1.00
A_c (%)	27.27	18.18	18.18	10.00

Table 7: Results of Calorific value of the three materials

Sample size	300µm	425 µm	600 µm	1180 µm	2000 µm
Sawdust	16.04MJ/kg	17.50MJ/kg	17.20MJ/kg	17.72MJ/kg	17.82MJ/kg
Corncobs	16.63MJ/kg	16.94MJ/kg	17.20MJ/kg	17.35MJ/kg	17.51MJ/kg
Prosopis Africana Charcoal	24.71MJ/kg	29.15MJ/kg	29.24MJ/kg	29.38MJ/kg	29.67MJ/kg

3.2. DISCUSSIONS

3.2.1. Moisture content

From the tests conducted, results are presented in Tables 1, 2 and 3. For all the material samples, the moisture content was kept as low as possible. Compared with wood, biomass briquettes are unique in that they provide opportunity to control during the process of manufacture the fuel density, moisture content, size and geometry as reported in the works of Kaliyan and Morey (2007) and Chaney (2010). Generally for best performance, the range should be between 10 - 15 percent of moisture as discovered in this work. However, the corncob samples have higher amounts of moisture content because it was the most difficult to compact, thus more water and binder was needed to ensure adequate compaction.

3.2.2. Ash content

Tables 4 to 6 shows the results of the test conducted generally for all samples the smaller particle size (300 **µm**) contained more ash due to the fact that the smaller particle sizes are less coarse, compact easily leading to incomplete combustion due to small numbers of pore spaces. Coarse particle sizes (from 1180 **µm** to 2000 **µm**) have greater number of pore spaces allowing oxygen to flow easily within the sample. However, for the medium sizes (425 **µm** to 600 **µm**) the compaction was moderate thus there was available space for the oxygen to flow and combustion was near complete. Lastly, the larger particle which were the most difficult to compact were more loosely bond. Hence, allowing adequate flow of oxygen and so combustion was complete resulting in less ash content.

3.2.3. Calorific value

The result (Table 7) shows the difference in energy content of each sample. The amounts of energy released in the samples were in ascending order such that the smaller particle sizes release less energy as compared to the larger ones except for the Sawdust samples where there was a sharp contrast in values between particle size (425 **µm** and 600 **µm)** as a result of high moisture content.

Results from the analysis showed that for increasing particle sizes there was corresponding increase in thermal efficiency. The most thermal efficient particle size was the 2000 **µm** particle size of the samples. The fine grinding resulted in a loss of some heat and made the sample vulnerable to oxidation as reported by Kumar and Pratt (1996). Abdullahi et al. (2011) also obtained the same results when selected biomass was investigated. It can also be seen that the measured calorific value for all the particle sizes falls in the range of 16**-** 30 MJ/kg for the materials considered.

IV. CONCLUSION

The effects of particle size on the thermal properties of Sawdust, Corncobs and *Prosopis Africana* charcoal briquettes were carried out. The investigation involved, the collection crushing and milling of the samples. The characterization of samples based on particle size using British standard Sieves (aperture sizes 150, 300, 425, 600, 1180 and 2000 **µm**) and the production of briquettes and pellets of each sample was done. The ash content, moisture content and calorific value of each pellet were also determined using standard methods. The results of the research showed that the finely ground particles (300µm) had low calorific value when compared to (2000µm) grain size.

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