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Production and Comparartive Study of Pellets from Maize Cobs and Groundnut Shell as Fuels for Domestic Use.

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ABSTRACT : *The economic development of any nation is unavoidably a prerequisite of the amount of energy available for its consumption. The need to develop alternative energy sources for fossil fuel is clear due to its scarcity, persistent increase in price and non renewability. The development of energy from biomass is one area among the various energy alternatives that has considerable promise and is receiving attention. This paper handles the production and comparative study of solid fuels from agricultural waste (i.e. maize cobs and groundnut shell) that can serve as alternative energy sources for domestic use, using the densification process. The material were grounded and sieved to particle sizes of 0.425mm and below and was compressed into pellets of 12.5mm diameter and 13mm length at a minimum pressure of 275 bars. The characteristics of the pellets determined were moisture content, ash content, combustion rate and calorific value. The result showed that groundnut shell pellets attained a higher temperature than maize cobs. The temperatures attained by 100g of each type of fuel were 756^{0}C and 600^{0}C for ground nut and maize cob pellets respectively. The result of the net calorific value test for maize cob was found to be 13.8MJ/kg while that of groundnut shell pellets was 13.9MJ/kg. These results showed that the pellets are capable of generating heat that is sufficient for domestic use if appropriate appliances are used.*

KEYWORDS:* *solid fuels, agricultural waste, groundnut shell pellet, maize cobs pellet, combustion rate, calorific value.

I. INTRODUCTION

A fuel is a collection of elements, which will readily combine with oxygen (combustion) and release thermal energy continuously in sufficient quantity for practical use. When a fuel is burnt chemical changes take place, which are all accompanied by the release of energy in the form of heat and light [1]. The patterns of consumption of these fuels have varied over the years as relative prices have also changed. For example oil has changed from being one of the cheapest forms of fuel to being almost the most expensive [2].Since increased energy consumption is an unavoidable prerequisite of future economic development, the need to develop alternative energy sources is clear.

The development of energy from Biomass is one area among the various energy alternatives that has considerable promise and is receiving attention. Biomass is a non- conventional and renewable energy obtainable mainly from organic matter and plants residue. In Nigeria for instance, energy supply is mainly through the conventional fuels (oil, natural gas and coal) but due to scarcity and increase in fuel prices most people in the rural and urban areas are always forced to use wood [3].According to a survey report of Sokoto Energy Research Center (SERC: [4] fuel wood was found to be a predominant energy source in the household with about 70-80% households depending on it as their cooking fuel in both remote villages and towns. A wide variety of techniques are available to utilize biomass resources, but the most efficient have been to burn them directly for heat. But this approach has a limitation because demand for energy is often remote from biomass production area. Hence to reduce transportation problem and to increase the versatility of biomass energy, it is often desirable to convert biomass to a variety of more convenient fuel forms. The crop residues that are commonly used as sources of energy includes rice husks, sugar cane fiber, groundnut shells, maize cobs, coconut husks and palm oil fiber etc. The use of biomass as alternative sources of energy is attractive because it addresses both problems of waste disposal and fuel wood shortages. The extraction of useful energy from biomass could bring very significant social and economic benefits to both rural and urban areas.

Pellet fuels are clean and easy to handle and this makes them particularly suitable for domestic use. They can be used in specifically designed stoves. Using pellet fuels reduces dependence on finite fossil fuels like oil or gas and does not contribute to the green house effects, which causes global warming. The physical and chemical composition of groundnut shell and maize cobs is shown in Table 1.

Table 1: *Physical and Chemical Composition of Groundnut shells and Maize cobs*

Properties	Units	Groundnut shell	Maize(corn) Cob
Carbon	%	14.99	19.73
Hydrogen	%	16.42	15.56
Nitrogen	%	1.21	0.38
Oxygen	%	63.62	54.98
Sulfur	%	3.00	4.48
Moisture content	%	8.76	42.98
Ash content	%	0.76	4.85
Gross Calorific Value	MJ/kg	17428	19480
Net Calorific Value	MJ/kg	13785	16028

Source: [5]

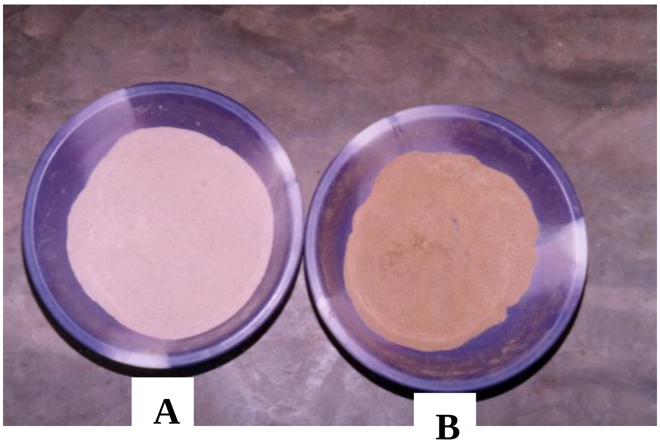
Some of the methods adopted for conversions of biomass are: anaerobic digestion; direct combustion; pyrolisis; gasification; fermentation and densification technology. These methods function to process biomass conveniently into solid, liquid and gaseous fuels. The efficiency of the conversion process determines how much of the actual energy can be practically utilized. Densification as employed in this research is the process of compaction of biomass at a very high pressure using a die or mould to produce solid fuels (e.g. pellet, cubes, log and briquette) that can be easily stored transported and burned more efficiently. This process improves the calorific value of the fuel and also reduces the cost of transporting the residue [6]. Densification of biomass under high pressure brings about mechanical inter locking and increased adhesion between the particles, forming intermolecular bonds in the contact area. The binding mechanism under high pressure can be divided into adhesion and cohesion forces, attractive forces between solid particles and interlocking bonds [7].

Pelletizing is the process of producing pellets by compaction of Biomass at a very high pressure. These products have significantly smaller volumes than the original biomass and thus have a larger Volumetric Energy Density (VED) making them a more compact source of energy, easier to transport and store than natural biomass [13].

II. MATERIALS AND METHODS

Materials collection : The groundnut shells were obtained in Yelwa-Kagadama whereas the maize cobs were collected at Federal Polytechnic Bauchi in Gwallameji, all in Bauchi Local Government area of Bauchi state.

Materials preparation : The groundnut shells and the maize cobs were pounded to reduce the sizeof the samples. It was later grounded into powder in a grinding mill. The powdered materials were sieved into different particle sizes ranging of 425µm and below. The weights of samples retained on each screen were expressed as a percent of the total weight. The percent passing is the cumulative amount retained subtracted from 100 [9]. Plate A and B showed the sieved samples.



(A) Maize Cobs (B) Ground Groundnut Shell

Mould design : A metallic mould was designed to withstand compaction pressure and to enable uniformity of size, ensure easy flow and high efficiency of pellets. A metallic mould will permit repetition and can be efficiently used for mass production [10]. Mild steel was considered for the mould material due to its lower cost, availability and machinability.

Experimental Method :

Determination of moisture content: The samples were weighed and dried in an oven for four hours at 105^{o}C and then weighed again. The moisture content was determined on the wet basis using the equation below [10].

$$m_c = \frac{(m_2 - m_1) - (m_3 - m_1)}{(m_2 - m_1)} \times 100$$

Where

m_c =moisture content
m_1 = wt of empty container
m_2 = wt of container + sample before drying
m_3 = wt of container + sample after drying.

Determination of ash content: The samples were weighed and burnt in a furnace at 350^{0}C and left overnight in the furnace. The ash content was then determined on the dry basis as follows [12].

$$A_c = \frac{(m_a - m_1)}{(m_2 - m_1)} \times 100$$

Where A_c = Ash content
m_2 = wt of sample + container
m_a = wt of container + Ash.
m_1 = wt of container

Determination of calorific value: Samples calorific values were determined using a bomb calorimeter at the metallurgical Research and Development center Jos

Determination of Combustion Rate: 50g and 100g of the groundnut shell and maize cob pellet samples were each weighed in sample containers and burnt. The combustion was initiated by the addition of a little kerosene. The temperature of the burning samples was taken at intervals until it completely burnt. This test was conducted in a form of open fire under indoor conditions.

Fig. 1. Determination of Combustion Rate.

Water Boiling Test: 50g and 100g of pellets were used to boil two litres of water, the temperature and time taken for the water to boil was measured.

Rate of deterioration of pellets : This was achieved by storing the pellets at room temperature with a temperature range of between 29°C to 33°C, relative humidity between 80% - 90% for a period of six months.

Groundnut shell pellet

Maize cob pellet

III. RESULTS AND DISCUSSION

Nature of Pellets: Each of the groundnut shell pellets weighed approximately 2.3g while maize cobs pellets weighed 1.9g. The pellets can completely dissolve when it comes in contact with water as such it should be stored in polythene bags or in a dry place. The groundnut shell is seen to be a better material for pellet fuel than maize cobs. The sulfur and nitrogen content of the fuel varied between 1 - 3% (Table 2). This value falls below 5% hence will not cause problem to the environment. [11], this percentage is low and has also been shown to be harmless to humans by Pellet manufacturers [12].

Moisture Content : The moisture content was calculated on wet basis and the result of the test carried out are as shown in Table 2. The values of the test showed that the moisture content was within the pellet fuel quality and standard of between 5 – 10% as recommended by the Pellet Fuel Institute [13].

Ash Content : This result is as shown in Table 2, with a highest value of 17.9% for maize cobs and 10.2% for groundnut shells. These values are higher than that of wood pellets as reported by [14]. However, it shows that about 70 – 80% of the fuel can be burnt completely and will likely produce a substantial heat that is needed for domestic use.

Calorific Value : The results of this test is as shown in Table 2. A little difference in the energy content of the maize cob pellets and groundnut shell pellets was observed. This can be attributed to the constituents of the fuel and moisture content which were 13.06% and 11.48% for groundnut shell and maize cobs respectively. These calorific values are lower when compared to 16.7MJ/kg and 19.3MJ/kg for groundnut shell and maize cob respectively [16]. The moisture contents were found to be 3-10% for groundnut shells and 4.5% for maize cobs. These results obtained (maize cobs 13.8MJ/kg and groundnut shell 13.9MJ/kg) still showed a high energy content that can meet domestic needs such as cooking, water boiling and space heating.

Combustion Rate Test : It was observed that the pellets maintained their shape even in the ash form. Two set of tests were conducted (for 100g and 50g) and the results were then compared.

Figure 1 shows the combustion rate of 50g groundnut shell and maize cobs pellets respectively. The groundnut shell pellets attained a temperature of about 750 °C in less than 30 minutes and sustained a temperature above 100 °C for a period of about 40 minutes while maize cobs pellets attained a maximum temperature of 600°C in less than 20 minutes and sustained a temperature of 100° C for 50 minutes.

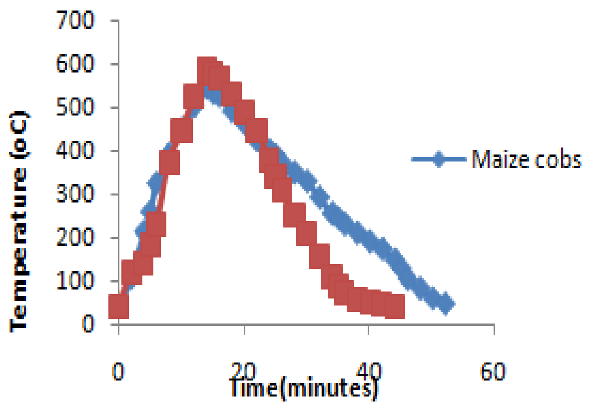


Fig 2: Combustion rates of 50g groundnut shell and maize cob pellets

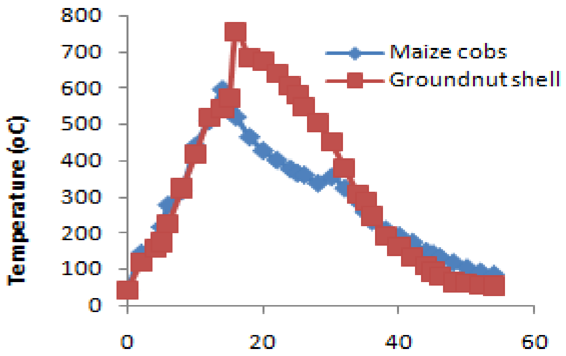


Fig 2: Combustion rates of 100g groundnut shell and maize cob pellets

Figure 3 shows the results for 100g of groundnut shell

Figure.2 shows the results of groundnut shells and maize cob pellets respectively. In these cases the groundnut shell generated a temperature of about 600 ^{o}C in less than 20 minutes which gradually reduces to about 100 ^{o}C after 35 minutes while maize cob pellets generated a temperature of 575 ^{o}C. This dropped gradually to about 100 ^{o}C in 40 minutes, and then settled at a room temperature of 45 ^{o}C. Figures 1 and 2 compare the combustion rates for 50g and 100g for groundnut shell and maize cob pellets. It can be seen that the groundnut shell pellets gave a higher temperature than the maize cob pellets.

Water Boiling Test : In the water boiling test, three different quantities of pellet fuel samples (50g and 100g) were used to raise the temperature of two liters of water. The recorded times are as shown in Table 3. This shows that as the quantity of fuel increases the amount of heat generated also increases and the shorter the time to bring the water to boil..The ground nut shell also show a higher energy value than maize cobs.

Table 2: Characteristics of Pellets Samples

Properties	**Pellets Sample**	**%**
Moisture content	Groundnut shell	5.8
	Maize cobs	3.6
Ash content	Groundnut shell	10.2
	Maize cobs	17.9
Gross Calorific value	Groundnut shell	15.31
	Maize cobs	15.55
Net Calorific Value	Groundnut shell	13.9
	Maize cobs	13.8
Nitrogen	Groundnut shell	1.66
	Maize cobs	2.21
	Groundnut shell	1.41
Sulphur	Maize cobs	2.23

Table 3: Water Boiling Test of Pellets

Sample	Time (min)	Temperature (^{0}C)
50g Groundnut shell Pellets	20	73
50g maize Cob Pellets	20	60
100g Groundnut shell pellets.	30	92
100g Maize cob Pellets.	30	84

IV. CONCLUSION

A renewable energy source was developed by converting groundnut shell and maize cobs into solid pellet fuel without a binder. In addition to providing a source of energy this also contributes to the efforts of restoring environmental quality. The cost of disposing unwanted materials left over after processing groundnut and maize will be substantially reduced. A metallic mould was used to enable uniformity of size, ensure easy flow and high efficiency of pellets. The mould also permits repetition for mass production. Mild steel was considered for the mould material due to its lower cost, availability and machinability. The pellets have light weight (1- 2 g), fairly strong and can withstand compressive force of at least 800N, so they can be easily transported. The pellet needs to be stored in a dry environment particularly that of the maize cobs because their strength drops with moisture increase. This is because the rate of moisture absorption is higher in maize cobs than groundnut shells which reduce the adhesion and cohesion forces. The sulfur and nitrogen content of the fuel varied between 1 - 3% this percentage is low and has also been shown to be harmless to humans. With flame temperatures above 600 ^{o}C, it can be employed in cooking, water boiling and room heating if appropriate pellet devices are used. With calorific value of above 13 MJ/kg pellets can be employed in small-scale industries for example (baking, food processing etc). The rate of deterioration of the maize cobs pellets is higher than that of the groundnut shell pellets which suggests that groundnut shell is a better material for pellet production.

Recommendations : It has been established that pellet fuel can be produced from groundnut shells and maize cobs without the use of a binder. Nevertheless, kinetic analysis of the flame, complete chemical analysis of the pellets, design of a pellet machine and pellet stove are some areas that further research work can be carried out.

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