Investigation of Bio-Waste As Alternative Fuel For Cooking

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***Abstract*—Nigeria has a vast natural resources especially forestland with the majority of its households relying on solid biomass such as charcoal and firewood as their cooking fuels. Combustion of solid biomass is a significant source of particulate and carbon monoxide emissions. However, the increasing demand and use of charcoal and firewood has led to an escalation of deforestation and the emission from the combustion of these fuels have been highly correlated to harmful health effect among other related problems. Bio-waste as an alternative fuel for cooking in Nigeria is still in its infancy and hence the need for this research. The research was carried out using binders (starch and spent oil) and biomass (rice husk and sawdust) to produce Refuse Derived Fuel (RDF) often referred to as pellets. Properties such as moisture content (%), ash content (%), tensile strength (N/mm) and higher heating value (kJ/kg) were determined for the RDF. Prior to the production of the RDF, the moisture and ash contents of rice husk and sawdust were 5.72% and 17.14%, and 15% and 10.23%, respectively. After the production of the RDF from rice husk, moisture content, ash content, higher heating value, and tensile strength of 0.908%, 11.5%, 6160.7 kJ/kg and 508.7 N/mm^2 of tensile strength, respectively, were obtained. Also, for the RDF produced from sawdust, moisture content of 0.93%, ash content of 16.5%, higher heating of 7808.1 kJ/kg and tensile strength of 576.8 N/mm^2 were measured. These results were found to be in agreement with previous studies on RDFs sourced from bio-wastes. Conclusively, the RDF seems to be a good substitute to wood as cooking fuel and would also reduce greenhouse gas emissions and thus save our environment from effects of climate change.**

Keywords—RDF, Biowaste, GHG, Cooking fuel, Climate change, Sustainable Energy.

I. INTRODUCTION

A large part of the world's population uses wood as fuel for household cooking and space heating, mostly in the developing countries. In poor developing countries' households, wood, charcoal and other solid fuels are often burned in open fires or poorly functioning stoves. It's a great challenge finding a means of expanding its energy resources especially to the rural households and also addressing the health risks and environmental consequences associated with over dependence on such fuels for cooking. Also, incomplete combustion leads to the release of small particles and other constituents that have damaging effect to human health in the household environment. The consequences of these are deforestation, desertification, pollution and global warming [1-4].

Hence, the search for a safe substitute fuel for firewood is essential. There are quite a lot of alternative energy which are expected to replace fossil fuel in the future, i.e. biomass, hydro, solar, tidal, wind and ocean thermal energy. Advances in biotechnology and bioengineering, have classified some resources classified as waste, which now form a basis for energy production. Literatures affirm that 86 % of energy being consumed all over the world is from fossil fuels. The large quantities of agricultural residues produced in developing nations can play an important role in meeting her energy needs [5-11].

Biomass pellets are made from organic wastes such as agricultural wastes, sawdust etc. and are suitable replacements for fossil fuels such as oil or coal, and can be used for cooking and to heat boilers in manufacturing plants. Biomass pellets are renewable sources of energy and prevents the release of fossil-derived carbon to the atmosphere. Use of biomass pellets can help in earning carbon credits for reducing emissions in the atmosphere, which is a critical target of the Sustainable Development Goals (SDGs) Programme [5,12].

One of the popular biomass pellets emerging in developed and developing countries is the sawdust pellets. This involves compressing and extruding sawdust to make a reconstituted log that can replace firewood. There are no binders involved in this process. The natural lignin in the wood, binds the particles of wood together to form a solid. Burning a wood pellet is far more efficient than burning firewood. Moisture content of pellets can be as low as 4 %, whereas green firewood may be as high as 65 %. Sawdust pellets have developed over time with two distinct types: those with hole through the centre, and those that are solid. A solid pellet is manufactured using a piston press that compresses sandwiched layers of sawdust together. Pellets with a hole are produced with a press. The hole is from the screw thread passing through the centre but it also increases the surface area of the log and aids efficient combustion [5,12-13].

Fuel pellets can be made from readily available waste materials. In urban areas, this can be sawdust and shredded

paper. In villages and rural areas, they can be made from leaves, grass, coffee and rice husks and other agricultural waste in many combinations. Waste plastic material cannot be used because the plastic gives off toxic gases when it burns. The use of biomass waste can contribute towards a reduction in the utilization of conventional solid fuels and thus resolve some of the long standing environmental issues. Currently, full scale utilization of biomass briquettes is in biomass stoves for domestic applications and in industrial grade boilers for power plants [14-15]. As a result of the growing importance and need for briquettes, particularly from biomass materials, literatures abound on various aspects of briquetting, the nature of the materials, the behaviour and characteristics of such materials during and after briquetting. The behaviour and characteristics of biomass residue briquetting can be classified into physical, mechanical and combustive depending on the measured parameters [9,16,17,18,19].

This study focuses on biomass pellets as Refuse Derived Fuel (RDF) from Municipal Solid Wastes (MSWs) such as sawdust, rice husk, waste papers. The aforementioned wastes constitute nuisance to our environment and are mostly burnt in open air which leads to environmental pollution with the release of harmful substances to the atmosphere. This present work intends to harness some MSWs as earlier stated as a source of heating as substitute to firewood and charcoal. In Nigeria, rural inhabitants and urban dwellers mainly use firewood, charcoal and fossil fuels as their source of energy for cooking and heating. Consequently, these sources cause deforestation; environmental pollution and it also result to high cost of living.

II. Materials and Methods

A. Pre-Treatment of Raw Materials

The pre-treatment of the raw materials (sawdust, rice husk, waste paper and spent oil) was carried out mechanically. The mechanical process is to reduce the biomass size by grinding or shredding. The size reduction by mechanical process (Grinding) facilitates handling, increases surface area, decreases crystallization and improves the efficiency. After the pre-treatment of raw materials, it improves the energy density of the biomass allowing it to be efficiently stable at the point of use. For the pre-treatment of the spent oil, a sieve of 4cm was used to remove the particles away from the spent oil before the point of use.

B. Preparation of Mixture

Before mixing the raw materials, which comes after the pretreatment of the sawdust, the ash content and moisture content were determined. Thereafter, the binder (starch) was boiled to solidify it before mixing it with the biomass (sawdust, rice husk, waste paper) and a little quantity of waste engine oil in a bowl, to produce a crude unfinished material. The quantity of biomass was less than that of the binder before mixing them in the bowl. After which a pellet mixture of approximately 12 g was produced.

C. Procedure for the Production of Refuse Derived Fuel

Pellet formation is fairly straight forward. The biomass (sawdust, rice husk, waste paper) and binders (starch and engine oil) were mixed by weight ratio and blended manually in a large mixing bowl. Various ratios of binders (38.5 g and 31.3 g) to waste biomass (50 g) of different types were then mixed to produce unfinished products. The crude mixture (approximately 12 g) was placed inside newspaper wrapping, and the ends were folded down so that both ends of the wrapping were covered. No adhesive was used until the crude mixture was compressed and this will remain prone to unwrapping. This raw pellet was then transferred into the mould, a short length of PVC with one end sealed. The diameter of the PVC pipe is 12.5 mm, and its length is 101.6 mm (four inches). The mould is to assist the pellet retain its cylindrical shape while a short metal rod slightly smaller than the PVC internal diameter was inserted into the open end of the mould to compress the pellet. Pressure (approximately 250 psi) was applied manually for a period of 15 seconds. This pressure not only reduced the pellet size, but also encouraged the binders to permeate the materials and form a single firm unit. It should be noted that this form of production is only used in laboratory experiments and actual commercial production will of course be large scale and automated. The size of a pellet produced as RDF was either 6 or 8 mm in diameter and about 3-4 times the diameter in length.

After the production of the pellets, they were sun–dried for 3 - 5 days to reduce the moisture content and to make a good mechanical durability. Randomly selected pellets were then taken to the laboratory for characterization as fuel.

D. Characterization of RDF

The combustible fraction, consisting of rice husk, sawdust and other non–biodegradable fractions of solid waste is processed into refuse derive fuel. RDF is thus a dry solid fraction usually with a high calorific value. The composition of RDF and Municipal Solid Waste (MSW) will vary according to the origin of waste material and the separation process [16, 20-22]. This will in turn greatly influence the properties of RDF such as moisture content, ash content, and higher heating value.

III. Results and Discussion

Heat value or calorific value determines the energy content of a fuel. It is the property of Refuse Derived Fuels (RDFs) that depends on its chemical composition and moisture content. The most important fuel property is its heat value [20-21]. Table 1 gives the fuel properties of the raw materials used in the production of RDF on a laboratory scale. The moisture content of rice husk that went into the production is 5.72 %, which is relatively lower than that of sawdust (15 %). Whereas, the ash content of sawdust (10.23 %) prior to the RDF production is moderately lower than that of rice husk (17.14%). It is observed from Table 2 that the moisture content of the RDFs decreased after processing the raw materials into the final products. This is due to the fact that the raw materials adjusted with the relative humidity of its surroundings. A reduction in moisture content increases the

mechanical strength of the raw materials and promotes hydrogen bridge cross-bonding between adjacent cellulose chains in regions of low spatial order which are primarily responsible for stiffness and rigidity. Same goes for the ash content of the material. Biomass has higher heating value due to lower moisture content and high oxygen content. The results from the analyses of pellets are summarized in Table 2. It is obvious that all the properties of sawdust pellet are higher than the properties of rice husk pellet. These energy values are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications [20-22]. The starch waste pellet is very suitable source in replacing or supplementing low end coal and RDFs.

TABLE I. FUEL PROPERTIES OF THE BIOMASS (RICE HUSK AND SAWDUST) BEFORE PRODUCTION

Types of fuel	Moisture content (%)	Ash content (%)
Sawdust	15	10.23
Rice husk	5.72	17.14

TABLE II. FUEL PROPERTIES OF THE BIOMASS (RICE HUSK AND SAWDUST)

Types of fuel	Moisture content (%)	Ash content (%)	Higher heating value (kJ/kg)	Tensile strength (N/mm^2)
Sawdust	0.93	16.5	7808.1	576.8
Rice husk	0.908	11.5	6160.7	508.7

The pellet is made from biomass (sawdust and rice husk), they are categorized by their heating value, moisture content and ash content and dimensions. The pellets can be used as fuel for power generation, commercial or residential heating and cooking. These pellet are extremely dense and can be produced with low moisture content below (10%) as shown in the table above, that allow them to be burned with very high combustion efficiency. Further, the advantage of the pellet geometry size is that it can be fed to a burner by hand or pneumatic conveying. The sample picture of a pellet is shown in Figure 1.

The study was pursued with the hope of promoting biomass and sustainability. Additionally, this process will lessen the impact of refuse on landfills and reduce our dependence on fossil fuels. RDFs (sawdust, manure, grass clippings and corn husks, etc) is a very benign and chemically-inactive material. There are no hazards that are associated with it, aside from accidental ingestion and possible splinters during handling. Therefore basic precautions regarding handling be followed to avoid unintentional consumption.

Fig. 1. Sample picture of the pellets

IV. CONCLUSION

The study was pursued with the hope of promoting biomass and sustainability. The result of this study indicates that pellets produced from the two biomass residues would make good biomass fuels. However, findings show that sawdust pellets has more positive attributes of biomass fuel than its rice husk counterpart. The study assessed biowaste as an alternative fuel for cooking in Nigeria. The Refuse Derived Fuels (RDFs) was found to be a good substitute to wood as cooking fuel. Of note is that the quality and energy amount of biomass briquettes depend on the type of original biomass residue and type of binders used among other variables. We hope that our work will lead to an appreciable rise in the use of RDFs not only from the surrounding community but in a global sense. Since this study is structured around waste products, there is no ultimate sacrifice or risk that the society has to make concerning the adoption of RDFs.

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