Synthesis of Composite Biomass Briquettes as Alternative Household Fuel for Domestic Application

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Abstract - This study paper presents the result of preliminary synthesis and characterization of composite biomass briquettes produced from different ratio of rice husk and maize cob using starch as binder. The moisture content of rice husks and maize cobs was determined before and after sun drying for seven days. It demonstrates that composite briquette can be produced from rice husk and maize cob effectively. These properties of each sample were improved progressively by varying their proportions.

Keywords: rice husk, maize cob, biomass; briquettes, composite

I. INTRODUCTION

Worldwide, woods and agricultural products remain the major primary source of energy for appreciable domestic and industrial application such as household cooking and heating of space. Wood as a form of energy is a vital emergency alternative fuel as many societies around the world are quick to reverse back to its usage as a source of energy when confronted with socio-economic challenges (Antwi-Boasiako and Acheampong, 2016). It has been reported that an estimated population of about three billion people around the world cook daily using wood as fuel (Yank *et al.,* 2016). Wood fuel will continue occupies a predominant position in the world's energy matrix as a number of developing countries solely depends on these solid fuels for domestic energy supply. At present the demand for wood charcoal for energy supply is consistently growing in Sub- Sahara Africa. It has been reported that about 76 % total resident of Kampala, Uganda uses wood charcoal as the major source domestic cooking (Tumutegyereize *et al.,* 2016). The situation might not be too different in other developing African countries. The continuous usage of wood is associated with a number of drawbacks such as deforestation and desertification. Alternative solid fuels are presently been sourced for energy supply so as to reduce the pressure constantly mounted on forest reserve for wood fuel thereby ensuring sustainability of the resource base; besides charcoal fuels emits toxic atmospheric pollutants which causes a number of health problems (Antwi-Boasiako and Acheampong, 2016).

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Several studies have reported the synthesis of renewable clean solid briquettes as fuel from a number of agricultural wastes (biomass) such as sawdust (Akande, 2002), banana peels (Wilaipon, 2008), corn cob (Adesanya and Raheem, 2009; Oladeji *et al.,* 2016) Waste paper and coconut husk composite (Olurunnisola, 2007), ground nut shell, rice husk (Musa, 2007), sugarcane bagasse (Onchieku *et al.,* 2012). Different countries around the world have different biomass resources. This biomass varies in properties from one geographical location to another depending on the region climatic condition, flora and agriculture produce.

Rice is a major crop grown in West Africa and rice processing generate a huge quantity of by product such as rice bran and husk. Rice husk represents an opportunity for greater energy sustainability in these parts of the world (Yank *et al.,* 2016). Rice husk is a wasteful by product of rice paddy (contains about 72% rice, 5%–8% bran, and 20%– 22% husk by mass on the average) (Ndindeng *et al.,* 2015). It has no food value, difficult to handle in piles and contaminated water bodies. Most often piles of rice husk are burned in open fire causing air pollutants. Only very few studies have added value to these by products. It can however be utilized as a source domestic heating fuel in place of wood (Yank *et al.,* 2016). Maize is another cereal crop that is grown worldwide and generally the most consumed grain in developing country like Nigeria. Maize Cobs and stalks are among the major residues associated with maize processing (Oladeji *et al.,* 2016). Enormous quantities of these wastes are left to decompose or burned in the field resulting in to environmental pollution and degradation (Jekayinfa and Omisakin, 2005).

Briquetting is one process of optimizing the efficiency of fuel wood; it permit the transformation of waste materials or plant residue in clean solid fuel for huge supply or generation of energy as an alternative heating source for household cooking, smoking of fishing and other related energy demanding industrial activities (Antwi-Boasiako and Acheampong, 2016). The processes involves the application of pressure on a mass of disperse particles with the sole aim producing a high density geometrical well packed solid material. Briquetting result in the provision of a substantial improvement in the transportation and storage capability of resulting solid, solid fuel with consistent combustion quality, reduction in incineration and biomass residues. Briquettes possess higher energy potential (thermal stability, flame temperatures and lower moisture content) and excellent combustion properties (density, calorific value and less smoke and soot) in comparison to the raw biomass (Avelar *et al.*, 2016).

With the present shortage petroleum derived fuel, ever-increasing prices of these fossil fuels, increasing energy demands and concerted drive towards environmental sustainability, briquettes have been widely perceived to be potential replacement for wood and wood charcoal in most of the developing part of the world for domestic cooking and water heating, production processes such as ceramic firing, tobacco curing, poultry rearing, tea drying, firing of brick, clay wares, manufacture of pottery, gasifiers fuel for electricity generation and powering of boilers to generate steam (Tumutegyereize *et al.*, 2016). This is essentially because briquetting is the most applicable technology for the production of green energy in the form of solid fuel for domestic utilization in rural household.

This study aimed at the preliminary synthesis composite bio briquettes produced from different blends of rice husk and maize cob using starch as binder

II. METHODLOGY

Material

The Maize cobs were collected from a local farmland along Kubwa expressway, Kubwa Abuja. The Rice husks were collected from Oyinlola rice mill, Kukwuaba, Abuja. The cassava starch was obtained from Kasuwan Gwari market, Minna, Niger state, Nigeria. The equipment used includes sieves, oven, mortal, pestel, milling machine, hydraulic briquetting machine, basin, measuring cylinder and weighing balance

Method

Production of briquettes using a hydraulic operated manual briquetting machine

The size of the maize cobs were reduced using a mortar and pestle before drying it and rice husk for 7 days at average temperature of 30 ^{0}C to reduce excess moisture after which it was pulverized with an electric powered milling machine. The pulverized maize cob and rice husk was sieved into a mesh size of 2.36 mm. 100 g of milled materials were mixed at three different formulation as 75% Rice husk 25% Maize cob, 50% Rice husk 50% Maize cob and 25% Rice husk 75% Maize cob. Each formulation were mixed with 50 g of dried cassava starch in a ratio of 2:1, hot boiling water of 180 ml was added and stirred thoroughly to form a semi solid paste. The experiment included loading varied mixture ratios of Rice Husks and Maize Cob respectively mixed with the same amount of binder and water, 75g of rice husk and 25g of Maize Cob was mixed with starch (Sample A). 50g of rice husk and 50g of Maize Cob was mixed with starch (Sample B). Finally, 25g of rice husk and 75g of Maize Cob was mixed with starch (Sample C).

Each formulation was compressed with the manually operated hydraulic briquetting machine after which it was oven dried for 2 days at 105^{o}C. After 2 days of heat treatment, it was cool at room temperature before sun drying for another 7 days at average temperature of 31 ^{0}C . Fig 1 shows the three formulation of briquette produced.

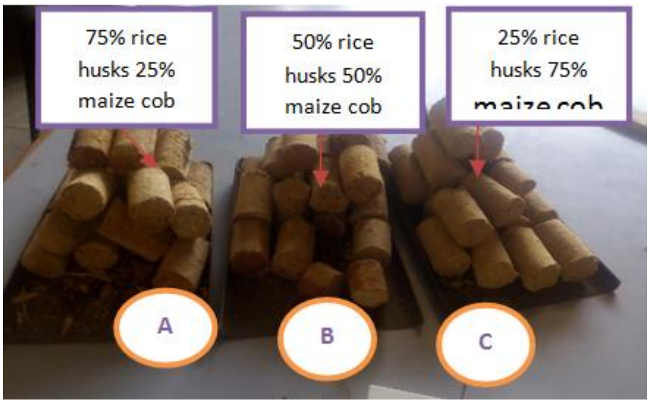

Fig I: Briquette produced

Characterization of Briquette

The volume of briquette samples were determined from replicated measures of diameter, height and central whole diameter at different points using a calliper. The moisture content, density and porosity index was determined according to the method reported by Adetogun *et al.*, (2014). The SO_4^{2-} and Cl^- was detected quantitatively with the aid of an IR detector, while NO_3^- was determined by means of a thermal conductivity detector (Librenti *et al.*, 2010). Heating value (HV) was calculated using the empirical correlation reported by Bailey *et al.*, (1982). HV = 2.326(147.6C + 144V) Kcal/kg (C= Percentage Fixed Carbon and V= Percentage Volatile Matter). The percentage ash content (%A), volatile matter (Oladeji *et al.*, 2016) and Fixed Carbon = 100 – (%V + %A) by difference.

III. RESULT AND DISCUSSION

Results

The results of the experiments are shown on Tables 4.1 and 4.2

Table 1: Moisture Content of sample (Before and after Sun drying)

Biomass	**Before drying** (%)	**After drying** (%)
Rice husk (RH)	6.46	3.88
Maize cob (MC)	61.39	9.94

Moisture content plays a great role on the resistance to mechanical aberration, density, calorific value and burning efficiency of the briquettes (Tarasov *et al.,* 2013). The initial moisture content of the rice husk (RH) and Maize cob (MC) before drying was 6.46 and 61.39 % wet basis. From Table 1, the results after drying were less than 10% as. Low moisture content of biomass prevents rotting and decomposition of the biomass.

Table 2: Physical properties of briquettes produced

Mix Proportion	**Avg. Height cm)**	**Avg. Volume (cm^3)**	**Avg. Mass (g)**	**Density (g/cm^3)**	**Porosity index**
75%RH 25%MC	6.55	82.32	58.84	0.715	0.346
50%RH: 50% MC	7.00	87.98	55.37	0.629	0.238
25%RH: 75% MC	6.88	86.41	43.68	0.506	0.756

Porosity is the measure of the cell openness (Adetogun *et al.,* 2014). Porosity index measures the number of pores in a substance. From the results, it is clear that the porosity index of the briquettes decreases with increase in density, except for mix proportion of 50% rice husk and 50% maize cob which exhibit a porosity index of 0.238**.** This decrease in porosity with equal mass of the biomass might be attributed preparation of mixture on percentage by mass basis (that is, it has more concentration rice husk than maize cob). Solid fuel on this nature with low porosity have fewer spaces for mass diffusion and this will hinders mass transfer of oxidant during combustion. Sample C (25% rice husk 75% maize cob) have the highest porosity of 0.756.This simply means that the briquette has higher compaction ration and better bonding of the solid fuel particle. The higher porosity observed with this sample implies the higher rate of infiltration of oxidant during combustion. This will have a great positive influence on the burning rate of the briquettes.

Density is a physical property. It is defined as structural arrangement of the molecules of the substance in a given volume (Adetogun *et al.,* 2014). This property significantly plays a key role on the combustion characteristics as denser materials will burn for a longer period of time. In this study it was determined from the measured average mass and volume of briquette. The briquette produced from 75% rice husk and 25% maize cob sample has the highest density of $0.715g/cm^3$, while briquette sample containing 25% rice husk and 75% maize cob the lowest in density ($0.506g/cm^3$). It is very apparent that Sample A is the most dense which implies it have longer burn out time and more durable when compared to other samples

Table 3: Proximate Composition of Biomass Briquette

Proximate Content	**Composite Blends 75RH: 25MC**	**50RH: 50MC**	**25RH: 75MC**
Volatile Matter	74.53	51.84	63.65
Ash Content	10.33	4.52	5.5
Fixed Carbon	15.14	43.34	30.85

The sample containing 75% rice husks 25% maize cob have the highest volatile matter (VM) of 74.53 % while the sample containing 50% rice husks 50% maize cob have least volatile matter of 51.84 %. It was discovered that as a result of blending with maize cob the quality of the combustion property increased, the volatile matter which is desirable increased from 67.98 % to 74.53%. The value obtained in this study was higher than a volatile matter of 68.20 % reported by Efomah and Gbabo (2015) for Rice husk briquette but lower than 83.06 % reported for Maize cob briquette (Oladeji *et al.,* 2014). This result shows that maize cob might have impacted positively to compensate for low value usually exhibited by Rice husk. According to Efomah and Gbabo (2015) higher VM of this nature is an indication of higher ease of briquette ignition and appreciable increase in flame length during combustion.

Fixed carbon is the solid combustible residue that remains after briquette has been heated and the volatile matter is expelled. The fixed carbon provides is an indication of solid fuel heating value. Fixed carbon for the briquette produced is within the range of 15.14-43.34 %. Briquette sample containing 50 % RH and 50 % MC has the highest fixed carbon of 43.34 %. A fixed carbon of 2.57 % was reported for Maize cob briquette (Oladeji and Lucas, 2014) and 15.7 % for Rice husk briquette (Efomah and Gbabo, 2015). The variation in composite blends has resulted in a product with higher carbon content. Lower content of carbon in solid fuel results into longer cooking time due minimal release of heat energy.

Ash content is known to significantly influence the stove operation efficiency and its cleaning frequency (Tarasov *et al.,* 2013). Ash content of desirable briquette must be very minimal. Ash content of briquettes ranges between 4.82-10.33% with the briquette sample containing 75 % RH and 25 % MC having the highest ash content while the same containing 50 % RH and 50 % MC (B) containing least ash content. The value obtained in this study is quite low when compared to 16.10 % ash content of Rice husk briquette by Efomah and Gbabo (2015). This implies that this briquette will reduced cleaning frequency when use in stove. The low ash content recorded is of immense importance to its maximum utilization. Briquettes with higher ash content are usually characterized with low heating value (Loo *et al.,* 2008).

Calorific value is the most essential properties of all types of fuels. The magnitude of calorific value of bio based fuels depends on its feed pre-treatment process, proximate

ISBN: 978-988-14048-2-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

composition, processing temperature and particle size (Tumuluru *et al.*, 2011). The briquette prepared from equal mass of rice husk and maize cobs has highest calorific value of 32242.882 Kcal/kg when the volatile matter was 51.84% and its ash content 4.82% while the least calorific value of 30161.20478Kcal/kg was obtained for 75 % RH and 25 % briquette sample when the volatile matter was 74.53% and its ash content 10.33%. The low calorific recorded for this sample is due to high quantity of ash. The calorific value of 25% rice husks 75% maize cob is the same with 50% rice husks 50% maize cob have no significant difference.

Table 4: Chemical properties of briquette based on Nitrogen, chlorine and sulphur content

	Composite Blends		
Chemical Constituents	**75RH: 25MC**	**50RH: 50MC**	**25RH: 75MC**
Nitrate	1.544	1.696	1.936
Sulphur	24	19.6	25
Chlorine	0.344	0.164	0.21

The chloride content of 25% maize cob and 75% rice husk is 0.210 mg/g as against 0.164mg/g for briquette made from 75% maize cob and 25% rice husk and 0.340 mg/g for 50 % maize cob and 50% rice husk briquette. Therefore 50% maize cob and 50% rice husk has more tendency of emitting chloride oxide into the atmosphere than the others during combustion. The sulphur content of 25% maize cob and 75% rice husk is 25.000 mg/g as against 19.600 and 24.00 mg/g for 75 % maize cob and 25% rice husk briquette and 50% maize cob and 50% rice husk briquette respectively. Therefore 25% maize cob and 75% rice husk has more tendency of emitting sulphur (iv) oxide into the atmosphere than the others during combustion. The nitrogen content of 25% maize cob and 75% rice husk is 1.936mg/g as against 1.696 and 1.544 mg/g for 75% maize cob and 25% rice husk and 50% maize cob and 50% rice husk briquette. Therefore 25% maize cob and 75% rice husk has more tendency of emitting nitrogen oxide into the atmosphere than the others during combustion.

CONCLUSIONS

This study has demonstrated that composite briquette can be produced from rice husk and maize cob effectively. These properties of each sample were improved progressively by varying their proportions. For domestic cooking, biomass briquette consisting 75% maize cob 25% rice husk was shown to be most efficient when compared with others in term of physical, chemical and thermal properties. The estimated calorific valves of A, C and B were 30658.50kcal/kg, 32242.88kcal/kg and 31910.53kcal/kg respectively. Based on the result of calorific value, sulphur and chloride content, ash content, fixed carbon, and volatile matter, briquettes that contain 75% maize cob and 25% rice husk (Sample B) was the best formulation for domestic energy application.

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ISBN: 978-988-14048-2-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)