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Comparative Study of the Burning Rate of Briquettes from Some Selected Agricultural Wastes

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ABSTRACT
Burning wood or agricultural residues produces smoke with a variety of pollutants, some of which are known as carcinogens. This study was carried out in order to investigate the comparative study of the burning efficiency of briquettes from the selected biomass. Different briquette samples were produced, by blending varying weight of agricultural waste (ricehusk, Bagasse, sawdust and groundnut shell) through carbonization and densification in the ratio of 1:1:1:1, 2:1:1:1, 3:1:1:1 and so on, each with four replicates for all biomass types under investigation. A manually operated opened-end piston press with a capacity of 30.0 kg/h, producing briquettes of density 0.81 g/cm' was used. Obtained values were statistically analyzed using completely Randomized design (CRD) or one-way ANOVA. From these results, it was established that stable briquettes was formed from rice husk, bagasse, saw dust and groundnut shell, which was smokeless, exhibits faster heat release, lasts longer when compared with conventional charcoal, holds great potential stores trainde for estation and desert encroachment. Commercialization of these briquettes can provide promising income for rural women & youths. Combustion characteristics investigated include; preparation time, burning rate, specific fuel consumption, fuel efficiency, water boiling test and controlled cooking test. The result obtained showed that the thermal fuel efficiency of the briquettes produced competes favorably with the control (conventional charcoal), a better ecofriendly and more suitable alternativefuel.

Keywords: Combustion characteristics, carbonization, densification, briquettes, agricultural wastes

I. INTRODUCTION

Today the world's forests face unprecedented pressures. While potentially a renewable resource, forest are disappearing faster than they are being replaced. The United Nations food and Agriculture Organization estimates that forests are being lost to agriculture, grazing, commercial timber, uncontrolled burning, fuel wood, and other factors at a rate of more than 1 I million hectares per year, with 90% of the cleared land never replanted (Adesigbin et a1., 2018). As forests disappear, the financial, physicals, burden of obtaining wood fuel for cooking and space heating increases for the world's poor, in response, many turn to crop wastes and dung as an alternative. However, the exploitation and utilization of the established energy sources and the development of the potential ones have remained intractable national challenge due to inadequate indigenous technical capacity and high cost of foreign expertise. Nigeria, and indeed other developing countries are now suffering serious and increasingly rapid deforestation. Energy is an essential ingredient of socio-economic development and transformation. Inadequate supply restricts socio-economic activities, limits economic growth and adversely affects the quality-of-life improvement in standards of (Hua-Hung et a1., 2015).

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Conventional energyresources

Nigeria, a country well-endowed with so many varieties of mineral and conventional energy resources which included: crude oil, natural gas, coal and uranium, with an excellent renewable energy; hydro, solar, wind, biomass; residues, waste, forage grasses and shrubs (Ewah, 2002).

Conversion of agricultural waste intocharcoal

It is no longer news that the fossil fuel era of nonrenewable resources is gradually coming to an end. The main objective is now to find solutions to match demand and supply of energy sources (Olalekan and Ayoola (2009). Biomass is readily available both in the urban and rural areas of Nigeria's six geopolitical regions. This abundant alternative energy is yet to be exploited for cooking which constitutes almost over 909a of the total energy consumption (Sengar, et al., 2016; Jekayinfa and Omisakin, 2014).

Biomass

The biomass resources in Nigeria can be identified as wood, forage grasses and shrubs, residues and waste. The overall biomass resource availability in Nigeria as at 1973 was put at 9.1 x 10'MJ (Momah and Soage, 1999; Okey et al., 2014; Mejdi and Lionel, 2017).

Rice Husks

Rice husks are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice husk can be put to use as building material, fertilizer, insulation material or fuel (Jindaporn and Songehai, 2007; Munira, 2019).

Sugarcane Bagasse

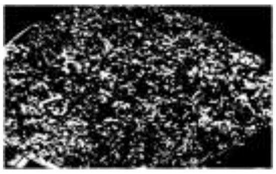
Bagasse is the fibrous matter that remains after sugarcane are crushed to extract their juice. It is used as a biofuel and in the manufacture of pulp and building mortality. For each 10 tons of sugar cane crushed, a sugar factory produces nearly 3 tons of wet bagasse, since bagasse is a by-product of the cane sugar industry, the quality of production in each country is in time with the quality of sugar cane produced (Rainey and Thomas, 2009).

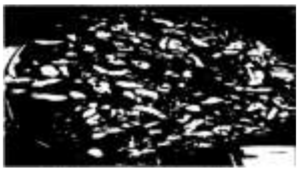
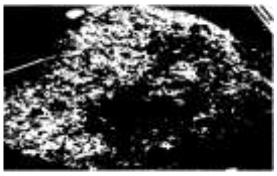
Groundnut shells

Groundnut shells are extremely flammable, they are used to make some manufactured fireplace logs. If you have a wood burning stove or a fireplace, sprinkle the shells over your wood to get a good blaze going quickly (Putnam 1991).

Sawdust

Sawdust is used in the manufacture of charcoal briquettes. The claim for invention of the first commercial charcoal briquettes goes to Henry Ford who created them from the wood scraps and sawdust produced by his automobile factory. (Adegoke and Lawal, 1997; Emerhi, 2011). These four materials are shown in Plate 1 (a), (b), (c) and (d).



(a) Ricehusks (b) Sugarcane bagasse (c) Groundnut shells (d) Sawdust Plate 1: Agricultural waste materialsused

Conversion of agricultural waste into charcoal

Wood and wood charcoal fuel has since time immemorial been the primary source of cooking fuel in Nigeria because it is cheap and available. Although, not without consequences on health and pollution because of smoking. It is no longer news that the fossil fuel era of nonrenewable resources is gradually coming to an end (Hua-Hung et al., 2015).

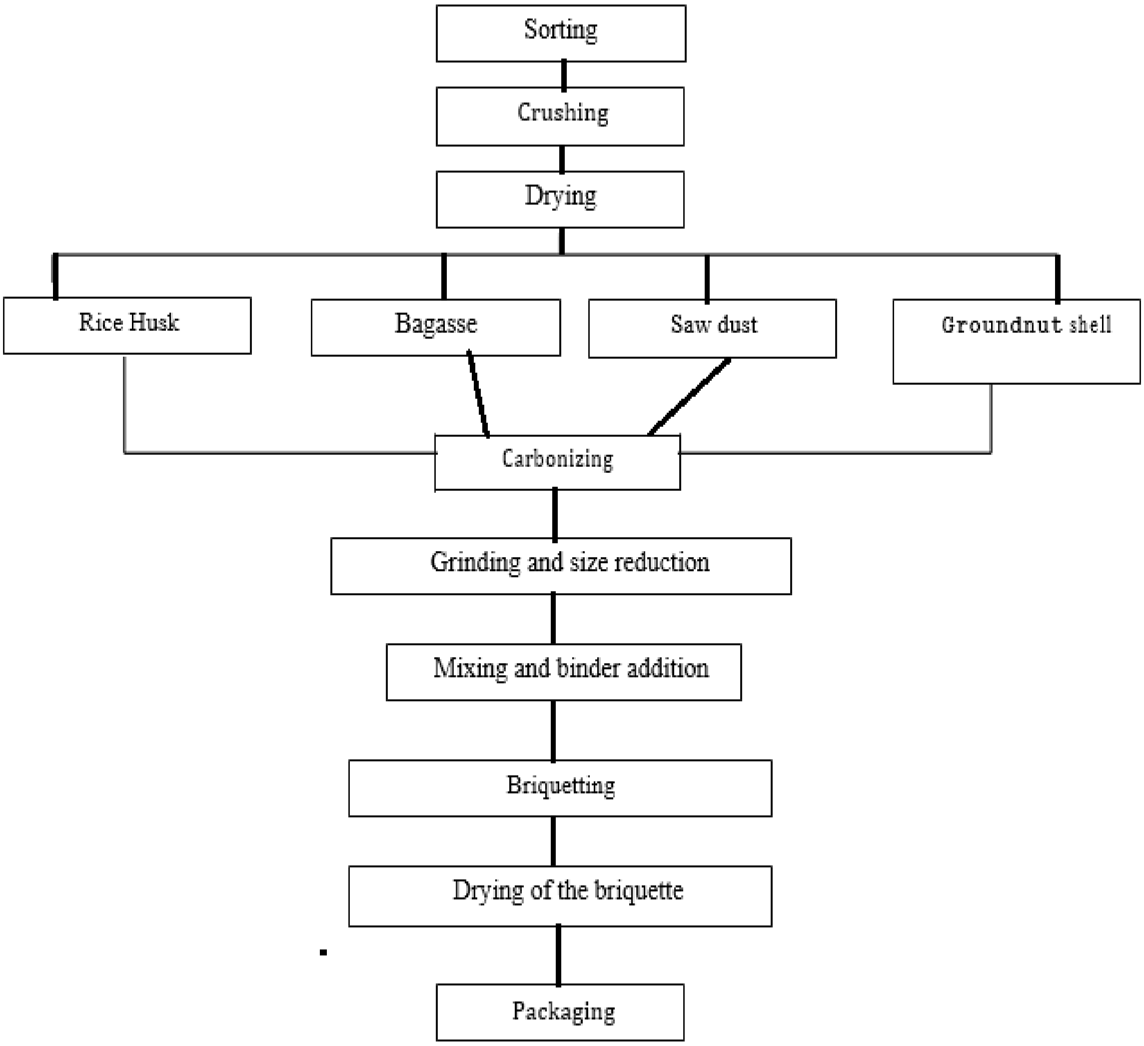


Figure 1: Processes involve in the production of briquettes

Carbonization

Carbonization is a process that takes place when organic matter is raised to high temperatures in the absence of oxygen. The process is made up of the following main stages: The moisture in the solid biomass must be removed before carbonization takes place. This can be achieved with drying prior to burning. The biomass then undergoes pyrolysis, which is the chemical decomposition of organic matter in the absence of oxygen. Pyrolysis leads to carbonization of materials. A relatively high temperature though is necessary for pyrolysis to take place, because agro waste is a fuel material that be carbonized. The most economical of all such balance is to adopt controlled carbonization which is the process of burning organic matter at a self-igniting temperature (Adegoke and Lawal, (1997).

Carbonizer

Charcoal is a carbon substance that remains when organic matter is heated to a high temperature in a low-oxygen environment. The carbonizer is made of cylindrical oil drum with two conical shapes made of sheet metals that are welded at the bottom in such cases the upper part has 24 holes for removal of smokes and the lower one with no holes so the path of the smoke is upwards using the inserted cylindrical pipe at the middle of the carbonization chamber.

Materials and Methods Experiment location

The experiment was conducted at the Department of Agricultural and Bio-Environmental Engineering Technology, Federal Polytechnic, Bauchi in the products processing workshop.

Agricultural waste and other materials used

i. Rice husk,
ii. Sugarcane bagasse,
iii. Groundnut shell,
iv. Sawdust,
v. Water and
vi. Binder.

Plate 2: Binding material

Equipment used

i. Carbonizer
ii. Manual extruder
iii. Bucket
iv. Stove
v. Energy efficient stove
vi. Tray pan and pans

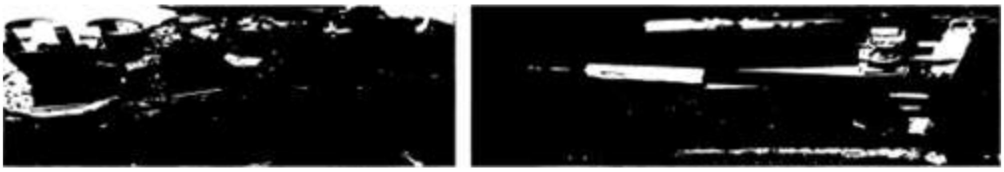


Plate 3: Some tools used Preparation and quantity of materials

The following agricultural waste were used in the making of the briquettes, Groundnut shell,
Rice husk, Bagasse and Sawdust, for each material, 5 bags of l00kg were collected and carbonized appropriately (Jindaporn and Songehai, 2007).

Briquettes preparations

The pre-treatment processing of briquette sample for this study comprised of drying, size reduction and compaction operations. The particle size distribution was achieved by using particle size of 0.5 mm. Each of the aggregate was subdivided into three ratios of 1:1:1:1, 2:1:1:1 and 3:1:1:1, while binder was added to each of the subdivided residue added to each of the subdivided residue ratios. The agitating process was done by hand to enhance proper blending prior to compaction. The blends were briquetted under ambient condition in a manually operated press designed to press briquettes of 1.5 inches in height by linch diameter and produce one briquette charcoal at a time. The parts of the press are made from galvanized pipe and angle iron. It is designed to produce a high density briquette. After feeding he mixed char into the pistol one can press the handle which is attached to the press to produce compact and uniform size briquettes. The briquettes were place in tray and under the sun for 2 days after plastic bags and seal them. Briquettes burning rate was determined according to Onuegbu, et a1., (2011);

$$\text{Burning rate} = \frac{\textbf{Total we ight of tile burnt briquette}}{\textbf{Total time taken}} \qquad 1$$

Calorific values of the sample was determined using Gallenhamy Ballistic Bomb Calorimeter according to ASTM. E711-87 (2004). Preparation time was determined by igniting the briquette, until the ignited briquette had entered into its steady state burn phase. Specific fuel consumption used in the experiment was estimated from the ration of mass of fuel consumed (in grams) to the quantity of boiling water (in liter), (Onuegbu et al. 2011).

$$\text{Specific fuelconsumption, SFC} = \frac{\textbf{mass of free conc med}}{\textbf{Total mass of boiling water}} \qquad 2$$

Fuelefficiencyof theenergywascalculatedaccordingtoequation 3;

$$\mu = \frac{M C_p (T_g - T_p)}{M_f E_f} \times \mathbf{100}\ \% \qquad 3$$

where;
p = Thermal fuel efficiency of the energy
P —— power output

My—— Mass of water in the pot (kg) Cp —- Specific heat of water (kJ/kgK)
T —— Initial temperature of water (K)
Tz —— Boiling temperature of water (K) Mc= Mass of water evaporated (kg)
L= Latent heat of evaporation (I)
M f—— Mass of fuel burnt (kg)
E/—- Calorific value of the fuel (kJ/kg)
M r—- Mass of water (kg)

Water boiling test is an important test required to determine burning rate of any energy source. Each of the briquette's ratio was used to boil one liter of water using biomass stove under similar conditions. Water boiling time taken to boil equal volume of water was recorded using stop watch.

The sieved carbonized materials of (Rice husk, Groundnut shell, Sawdust, Bagasse) were divided into different rations.
R = Rice husk (R)
B = Sugarcane Bagasse (B) SD = Sawdust (SD)
G = Groundnut shell (G)

3 group ration of carburized samples Table 1: Group 1
Table 2: Group 2
Table 3: Group 3
Each ratio was mixed with the binder materials in other to strengthening the briquettes toenhance charcoal adhesion and produce identical briquette. The Number of briquettes produced per group are as follows: Group I = 40
Group 2 =49
Group 3 =59

Preparation of mixing

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	2	1	1	1	1	2	1	1	1	1	2	1
1	1	1	1	3	1	1	1	1	3	1	1	1	1	3	1

Bulk density determination

Density is an important property of the solid fuel. High density products are desirable in terms of transportation storage and handling. The bulk density of the briquetted biomass charcoal prepared was determined by measuring dimensions and weighing of 5 samples. Weighing was performed by using an electronic weighing balance (OHAUS, Model ARB 120) and the dimension measurement was conducted by using a digital Vernier-caliper. Five samples were tested for each experiment and the average density was reported (Onuegbu et al., 2011).

$$\text{Density} = \frac{\text{mass}}{\text{Volume}} \qquad 4$$

where:
Mass of briquette = 24.0g

$$\text{Volume of a cylynder} = \pi r^2 h \qquad 5$$

$$\text{Therefore, Density} = \frac{24}{\pi r^2 h} \qquad 6$$

Calorificvalues

One of the most important characteristics of a fuel is its calorific values, that is the amount of energy per kg it gives off when burnt. The calorific values can thus be used to calculate the competitiveness of a processed fuel in a given market situation. There is a range of other factors, such as case of handling, burning characteristics etc. which also influence the market values but calorific values is probably the most important factor and should be recognized when selecting the raw materials impute. Table 4 indicates that R with the ash content of 15.tJ has the highest percentage follows by G, B and SD while in head of combustion (kcal), G was the highest with 4661 cal/kg, while the least was R (Onuegbu et al., 2011; Ogwu et al., 2014). Equation 7 was used to calculate the calorific value;

$$\text{Calorific value} = \frac{\text{Measured vatue (J) —Comptete combustio n}}{\text{Sample size}} \qquad 7$$

Ash Content

Ash content produced by the composite briquette will normally influence the calorific value test. The ash content is inversely proportional to its calorific value. At the same time, ash content is an important characteristic of briquette for ash handling and disposal requirement (Huko et al., 2015). Hence, biomass of higher ash content tends to consume more fuel for cooking than biomass of lower ash content. According to Onuegbo et a1. (201 I). Jekayinfa and Omisakin (20tJ5) reported the ash content values for some agricultural wastes were as follows; R (15.0 9‹), B (1.8 9‹); SD (0.7 9r) and G (2.8 %). Equation 8, was used to calculate the ash content of the briquettes.

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$$\% \text{ Ash contents} = \frac{M_{ash}}{M_{briquette}} \times 100\ \% \qquad 8$$

where M is the mass of the sample. Munira et a1., (2019).

Table 4: Calorific values of the biomass charcoals

Type of material	Ash (%)	Head of Combustion (kcal)
R	15.0	3881
B	1.8	4380

Source: (Emerhi, 201I)

Statistical Analysis

The obtained values were statistically analyzed using completely Randomized design (CRD) or one-way ANOVA. Appropriate graphs were plotted to show the trend of behavior of the samples under different conditions of treatment for the various parameters investigated.

Carbonizer Consideration

Charcoal is a carbon substance that remains when organic matter is heated to a high temperature in a low-oxygen environmental it is designed and manufactured by the author that the carbonizer provides a means of creating this low — oxygen environment. The carbonizer is made of cylindrical oil drum with two conical shapes made of sheet metals. The carbonizer is covered at the top after inserting the dried agricultural wastes. The biomass is tightly packed into the inner drum and fired for 30 minutes to 45 minutes (depending upon the biomass) in this method 30 'to of carbonized charcoal can be obtained (Sengar et al., 2016; Davies et al., 2013).

Stove

Energy efficiency stone has a frame which is made up of steel with a built — in charcoal brazier. Four of such stoneswhere utilized in conducting all the test.

Results and Discussions Burning Rate

The burning rate of the briquettes produces is calculated using the equation 9, (Munira et al., 2019);

$$\text{Burning rnte} = \frac{\text{lengt h burnt (cm)}}{\text{total time taken (s)}} \qquad 9$$

The burning rate values of the energy sources ranged between 12+9 g/min (|R), 13 + 1 I g/min (B), 17 + 12 g/min (SD), 20 + 12 g/min (G) and l0+ 9 g/min Charcoal (control). The variation of the burning rate values of the fuel types was significantly different (P<0.005). Charcoal recorded the low rate than other energy sources. This observation could be due to porosity exhibited between inter and intra particles which enable easy infiltration of oxygen and out flow of combustion briquettes. Onuegbu et al. (2011) and Munira et a1., (2019) reported that some factors could be responsible for burning rate of biomass (briquettes) such as chemical composition, volatile matter content and geometry (bulk and packing Orientation) of the biomass (Lu and Wang, 2000).

Plate 4: Produced briquettes

Preparation Time

The preparation time of the studied fuel types varied between 4.33 + 3.08 min (R), 3.08+2.58 min (B), 3.25+ 3.08 min (SD), 3.08+ 2.15 min (G) and 5.84 min (charcoal). There was significant difference in variation of the preparation time of the energy sources. The observed values on preparation time showed that charcoal took a longer time for it to start burning as compared to other energy sources. This could be due to its low volatile matter as compared to other biomass and high ash content. Bolaji (2005) recommended that briquettes for domestic use must be easily ignitable but with low porosity index.

Specific Fuel Consumption

The fuel consumption used in the experiment was estimated form the ratio of mass of fuel (g) to the quantity of boiling water (f), equation 10;

$$S = \frac{\text{Mass of fuel consumed}}{\text{Total mass o f boilin g water}} \quad 10$$

The specific fuel consumption of the fuel sources were 0.44 + 0.33 g/s (R), 0.55 + 0.43 g/s (B), 0.89 1 0.39 g/s (SD), 0.52 + 0.33 g/s (G) and 0.62 + 0.27 g/s (control). The variation of the specific fuel consumption values of the studied energy sources was significantly different (P<0.005).

Fuel efficiency

The fuel efficiencies of the studied fuel sources were R, (2.27 * 0.29 9•); B, (16.49 * 0.57 to); SD, (21.64 * 0.53 9•); G, (34.24 * 0.28 to) and charcoal (43.29 * 0.19 to). The observed values differed significantly (P<0.005). Fuel efficiency of the briquettes produced competed favorably with charcoal. Furthermore, the fuel efficiency of charcoal (43.29 + 0. l99r) was the height, followed by G briquette, (34.24 * 0.28 to), the least was R briquette, (Davies et a1., 2013). Emerhi, (2011) reported fuel efficiency of cash shell briquettes of 15.5 %. This value is lower than the obtained values in this study (Bless et a1., 2003).

Calorific Values

From Figure 3 the calorific values of the energy sources ranged from 6552 kcal/kg (charcoal), to 388 I kcal/kg, R (Emerhi, 2011). The variation of the calorific values of the fuel types was significantly different (P<0.005). The calorific value of G was higher than calorific values of SD, B and R but lower than charcoal. This is an indication that more heat during combustion might be generated from groundnut shell briquettes than saw dust, bagasse and rice husk but less than charcoal (control). Significant differences of the calorific value were found between briquettes.

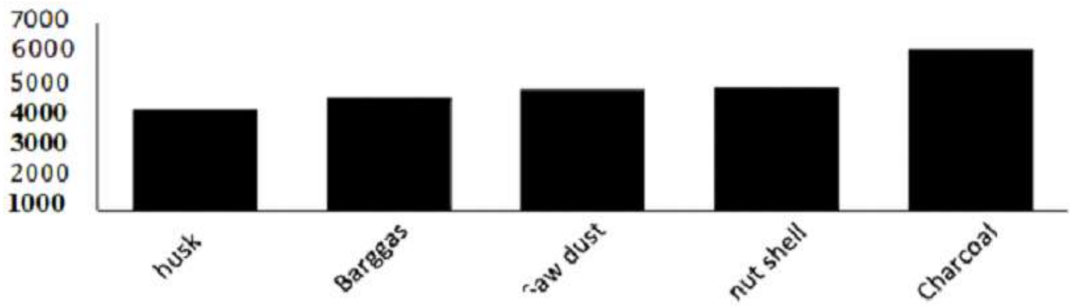

Figure 3: Calorific value of different energysource Water BoilingTest

In Figure 4, boiling time values were 17.11 * 15.17 min (R), 17.56 * 15.40 min (B), 15.40 * 14.25 min (SD), 16.60 * 10.55 min (G) and 15.33 * 14.52 min (charcoal). The values of the boiling time of the energy sources were significantly different (P<0.005). Among the energy sources groundnut at ratio 1:1:1:2 had the shortest boiling time while bagasse at all ratios had the longest duration of water boiling time (Table 5).

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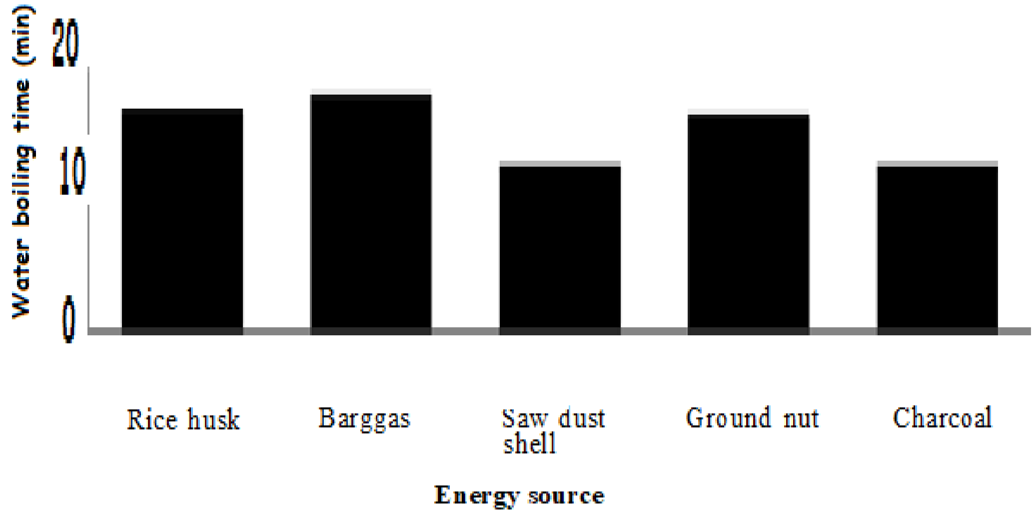

Figure 4: Water boiling time of different energy sources.

Table 5: Water boiling tests for different ratios and control

Mixing ratio	Preparation time	Max boiling	M.F.C. (g)	Burning rate	S.F.C (g)
R					
1:1:1:1	3.08	15:17	190.2	12.68	0.44
2:1:1:1	4:33	15:17	188. 1	12.54	0.33
3:1:1: 1	4:33	17:11	154.2	9.07	0.41
Control	5.84	14:52	137.2	9.08	0.27
1: 1:1: 1	3.08	17:57	199.9	11.75	0.43
1:2:1: 1	2:58	17:57	202.9	11.94	0.55
1:3:1: 1	2:58	17:57	222.9	13.11	0.55
Control	5.84	14:52	139.2	9.94	0.28
SD					
1: 1:1: 1	3.08	15:4	187.3	12.49	D59
1: 1:2: 1	3:25	14:25	248.0	17.71	D.45
1 :1:3: 1	3:25	15:4	251.9	16.79	0.89
Control	5.84	14:58	277.8	19.84	0. 62
G					
1: 1:1: 1	3.08	16:6	196.9	12.31	0.49
1: 1:1:2	2:15	10:55	185.7	18.57	0.33
1: 1:1:3	2:15	12:53	146.2	20.52	0.52
Control	5.84	15:33	168.5	11.23	0.32

Density of Briquettes

Comparison between each briquette indicated that R had the highest density followed by G then SD and finally B.

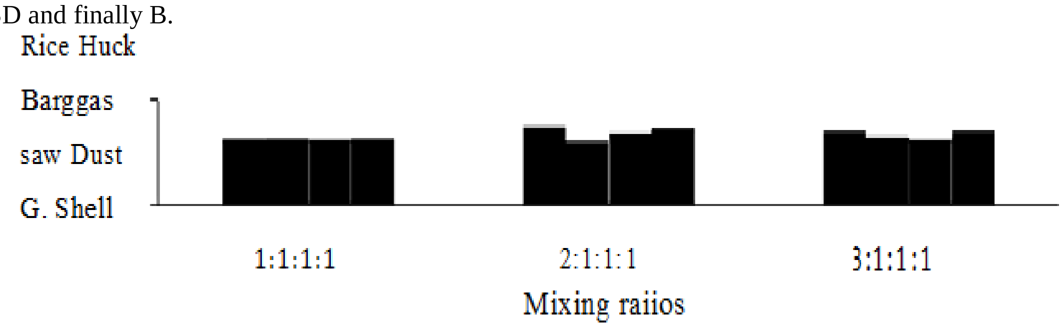

Figure 4: Density of different mixed charcoal briquettes with various mixing ratios

II. CONCLUSION AND RECOMMENDATIONS

Conclusions

This study demonstrated that briquettes can be utilized as a suitable alternative to domestic and if further research is carried out, it can be used for industrial fuel. The result confirmed that possibility of utilizing R, B, SD and G, as fuel briquette of good source that support clean combustion. The agricultural waste possess the high material strength as well as high value combustible fuel, which qualify them as suitable alternative to charcoal for domestic and industrial energy. The burning rate of the briquettes produced from this densification variables can be favorably compared with charcoal. Furthermore, the burning rate of G at ratio 1:1:1:3 was the highest, while the charcoal (control) has the least burning rate. Among the energy sources G, 1:1: I:2 had the shortest boiling time while, B at all ratios had the longest duration of water boiling time. The variation of the specific fuel consumption values of the studied energy sources was significantly different (P<0.005). The observed values on preparation time showed that Control took the longest time for it to stan burning as compared to other energy sources. Thus, densification process had enhanced combustion and handling characteristics of briquettes.

Recommendations

i. The fuel briquettes produced are environmentally friendly, if used will reduce desertification and its environment implication and reduce health hazard associated with the use ofcharcoal.

ii. CombinationofR,B,SDandGareverysuitableforbriquetteproductionfordomestic and possibly industrialuses.

iii. If the government would invest more in this area of energy diversification, it will go a long way in increasing the income per capital of the country, serving also as a source of revenue for the nation particularly in the rural and urban areas by converting waste towealth.

iv. More researches should be carried out on other agricultural wastes for better comparism.

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