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Characteristic Analysis of Bio-coal Briquette (Coal and Groundnut Shell Admixtures)

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ABSTRACT

In this research work, briquettes of coal and groundnut shell were produced. The different briquette samples produced were made by blending various compositions of coal and grinded groundnut shell in the following ratios of 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 using clay/rice starch as a binder and calcium oxide as the desulphurizing agent. The briquettes were produced mechanically using a manual briquetting machine. The results of the characteristic and post-briquette analysis showed that the different compositions of the briquettes had reasonable calorific value but that 60% coal:40% groundnut shell briquettes with following values for ash content 32.5 %, fixed carbon 51.50 %, moisture content 7 %, density 0.71 g/cm3, volatile matter 9.0 %, porosity index 48.12 %, HCV 12.10 MJ/kg, LCV 8.04MJ/Kg water boiling test 20 mins, ignition time 13 mins, and burning time 56.14 mins exhibited optimum combustible quality when compared with other compositions of briquettes produced.
Keywords: Briquette, Coal, Groundnut Shells, Desulphurizing Agent, Binder

I. INTRODUCTION

The decreasing availability of fuel wood, coupled with the ever-rising prices of kerosene and cooking gas in Nigeria, draw attention to the need to consider alternative sources of energy for domestic and cottage level industrial use in the country. Such energy sources should be renewable and should be accessible to poor. A transition to a sustainable energy system is urgently needed in the developing countries such as Nigeria. This should, of necessity, be characterized by a departure from the present subsistence level energy usage levels based on decreasing firewood resources, to a situation where human and farming activities would be based on sustainable and diversified energy forms [1].

Biomass, particularly agricultural residues seem to be one of the most promising energy resources for developing countries [2]. Rural households and minority of urban dwellers depend solely on fuel woods (charcoal, firewood and sawdust) as their primary sources of energy for the past decades [3]. Of all the available energy resources in Nigeria, coal and coal derivatives such as smokeless coal briquettes, bio-coal briquettes, and biomass briquettes have been shown to have the highest potential for use as suitable alternative to coal/ fuel wood in industrial boiler and brick kiln for thermal application and domestic purposes. Global warming has become an international concern. Global warming is caused by green house gasses which carbon dioxide is among the major contributors. It was shown that increased emissions of CO2 have been drastically reduced owing to the fact that the rate of deforestation is higher than the afforestation effort in the country [4].

The use of fuel wood for cooking has health implications especially on women and children who are disproportionately exposed to the smoke apart from environmental effects. Women in rural areas frequently with young children carried on their back or staying around them, spend one to six hours each day cooking with fuel wood. In some areas, the exposure is even higher especially when the cooking is done in an unventilated place or where fuel wood is used for heating of rooms [5].

Agro waste is the most promising energy resource for developing countries like ours. The decreasing availability of fuel woods has necessitated that efforts be made towards efficient utilization of agricultural wastes. These wastes have acquired considerably importance as fuels for many purposes, for instance, domestic cooking and industrial heating. Some of these agricultural wastes for example, coconut shell, wood pulp and wood waste can be utilized directly as fuels [6].

Fortunately, researches have shown that a cleaner, affordable fuel source which is a substitute to fuel wood can be produced by blending biomass (agricultural residues and wastes) with coal. Nigeria has large coal deposit which has remained untapped since 1950's, following the discovery of petroleum in the country. Also, millions of tonnes of agricultural wastes are generated in Nigeria annually. But it is unfortunate that farmers still practice "slash-and-burn" agriculture. These agricultural wastes they encounter during clearing of land for farming or during processing of agricultural produce are usually burnt off. By this practice, not only that the useful raw materials are wasted, it further pollutes the environment and reduces soil fertility [7].

 peat block	 Coal briquette	 Coal briquette	 Straw or hay briquettes
 Quick Grill Briquette	 Yeontan, Korean Coal briquette	 Mametan, Japanese Coal briquettes	 Ogatan, Japanese charcoal briquettes made from sawdust.
 Solid type Ogatan	 High calo tan, Made from coffee dust.	 Tadon and Shichirin	

Figure 1: Samples of briquettes from different raw materials

II. METHODS AND MATERIAL

2.1 Materials

- ✓ Coal: Sub-bituminous coal was obtained from Onyeama mine, Enugu, Enugu State.
- ✓ Groundnut shell: This was obtained from University of Port Harcourt campuses, Rivers State (i.e. cooked groundnut shell) from already eaten cooked groundnut.
- ✓ Rice starch: This was brought from parboiled rice in my Kitchen.
- ✓ Calcium oxide was bought from a chemical shop in Aba, Abia State.
- ✓ Clay was bought from engineering geology laboratory, Ofrima Abuja Campus.

2.2 Preparation of Materials

Coal: The coal blocks were crushed and ground to fine powder by hammer milling. The coal powder obtained after grinding was sieved to obtain coal of very small particle size in diameter. The pre-briquetting, characterization, and post-briquetting analyses were as applied by [8], [9], and [10]:

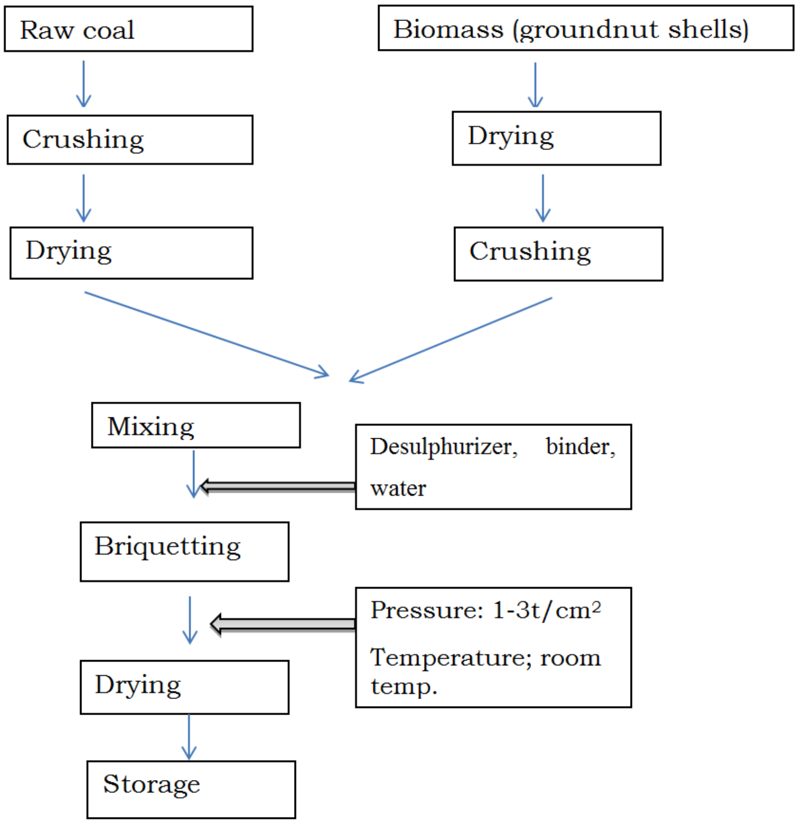

Figure 2. The basic flow process for bio-coal production

STEP 1

STEP 2

STEP 3

STEP 4

STEP 5

STEP 6

STEP 7

STEP 8

1. Coal blocks
2. Hammer milled coal pellets
3. Sieved coal dust
4. Grinded groundnut shells
5. Ground nut shell powder
6. Measurement of samples
7. Individual samples measured out
8. Mixing with clay and CaO.
9. Briquetting

Figure 3: Briquette making steps in pictures

2.4. Pre-Briquetting Analysis of The Raw Materials:

a. Determination of the moisture content of the raw materials

$$\text{Moisture content (MC \%)} = \frac{\text{Initial weight of sample} - \text{final weight of sample}}{\text{initial weight of sample}} \times 100$$

b. Determination of the volatile matter in the raw materials.

$$\text{Volatile Matter (VM \%)} = \frac{\text{weight of sample after cooling} \times 100}{\text{Weight of sample taken}}$$

c. Determination of the ash content of the raw materials.

$$\text{Ash content (AC \%)} = \frac{\text{final weight of sample}}{\text{initial weight of sample}} \times 100$$

d. Determination of the fixed carbon content of the raw material.

$$\text{Fixed carbon content (\%)} = 100 - (\text{moisture content(\%)} + \text{volatile matter(\%)} + \text{Ash content(\%)}$$

e. Determination of the calorific value of the raw materials.

Gross (or higher) calorific value **(HCV) = 20.0 x (1 - A - M) MJ/kg** where A is the ash content and M the moisture content of the actual fuel.

The lower (or net) calorific value, which takes into account unrecovered energy from the water vapour from inherent moisture and from the oxidation of the hydrogen content.

Lower calorific value **(LCV) = 18.7 x (1- A - M) - 2.5 x M) MJ/kg**

2.5. BIO-COAL BRIQUETTE FORMULATION.

Table.1: Bio-coal briquette formulation.

Raw material (%)	100:0	80:20	60:40	40:60	20:80	0:100
Coal Dust(g)	200	160	120	80	40	0
Groundnut shell(g)	0	40	80	120	160	200
CaO(g)	60	50	40	30	20	10
MgO/Clay(g)	30	30	30	30	30	30
Water(ml)	250	250	250	250	250	250

Procedure:

A specific quantity of biomass, coal and CaO/Clay were weighed out using a triple beam balance into a 100ml plastic basin. They were mixed thoroughly until a homogenous (uniform) mixture was obtained. A measured quantity of water was added to give a paste that can agglomerate. The briquetting moulds of the hydraulic press briquette mould were filled with mixture, making sure the moulder plates were inserted first. The mould lid was closed and the mixture was briquetted by applying pressure on the hydraulic jack. This action moves the movable part of the mould up to the immovable part (the lid), causing the mixture in the mould to be compressed, and it agglomerate into a briquette.

2.6. CHARACTERIZATION OF THE BIO-COAL BRIQUETTES SAMPLES

a. Determinations of density (cylindrical mould)

$$\text{Density } (g/cm3) = \frac{\text{Mass(g)}}{\text{Volume(cm3)}}$$

b. Determination of Ignition Time

Ignition time is the time taken for a flame to raise the briquette to its ignition point.

c. Water boiling tests of the briquette samples
The time taken for a definite quantity of briquette sample (100g) to boil a specific quantity of water.

d. Determination of Burning Time/Rate
Burning rate = Ash time – Ignition time

e. Porosity Index Determination

$$\text{Porosity index} = \frac{Mass\ of\ water\ absorbed\ (M3)\ \ x\ 100}{mass\ of\ the\ sample\ (M1)}$$

2.7. POST-BRIQUETTING ANALYSIS OF THE BIO-COAL BRIQUETTE SAMPLES:

- ✓ The moisture content of the bio-coal briquette samples.
- ✓ The volatile matter in the bio-coal briquette samples.
- ✓ The ash content of the bio-coal briquette samples.
- ✓ The fixed carbon content of the bio-coal briquette samples.

e. The calorific value of the bio-coal briquette Samples

III. RESULTS AND DISCUSSION

3.1 PRE-BRIQUETTING ANALYSIS OF THE RAW MATERIALS

Table 2: Pre-briquetting analysis of the materials

Parameter	Coal	Groundnut shell
Moisture content (%)	6.10	10.30
Ash content (%)	23.00	54.70
Volatile matter (%)	14.00	6.00
Fixed carbon (%)	56.90	29.00
HCV (MJ/Kg)	14.18	7.00
LCV (MJ/Kg)	10.41	1.73

Table 3 : Characteristic analysis of the bio-coal briquette samples

Briquette samples	Density (g/cm^3)	Porosity (%)
100% CD	0.76	22.02
80%CD 20%GS	0.75	39.68
60%CD 40%GS	0.71	48.12
40%CD 60%GS	0.69	53.66
20%CD 80%GS	0.67	69.87
100%GS	0.63	78.69

Key- CD= Coal dust, GS= Groundnut shell

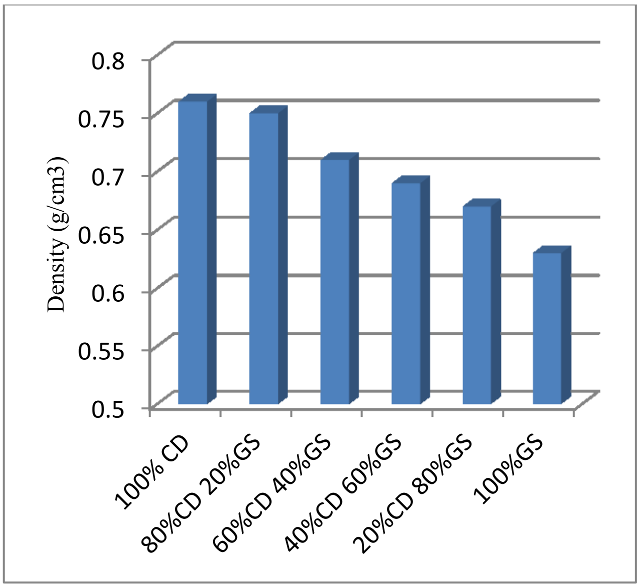

Figure 4: Density plot for bio-coal briquette samples

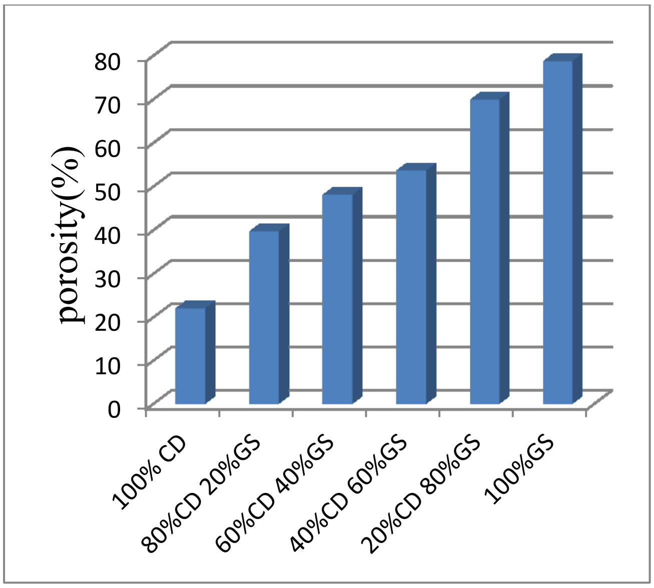

Figure 5: Porosity (%) plot for bio-coal briquette samples

Table 4: Characteristic analysis of the bio-coal briquette samples

Briquette samples	Water boiling test (mins)	Burning time (min)	Ignition Time (mins)
100% CD	18	40.00	18
80%CD 20%GS	24	48.56	15
60%CD 40%GS	20	56.14	13
40%CD 60%GS	22	43.10	10
20%CD 80%GS	19	33.50	8
100%GS	12	27.20	5

Key- CD= Coal dust, GS= Groundnut shell

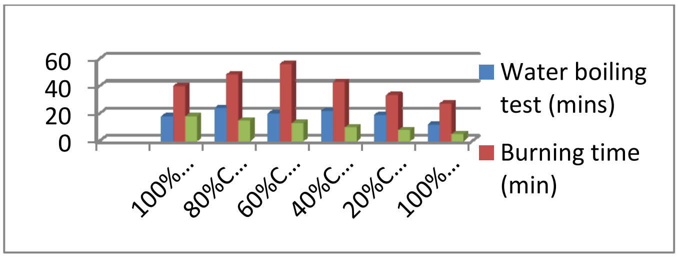

Figure 6 : characteristic plots for bio-coal briquette samples

Table 5: Post-briquetting analysis of the bio-coal briquette samples

Briquette samples	Moisture content (%)	Volatile (%)	Ash Content (%)	Fixed carbon (%)
100% CD	6.00	11.7	19.76	62.60
80%CD 20%GS	6.50	11	26.48	56.02
60%CD 40%GS	7.00	9.0	32.50	51.50
40%CD 60%GS	8.50	7.4	36.12	47.98
20%CD 80%GS	9.00	6.6	41.41	42.99
100%GS	10.00	5.0	45.77	39.23

Key- CD= Coal dust, GS= Groundnut shell

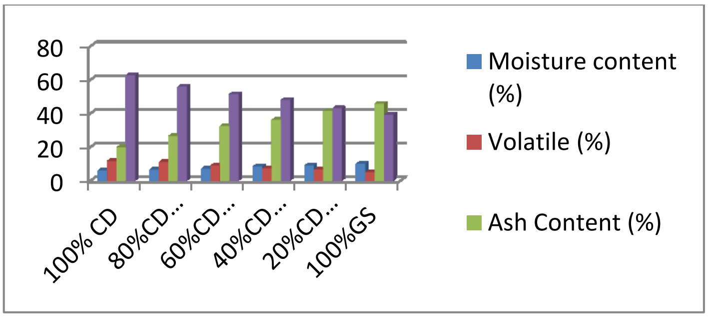

Figure 7: Post-briquetting analysis plots for the bio-coal briquette samples

Table 6: Calorific values of the bio-coal briquette samples

Briquette samples	HCV (MJ/Kg)	LCV (MJ/Kg)
100% CD	14.85	11.08
80%CD 20%GS	13.40	9.49
60%CD 40%GS	12.10	8.04
40%CD 60%GS	11.08	6.38
20%CD 80%GS	9.92	5.07
100%GS	8.85	3.60

Key- CD= Coal dust, GS= Groundnut shell

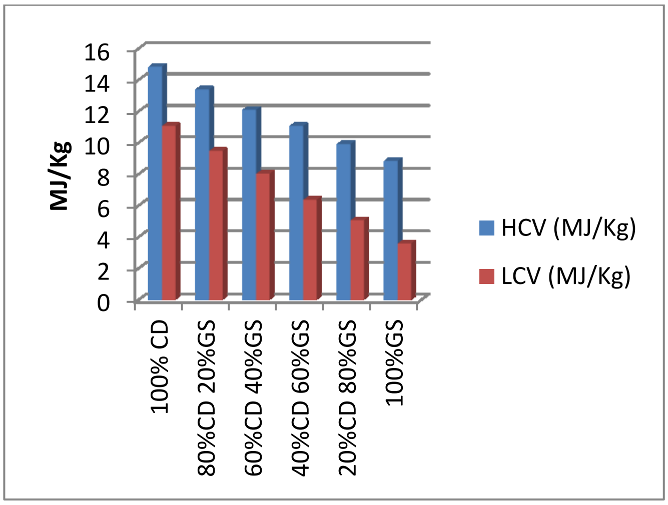

Figure 8: Calorific plots for the bio-coal briquette samples

Figure 9 : Locally produced briquettes

3.3 DISCUSSION

From Table 2, it can be seen that groundnut shell has higher moisture content than coal due to it pore allowances. From literature, the moisture content of biomass should be as low as 10-15% so that there will be complete combustion of the briquettes [11]. Low moisture content of biomass also helps in their storage (prevents rotting and decomposition). It can also be seen clearly from the table that groundnut shell has the higher value of volatile matter than coal. From literature, the volatile matter content of biomass is usually higher than that of coal.

The ash content results show that coal has the higher ash content value than groundnut shell. From literature, typical biomass contains fewer ashes than coal, and their composition is based on the chemical components required for plant growth, whereas coal ashes reflect the mineralogical composition [11]. As expected, the carbon content of coal is higher than that of groundnut shell as shown in the Table 2.

The results of proximate analyses of the raw material are shown in Table 2. From the results, it is clearly shown that the coal sample has higher calorific value (7:14.18MJ/g), fixed carbon (29:56.90%), volatile matter (6:14%) than the biomass samples but lower ash content (23:54.70%), and moisture content (6.10:10.30%). The calorific value of coal indicates that it will release more heat during combustion than the biomass while the biomass on their own side will ignite more readily and burn faster than the coal because of their higher porosity (more spaced and fibrous packing). Also, the high ash content of the coal is an indication that it contains more mineral (non-combustible) matters than the biomass materials and its concentration will have great influence on the amount of ash that will be generated by bio-coal briquettes

In the characterization test carried out as shown in Table 2, the density, and porosity plot shown in figures 3 and 4 respectively. It can be seen that the density of the samples increase with decrease in biomass load and this will help for easy transportation of the sample. Since coal is denser than groundnut shell, the briquettes produced with higher composition of coal had a higher density value than those briquettes of ground nut shell. The lower the porosity index of the briquettes the higher the density of the briquettes produced, the values showed that 100% coal briquette has a higher density than 100% groundnut shell.

The results of ignition time showed that the ignition time of the briquettes decreases with increase in biomass concentration. This can be explained from the fact that the biomass contains more volatile matter than the coal. Therefore, increasing its concentration in the briquette will definitely increase the ignitibility of the briquette. The coal briquette samples 100%CD took the longest time to ignite, 18mins. But with incorporation of biomass, the ignition time dropped progressively. The ignition time of the 40%CD 60%GS sample was shorter, and that of 100%GS was the least with 5mins. The sample with relatively low ignition time will be more efficient. The ignition time of the briquettes improved with blending coal and groundnut shell. The briquettes produced are portable, safe to handle and with improved cooking efficiency due to the addition of the groundnut shell to the coal.

Among the factors that control the burning rate of a material are chemical composition and geometry (bulk, packing, orientation) of the material. Biomass contains more volatile matter than the coal and it is more porous which allows for easy infiltration of oxygen and out flow of combustion products which explains the reason why we had a sharp increase in the 60%CD 40%GS sample where the composition was most favored in pore arrangement, volatile composite, fixed carbon and optimal density. Therefore, increasing the proportion of the biomass is expected to increase the burning rate of the briquettes.

Table 4, show the results of the parameters determined during the water boiling test. Provision of sufficient heat for the time necessary is an important quality of any solid fuel. The results of water boiling test showed that the time required for each set of briquettes to boil an equal volume of water increased with increase in the biomass concentration up to 60%CD 40%GS. However, the fact that the briquette samples containing 40% biomass boiled water faster than the one containing 60% is a clear indication that somewhere beyond this concentration, the water boiling time will eventually begin to rise and fall towards 80-100%. The coal briquette, 100%CD, took the longest time to boil water (24min) while the sample 100%GS took the shortest time (12min). The burning rate (how fast the fuel burns) and the caloric value (how much heat released) are two combined factors that controlled the water boiling time. This explains why sample 100%GS was able to boil water faster than Sample 100% CD even when the latter burns longer than the former. This means that the calorific value alone is not a single factor controlling cooking efficiency but burning rate is equally important. The lower the water boiling time the more economical the briquette will be. However, comparing the specific fuel consumption, the burning rate and the water boiling time, it is observed that the cooking efficiency of the briquettes increase with increase in biomass concentration (within the biomass range of 0% to 5%) and somewhere beyond this biomass range, the cooking efficiency will start to drop. This is because of the fact that the briquette burns slowly, as a result, lots of the heat released was lost before the water boils.

Similarly, from Table 5, the moisture content of the coal briquette without biomass (control) is 6.00%. For the groundnut shell-coal briquettes; the moisture content increased from 6.50% - 8.50% and decreased from 10.30% - 9% for groundnut shell briquette.

The ash content of the briquette without biomass (control) is 19.76%. The value of the ash content decreases from 23% - 19.76% and increases for coal, and from 19.76% - 41.41% for the bio-coal briquette samples. This can be attributed to the lower density, higher porosity index, and of course decreasing fixed carbon content with increasing biomass load.

The results in Table 6, show that the higher calorific values of 14.85 MJ/kg and 8.85MJ/kg for 100%CD and 100%GS respectively. Considering the calorific values of the plant materials before briquetting, it was shown that there is an increase in the calorific value after conversion of the wastes into briquettes. This increase is partly attributed to the slight difference in the moisture content of the materials; as at the time of the analyses, coal block and compressed groundnut shell had moisture content of 6.10% and 10.30% respectively while their briquettes had moisture contents of 6% and 9% respectively. Also, the rice starch as a binder has been reported to have the ability of increasing the calorific value of briquettes. However, the heating value of the briquettes can be enhanced by blending the wastes with some quantity of desulfurized coal before briquetting especially when the briquettes are to be used for industrial application.

From Table 2, it can be seen that groundnut shell has higher moisture content than coal. From literature, the moisture content of biomass should be as low as 10-15% so that there will be complete combustion of the briquettes [11]. Low moisture content of biomass also helps in their storage (prevents rotting and decomposition). It can also be seen clearly from the table that groundnut shell has the higher value of volatile matter than coal. From literature, the volatile matter content of biomass is usually higher than that of coal.

The ash content results show that coal has the higher ash content value than groundnut shell. From literature, typical biomass contains fewer ashes than coal, and their composition is based on the chemical components required for plant growth, whereas coal ashes reflect the mineralogical composition [11]. As expected, the carbon content of coal is higher than that of groundnut shell as shown in the Table 2.

From the results in Table 3, it can be seen that the density of the samples decrease with increase in biomass load while on the other side porosity index increase with more biomass loading, this will help for easy transportation and burning character of the sample. The results in Table 4 show that ignition time of the sample decrease with increase in biomass load.

IV. CONCLUSION AND RECCOMMENDATION

CONCLUSION

From the results of the tests and analyses, the following conclusions can be drawn on the possibility of using groundnut shell as biomass in the production of bio coal briquettes:

- The bio-coal briquettes take less time to boil water, cook food than coal briquette under similar conditions, burn smoothly with very little generation of smoke and harmful gases, are easier to ignite, have low ash content than coal briquettes.
- Although briquettes, as with most solid fuels, are priced by weight or volume, market forces will eventually set the price of each fuel according to its energy content. However, the production cost of briquettes is independent of their calorific value as are the transportation and handling costs. The calorific value 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 ease of handling, burning characteristics etc., which also influence the market value but calorific value is probably the most important factor.
- The results of water boiling test showed that the time required for each set of briquettes to boil an equal volume of water decreases with increase in the biomass concentration up to 60% for groundnut shell bio-coal samples. The burning rate (how fast the fuel burns) and the caloric value (how much heat released) are two combined factors that controlled the water boiling time.
- There is no fly ash when burning briquettes. Briquettes have consistent quality, have high burning efficiency, and are ideally sized for complete combustion. Combustion is more uniform compared to coal and boiler response to changes in steam requirement is faster due to higher quantity of volatile matter in briquettes. Compared to fire wood or loose biomass, briquettes give much higher boiler efficiency because of low moisture and higher density. Briquettes, are easy to store, pack and hygienic to handle.

RECOMMENDATION

- An energy source that meets such sustainability requirements is fuel briquette. If produced at low cost and made conveniently accessible to consumers, briquettes could serve as complements to firewood and charcoal for domestic cooking and agro-industrial operations, thereby reducing the high demand for both. Besides, briquettes have advantages over fuel wood in terms of greater heat intensity, cleanliness, convenience in use, and relatively smaller space requirement for storage
- Briquettes can replace following conventional fuels; diesel, kerosene, furnace oil, lignite, crude coal, and firewood
- Key features of the briquettes plant project will include high profitability, excellent growth potentiality, ready market, wide variety and easy availability of agro-waste from various crops, short gestation and quick returns, employment potentiality, conversion of natural resources into hi-tech energy and maintenance of ecological balance.
- The following industries can make maximum use of briquettes; ceramic and refractory industry, solvent extraction plant, chemical units, dyeing plants , milk plants, food processing industries, vegetable plants, spinning mill, lamination industries, leather industries, brick making units, other industries having thermal applications, gasifies system in thermal, and textile units

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