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Evaluating the bio-energy potential of groundnut shell and sugarcane bagasse waste composite

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Abstract

An assessment has been carried out on bio-coal briquettes from coal with sugarcane bagasse and coal with groundnut shell. Proximate analyses and elemental compositions of the coal and biomasses were determined. Different samples of briquettes were produced by blending varying composition of the coal with the biomasses in the ratio of 100:0; 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0: 100, using calcium carbonate as a desulfurizing agent and cassava starch as a binder. A manual hydraulically operated briquetting machine was used with the pressure kept at 5MPa. The results of the properties evaluated shows that biomass increases the burning efficiency of briquettes with increase in the biomass material, increasing combustion rate, faster ignition, producing lesser ash and fewer pollutants. Results obtained shows that the calorific value of briquettes produced from coal-groundnut shells and coal-sugarcane bagasse ranges from 16.94 - 20.81 and 17.31 – 21.03 MJ/kg respectively. The ignition time ranges from 6.9 – 12.5 minutes for coal-groundnut shells briquettes while that of coal-sugarcane bagasse ranges from 6.5 – 11.1 minutes. The bio-coal blends with sugarcane bagasse were better than that of groundnut shells. However, both sugarcane bagasse and groundnut shells produce bio-coal briquettes that are very efficient, providing sufficient heat as at the time necessary, generating less smoke and gases (e.g sulphur) that are harmful to environment, and generating less ash, as these have adverse effect during cooking.

Keywords: Evaluating, Bio-coal briquette, Sugarcane bagasse, Groundnut shell, Coal

1. Introduction

Energy resources are categorized into two, renewable and non-renewable. The renewable one is believed to be a preferred option since the non-renewable counterpart such as diesel, gasoline kerosene, etc since the later does not have the capability to be replenished and would be exhausted. The environmental implications as a result of emissions of CO_2, SO_x, NO_X etc during combustion of the non-renewable resources, motivated the use of renewable for cooking and heating purposes. Agricultural waste has been considered as one of the most versatile for cooking and heating purposes.
One of the major forces behind research of this kind is the need to deal with the environmental effects and health hazards related with the use of solid fuels (coal and fuel wood). It is also an effective way of control agro wastes. In recent times, it has been proved that blending coal and biomass (agro wastes) gives a briquette better combustion properties and pollutant emission compared to the conventional coal briquettes. This type of briquette is known as bio-coal briquette. Bio-coal briquettes is a type of solid fuel prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent [1]. The mechanism behind this is that, since the biomass component of the briquette ignites at low temperature compare to the coal, this ensures that the volatile matter in the coal which would have otherwise being liberated as smoke at low combustion temperature combusts completely. The complete combustion of the volatiles reduces smoke and as well, contributes to the total heat released by the fuel. The ash of bio-coal has been shown to be effective for soil treatment and enrichment [2].

Bio-coal briquettes are briquettes formed by blending coal with vegetable matter (biomass), and then treating with desulphurizing agent using an amount corresponding to the sulphur content in the coal. The method most widely used is where the coal and biomass (dried) are pulverized, and mixed with sulphur and chlorine fixation agents such as calcium carbonate, calcium hydroxide, etc (i.e lime based products). The desulphurizng agents fix the sulphur into the sandy ash during combustion, making the ash rich in nutrients (that can be used by plants). Thus, several coal ranks, including low grade coal containing high suphur and ash contents can be used for producing biocoal briquettes [3]. It have being proved that calcium hydroxide or calcium oxide is the best desulphurizing agent with desulphurizing efficiency reaching over 80%. Calcium hydroxide is the best desulphurizing agent because of the following: Calcium hydroxide was decomposed at 350℃, and H_2S is released from volatile matter.

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$Ca(OH)_2 \rightarrow CaO + H_2$
$CaO + H\_2 S \rightarrow CaS + H\_2 O$
$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 . \frac{1}{2} H_2O + \frac{1}{2} H_2O$

Coal can be mix together with a small quantity of agricultural waste to produce briquettes (bio-coal briquettes) which burn efficiently and ignite fast, producing little or no smoke and making it cheaper than coal briquettes. Most researches done in this area focused on briquetting groundnut shell and sugarcane bagasse alone, but little information is available on features of composite briquettes. This research was aimed at investigating the effect of biomass on coal briquettes and compares the properties of bio-coal briquettes.

2. Materials and methods

Groundnut shells were collected from Dawanu grain market and Sugarcane bagasse was from the factory site at Sharada Industrial estate in Kano, Nigeria. Sub-bituminous coal from Okaba Mine was sourced from the Okaba coal site in the Kogi state, Nigeria, while calcium hydroxide, cassava starch were procured from Sabon-gari market, Kano. Manual hydraulic briquetting machine was fabricated at Hydraulic Equipment Development Institute, Kano.

2.1 Preparation of the raw materials

The sugarcane bagasse and groundnut shells were collected and air dried for 5 days to reduce the moisture content of the materials. The materials were chopped and ground in an electric milling machine to pass through a 4mm standard sieve. The coal sample was sun dried for 5 days to reduce its moisture content. It was broken into smaller sizes using hammer and was then ground in an electric milling machine to pass through 1mm sieve. Each of the raw materials was kept separately in polyethylene bags.

2.2 Proximate analysis of the materials

2.2.1 Determination of moisture content (MC)

The moisture content of raw biomass was determined by calculating the loss in weight of material using hot air oven dying method at 105℃ to 110℃ for one hour and up to constant weight loss [4].

$$MC\ (\%\ wb) = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \qquad (1)$$

Where,
W_1 = weight of crucible (g)
W_2 = weight of crucible + sample (g)
W_3 = weight of crucible + sample, after heating (g)

2.2.2 Determination of a volatile matter (VM)

The dried sample left in the crucible was covered with a lid and placed in an electric furnace (muffle furnace), maintained at 925 ± 20℃ for 7 minutes. The crucible was cooled first in air, then inside a desiccator and weighed again. Loss in weight was reported as volatile matter on percentage basis [4].

$$VM\ (\%\ wb) = \frac{W_5 - W_6}{W_5 - W_4} \times 100 \qquad (2)$$

Where,
W_4 = weight of the empty crucible (g)
W_5 = weight of empty crucible + sample (g)
W_6 = weight of the crucible + sample after heating (g)

2.2.3 Determination of ash content (AC)

The residual sample in the crucible was heated without lid in a muffle furnace at 700 ± 50℃ for one half hour. The crucible was then taken out, cooled first in air, then in desiccators and weighed. Heating, cooling and weighing was repeated, till a constant weight is obtained. The residue was reported as ash on percentage basis [4].

$$AC\ (\%\ wb) = \frac{W_9 - W_7}{W_8 - W_7} \times 100 \qquad (3)$$

Where,
W_7 = weight of the empty crucible (g)
W_8 = weight of empty crucible + sample (g)
W_9 = weight of the crucible + ash (g)

2.2.4 Fixed carbon determination

The fixed carbon percentage was calculated by using following relationship.

Percentage of fixed carbon = 100 – (MC + AC+ VM)% [4].

The calorific value was determined using Leco AC-350 Oxygen Bomb Calorimeter interfaced with a microcomputer was used to assess the heat values of the produced briquettes The total sulphur content was analyzed using the Eschka method [5].

2.3. Preparation of the briquette samples

A manual hydraulic briquetting machine with moulds of 4.0 cm diameter was used. Briquettes of varied biomass concentrations were produced by mixing the coal and groundnut shells and coal and sugarcane bagasse at various composition ratios by weight; (100: 0, 90:10, 80:20, 70:30, 60:40, 50:50, 60:40 and 0:100) The briquette samples and their composition are shown on Table 1.

Table 1 Composition of briquettes samples

Sample	Coal (%)	Biomass (%)
C100	100	0
B10	90	10
B20	80	20
B30	70	30
B40	60	40
B50	50	50
B60	40	60
B100	0	100
G10	90	10
G20	80	20
G30	70	30
G40	60	40
G50	50	50
G60	40	60
G100	0	100

Where,

B = Sugarcane bagasse
G = Groundnut shell
C = Coal

For each set of briquette, 5% $Ca(OH)_2$ based on the mass of coal was used as the desulfurizing agent and 20% cassava starch based on the entire mass of the mixture was used as the binder. The pressure was maintained at 5 MPa throughout the production. The samples were weighed using digital weighing balance.

2.4. Analyses of the briquette samples

Calorific value, Ash and moisture content of the briquettes were analyzed using the same procedure as in the proximate analysis.

2.4.1 Water absorbed

It is a measure of percentage of water absorbed by a briquette when immersed in water. Each briquette was immersed in 25 mm of water at 27°C for 30 seconds. The percent water gain was then calculated and recorded by using following formula [4]. It was used to measure the porosity of briquettes.

$$\text{Water gained (\%)} = \frac{w_b - w_a}{w_b} \times 100 \quad (4)$$

Where,

w_a= weight before immersion
w_b=weight after immersion

2.4.2 Ignition time

Ignition time was determined by burning 200 g of briquettes in charcoal stoves. Since end-point of lighting was subjective and dependent on some judgement according to what stage the ignition has been achieved, two similar charcoal stoves were ignited at the same time by placing equal amount of paraffin on the floor of the charcoal stoves and lit using a lighter. In this process, ignition time was taken as the average time taken to achieve steady glowing fire as recommended by [6].

2.4.3 Burning time

Burning time is obtained by observing the mass changes recorded on mechanical balance and also by using a stop watch. It is the time the biomass combustion is complete. With the known amount of total burnt briquettes and burning time, average combustion rate can be calculated by using following formula [7].

$$Combustion\ Rate = \frac{Total\ Mass\ of\ Burnt\ Briquette}{Buring\ Time} \quad (5)$$

2.4.4 Heat release

By knowing the calorific value and burning rate of briquette, the heat release can be calculated [7].

$$\text{Heat release} = \text{Calorific value} \times \text{Combustion rate} \quad (6)$$

3. Results and discussion

From Table 2, it can be seen that groundnut shells have the highest value of moisture content, next is sugarcane bagasse, and coal has the lowest value. The volatile matter content shows that sugarcane bagasse has the highest value of volatile matter, followed by groundnut shells, then coal. The ash content result shows that coal has the highest ash content value, followed by groundnut shell, and then sugarcane bagasse. It can also be seen from the table that the ash content of groundnut shells and corn cob are lesser than that of coal, the lower the ash content, the better the quality of the fuel. Reference [8] wrote that 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. Coal has the highest fixed carbon content, followed by groundnut shells, and then sugarcane bagasse. This implies that the coal have more quantity of carbon which can be burnt than that of groundnut shells and sugarcane bagasse. The calorific value of coal is higher than that of groundnut shells and sugarcane bagasse. This implies that during combustion, coal will produce more heat and energy, followed by sugarcane bagasse.

Table 2 The results of proximate analyses of raw materials

Parameters	**C**	**B**	**G**
MC(%)	3.63	4.77	9.12
AC (%)	16.55	2.51	3.47
VM (%)	49.97	74.71	68.28
FC (%)	29.85	18.01	19.13
CV(MJ/kg)	22.66	18.64	17.12

From Table 3, it is observed that the moisture content of 100% groundnut briquettes is higher than that of the 100% coal, 100% sugarcane bagasse and the bio-coal briquettes. From the results of the proximate analysis of the briquettes, it can be seen that the biomasses (sugarcane bagasse and groundnut shell) alone have higher moisture content than their respective bio-coal briquettes. This reduction in moisture content is caused by their addition into coal, which means coal helps to reduce the moisture content of the bio-coal briquettes.

Table 3 The results of proximate analyses of briquettes

Sample	**MC (%)**	**A C (%)**
B00	7.05	16.27
B10	7.20	18.55
B20	7.61	12.82
B30	7.83	11.32
B40	8.14	11.24
B50	8.21	11.10
B60	8.43	10.43
B100	8.57	5.57
G10	7.26	18.87
G20	7.65	12.91
G30	7.78	11.37
G40	8.14	11.23
G50	8.23	11.17
G60	8.44	11.03
G100	8.63	6.21

The ash content results in Table 3, shows that for the two types of bio-coal briquettes produced, the quantity of ash produced decreases as the quantity of biomass in the coal increases. This is because the biomasses have lower ash content than coal, resulting in the ash content reduction as biomass percentage increases. Groundnut shell-coal briquettes have higher ash content than sugarcane bagasse-coal briquettes. This is obvious since groundnut shells contain higher percentage of ash than sugarcane bagasse. The fibrous nature of the sugarcane bagasse also helps to burn it well. This is in agreement with [9] whom wrote that the more fibrous a biomass sample is, the more it burns well, producing more heat and energy, and less quantity of ash.

From the result of calorific value of briquettes in Figure 1, it was observed that briquettes prepared from 100% coal have a higher calorific value than those prepared using 100% sugarcane bagasse, 100% groundnut shell and their various combinations. It was also observed that for both bio-coal briquettes, as the percentage composition of biomass in the coal increases, and the coal percentage reduced, their calorific value also reduces. It was also observed that the calorific value of the sugarcane bagasse-coal briquettes is higher than that of the groundnut shell-coal briquette of the same coal percentage composition. This means during combustion, sugarcane bagasse-coal briquettes will release more heat and energy, than groundnut shell-coal briquettes coal of the same percentage coal composition.

It is observed from Figure 2, that the volume of water absorbed increases as the percentage of biomass in the coal increases. This is because the presence of biomass in the briquettes increases the number of pores (air spaces) where water molecules adhere to the samples. Therefore, as the percentage of biomass increases, more pores are created and porosity of the briquettes increases. The impact of the increase in porosity is more in sugarcane bagasse-coal briquettes than groundnut shell-coal briquettes. This is because of the fibrous nature of the sugarcane bagasse particles. Therefore, addition of biomass into coal briquettes increases their porosity: The volume of water absorbed in the 100% coal briquette was the lowest. This is as result of the tightly packed coal particles which resulted in relatively reduced number of pores (air spaces).

From Figure 3, it can be seen that coal briquettes have the highest ignition time, while sugarcane bagasse has the lowest ignition time. The figure also reveals that addition of biomass reduces the ignition time of the briquettes. This proves that the biomasses have shorter ignition time, and will ignite easily than coal. As the percentage of biomass increases, the ignition time decreases. It is also observed that sugarcane bagasse-coal briquettes have shorter ignition time than their corresponding groundnut shell-coal briquettes. This is because sugarcane bagasse has shorter ignition time than groundnut shell. The fibrous nature of sugarcane bagasse is likely to be the reason for this short ignition time while the presence of some mineral constituents (Al, Fe, etc) as reported by [8] might be responsible for the high ignition time of coal.

Figure 4, showed that biomass reduces the time required for the briquettes to burn a specific quantity of briquette (i.e. 1gram). The 100% coal briquette takes longest time, while 100% sugarcane bagasse takes the shortest time. The values obtained also reveals that groundnut shell-coal briquettes take longer time, then the corresponding sugarcane bagasse-coal briquettes. This is as a result of the low calorific value of the groundnut shell as compared with sugarcane bagasse. The other reason for this is because the sugarcane bagasse briquettes are more porous (because of the particle nature). Therefore, air passes through the briquettes making them to burn faster than the relatively fine textured groundnut shell which is less porous. It also shows that the lesser the time required for burning a specific quantity of briquette.

A combustion rate is one of the important characteristics to show the quality of briquettes, it is the amount of a material that undergoes combustion over a period of time. The briquettes have different compositions hence will have different combustion rate. Figure 5, shows the effect of different compositions on the combustion rate. As shown in the figure, combustion rate for both types of bio-coal briquette increases as the biomass composition increases. By comparison of these two types of bio-coal briquette, it is found that the sugarcane bagasse–coal briquettes have a higher combustion rate than its groundnut shell-coal counterparts.

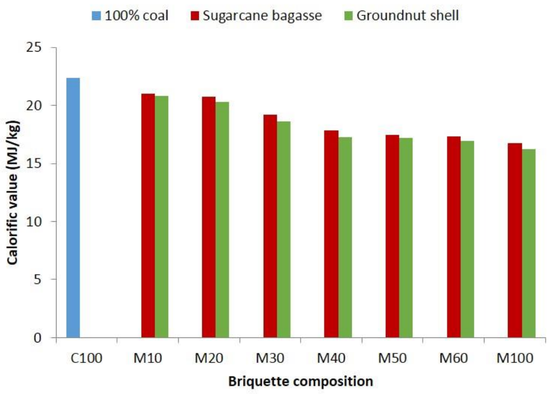

Figure 1 Results of calorific values of briquettes

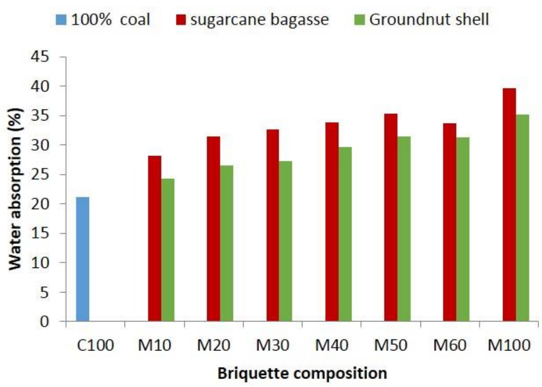

Figure 2 Results of water absorption of briquettes

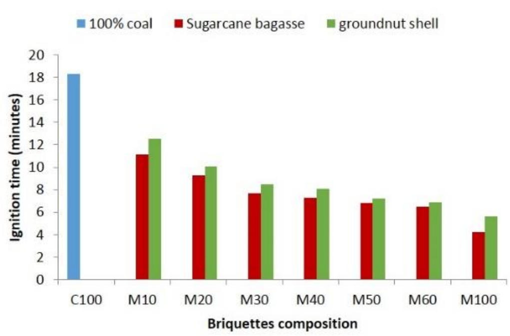

Figure 3 Results of ignition time of briquettes

As stated by [10], the biomass with fibrous structures usually facilitates the spread of fire or ember during combustion due to better air circulation through the air gap of briquette. This is responsible for the high combustion rate of sugarcane bagasse briquettes. This trend is similar with the graph which explains the relation between water absorption and briquette composition. This is because combustion rate relates closely with the porosity of briquettes.

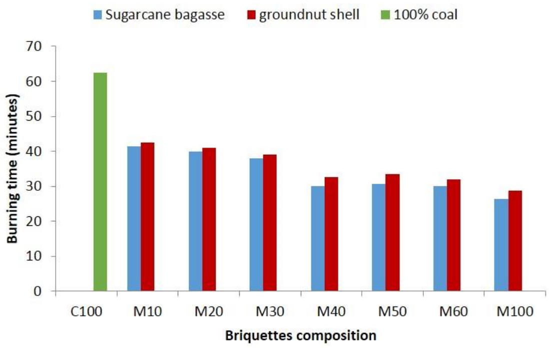

Figure 4 Results of burning time of briquettes

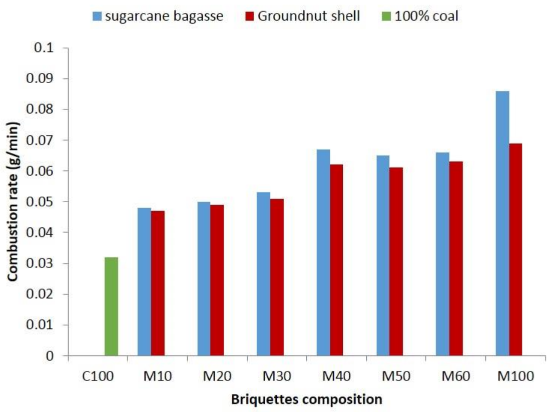

Figure 5 Results of combustion rate of briquettes

4. Conclusions

With the addition of biomass, bio-coal briquettes have better fuel properties and lower ignition temperature of 6.5 - 12.5 minutes than 18.3 minutes for coal. Therefore, bio-coal briquettes are easier to ignite. They can be successfully used for cooking as well as space heating in cold and mountainous regions. In addition, desulfurizing agent has captured the sulphur content in the coal. Thereby, reducing the harmful emissions coming from coal combustion in cooking, water heating, brick kilns and different industries can be checked by using bio-briquettes. Large amounts of low quality coal, lignite and biomass residues that are abound can be used more efficiently to produce bio-coal briquettes which can replace to some extent the fuel wood used in industrial boilers, kilns and cooking. In conclusion, from the results of these tests and analyses carried out, the following conclusions can be drawn sugarcane bagasse and groundnut shell meets the requirement in the production of bio-coal briquettes. The bio-coal briquette sample with 40% sugarcane bagasse gave the best combustible values when compared with the other bio-coal briquettes. The properties were improved with increase in sugarcane bagasse concentration up to 40%. But for industrial heating that requires a long simmering phase, bio-coal briquettes containing 10% bagasse may be preferred due to its high calorific value.

The chemical composition of the biomass samples contributes less to their burning properties since they contain few non-combustible cations such as Al, Fe, etc, but the particle nature contributes much to their burning properties. These biomasses enhance the burning properties of coal briquettes. Biomass increases porosity and porosity index, calorific value and burning efficiency, and reduces the ash content, cooking time, ignition time, exhaust gas and smoke emission of coal briquettes. Therefore, bio coal briquettes

5. References

[1] Tiwari C. Producing fuel briquettes from sugarcane waste. EWB-UK National Research & Education Journal 2011;220-550:39-45.

[2] Von Schirnding Y, Bruce N, Smith K, Ballard-Tremmer G, Ezzati M, Lvovschy K. Addressing the impact of household energy and indoor air pollution on the health of the poor: Implication for policy action and intervention measures. Washington: WHO; 2010.

[3] Kim H. Utilization of biomass for homeostasis engineering, binding and desulphurization characteristics of pulp black liquor in bio-coal briquettes. Toyohashi: Department of Ecological Engineering; 2003.

[4] Sengar SH, Mohod AG, Khandetod YP, Patil SS, Chendake AD. Performance of briquetting machine for briquette fuel. International Journal of Energy Engineering 2012;2(1):28-34.

[5] American Society for Testing and Materials. Annual book of ASTM standards, Section 5.50, Petroleum products, Lubricants and Fossil Fuels. West Conshohocken: American Society for Testing and Materials; 1992.

[6] Rotich S. Carbonization and briquetting of sawdust for use in domestic cookers [M.Sc. Thesis]. Nairobi: University of Nairobi; 1996.

[7] Faizal HM. Physical and combustion characteristics of densified palm biomass [M.Sc project]. Johor Bahru: Universiti Teknologi Malaysia; 2009.

[8] Maciejewska A, Veringa H, Sanders J, Peteve SD. Co-firing of biomass with coal: Constraints & Role of biomass pre-treatment. Institute for Energy; 2006.

[9] Moore W, Johnson D. Procedures for the chemical analysis of wood and wood products. Madison: U. S. Forest products Laboratory, Department of Agriculture; 1999.

[10] Yaman S, Sahan M, Haykiri-Acma H, Sesen K, Kucukbayrak S. Fuel briquettes from biomass-lignite blends. Fuel Processing Technology 2001;72:1-8.