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Research Note

Determination of the Bioenergy Potential of Melon Shell and Corn Cob Briquette

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P A P E R I N F O

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A B S T R A C T

In this work, research were carried out on properties of biocoal briquettes produced from Okaba coal in Nigeria, melon shell on one hand and corn cob on the other hand with a view to find out their effect on coal briquette. The research involves the production of briquettes from coal and the biomass at the following ratios of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0:100, coal to biomass, using cassava starch as binder and calcium hydroxide as desulphurizing agent. The briquettes were produced mechanically using a manual briquetting machine with pressure maintained at 5MPa. It was found that the burning rate and reduction in smoke emission revealed improvement with increase in biomass concentration. The findings also show that sulphur content in the biocoal briquette reduces with increase in the biomass. The biobriquette with 10% corn cob had the highest calorific value of 22.05 MJ/kg while the 60% melon shell composition had the least value of 21.14 MJ/kg, the 40% corn cob composition had the lowest burning time of 30.1seconds and high combustion rate of 0.076 g/min; while the 10% melon shell composition had the highest burning time and lowest combustion rate. The biocoal briquette sample with 40% corn cob gave the best combustible values, but for industrial heating that requires a long simmering phase, biobriquettes containing 10% corn cob may be preferred due to its high calorific value.

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INTRODUCTION

Global leaders in 1992 meet in Rio de Janeiro and formulated the central provisions of sustainable development of the future world. Since then, sustainable development was legitimized as the main long-term principle of the development of the global society. Coal combustion is known to release the highest levels of pollutants such as,, particulates and trace elements like mercury etc. Fears about environmental implications of continuous burning of coal for power and heat generation are being raised. Increased use of coal for energy generation will worsen global environmental problems unless cleaner and more efficient coal technologies are deployed. For this reason, it is imperative to find alternates for coal and fuel wood which will ensure that the issue of pollution from coal combustion and excessive use of fuel wood are minimized. Biobriquettes have been proved to have the utmost potential for use as suitable substitute to coal/wood fuel in domestic, industrial boiler and brick kiln for thermal application. Therefore, biobriquettes serve as the most effective method of combating deforestation in the countries where coal is cheap and readily available.

Biocoal briquette is a type of solid fuel prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent [1, 2]. Moreover the presence of sulphur fixation agent known as desulfurizing agent ensures that most of the sulphur content of the coal is fixed into the ash instead of being liberated into the atmosphere as sulphur (iv) dioxide [3]. Kwong et al. [4] have reported that during combustion, the co-combustion of the coal and the biomass gives a better combustion performance and reduces pollutant emission. Biocoal briquette has a favourably ignition, better thermal efficiency, emits less dust and soot. The ash of biocoal briquette has been shown to be effective for soil treatment and enrichment [5]. Raju et al. [6]

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have stated that preserving the forest resources by substituting fuel wood with biobriquette, along with the use of the ash from this briquette for soil treatment will compensate for fossil carbon emitted by the coal component of the briquette. Hence, biocoal briquette is considered to be a clean technology. Melon, botanically called *Cucumis* is a popular crops grown in every part of Nigeria. When processed melon is used as additive for cooking soup and oil is also extracted from it. Melon shell, a residue from melon is available in large quantities on farms and processing sites constituting a waste disposal problem. Therefore, attempt must be made in upgrading its usefulness with the aim of solving some environmental problems associated with its disposal. Melon shell in its natural form cannot be utilized as fuel economically since they are loose and of low density materials, which make them difficult to burn in a controlled and effective manner, hence they need for its densification. Densification and effect of binders and characterization of briquettes with different ratio of biomass have been previously investigated [7, 8].

Corn (maize) is an important food for many people in Africa, Asia and Latin America and is used in animal feeding in North America and some parts of the world. In sub-Saharan Africa, corn is a staple food for an estimated 50% of the population IITA[1] , and it remains the most important agricultural crop for over 70 million farm families worldwide. Corn is used as human food in the form of tortillas, porridge, popcorn and barbecues and as forage and silage for animals. It is also a good source of industrial products such as starch, vitamin, fiber, oil and ethanol.Cobs, leaves and stalks are important residues of corn processing and consumption. For every 1 kg of dry corn grains produced, about 0.15 kg of cobs, 0.22 kg of leaves and 0.50 kg of stalks are produced. Currently, these residues have a number of limited applications [9]. However, corn cob is still discarded in not very productive ways usually burnt which results in irreparable harm to environment, directly tied to air pollution. The main objective of this study therefore was to investigate the bioenergy potentials of melon shell and corn cob the heating properties of coal briquettes.

MATERIALS AND METHODS

Preparation of materials

Melon shell and corn cob are selected as raw materials because of their availability. Melon shell was collected from processing site in Ogbomoso, Oyo state Southwest of Nigeria while corn cob was collected from Tudunwada, Kano state Northwest of Nigeria. The coal was collected at the Okaba coal mine site in Kogi state North central of Nigeria. The samples were dried, pulverized with a mechanical grinder and sieved to pass through laboratory test sieve of 1 mm (for coal) and 4 mm (for melon shell and corn cob) respectively using the particle size analysis equipment consisting of sieve shaker and Tylers sieves

Proximate analysis

ASTM standards were used to determine the moisture content (MC), volatile matter (VM) and ash content (AC). The standard for each analysis are moisture content ASTM D3173, volatile matter ASTM D3175 and ash content ASTM D3174. ASTM D-3173 is a coal and gas standard, which is used to determine total moisture in briquette for this experiment. The analysis of total moisture is used to determine other properties such as volatile matter, ash content and fixed carbon. The sample of briquette with higher moisture content needs more heat for moisture vaporization.

ASTM D3175 is a standard test method for volatiles matter in the analysis sample of briquette. This test determines the percentage of gaseous products, exclusive of moisture vapor, in the analysis sample which are released under the specific conditions. The amount of volatiles matter determines the amount of smoke released during the combustion process. ASTM D3174 is a standard method used in this experiment for determining ash content in the briquette sample. Ash is non-combustible residue left after briquette sample is burnt. It represents the bulk mineral after carbon, oxygen, sulphur and water has been driven off during combustion. Ash obtained after combustion differs in composition from the constituents present in the original biomass material. Ash obtained from this testing method differs in amount if compared with ash produced in furnace operations and other firing systems because incineration conditions influence the chemistry and amount of ash. High ash content means high non-combustible residue. This would lead to reduction of amount of heat from a combustion process. Finally, fixed carbon (FC) is determined by deducting the summation of moisture content, volatiles matter and ash content from 100%. It is the carbon found in the material which is left after volatile materials are driven off. This value is different from the ultimate carbon content because some carbon is lost in hydrocarbons with the volatiles. The calorific value (CV) 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 Eschka method [10].

[1] International Institute of Tropical Agriculture, 2009

Preparation of the briquette samples

A manual hydraulic briquetting machine with moulds of 4 cm diameter was used. Briquettes of varied biocoal concentrations were produced by mixing the coal and biomass at various composition ratios by weight; (100: 0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, and 0:100). For each set of briquette, 5% 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 5MPa during the production. They briquettes were sun dried for 19 days before analysis. The composition of briquettes samples are summarized in Table 1.

TABLE 1. Composition of briquettes samples

Sample	Coal (%)	Biomass (%)
C100	100	0
MS10	90	10
MS20	80	20
MS30	70	30
MS40	60	40
MS50	50	50
MS60	40	60
MS100	0	100
CC10	90	10
CC20	80	20
CC30	70	30
CC40	60	40
CC50	50	50
CC60	40	60
CC100	0	100

Where C = Coal, MS = Melon shell , CC = Corn cob

Properties of briquettes

The important thermal properties of briquettes tested included their calorific value, volatile matter, ash, porosity index, ignition time, burning time and combustion rate. The determination of ash and moisture content involves the same procedure as that of raw biomass material.

Porosity Index: The porosity of the briquettes was determined based on the amount of water each sample was able to absorb. The porosity index was calculated as the ratio of the mass of water absorbed to the mass of the sample immersed in the water [11].

$$\text{Porosity Index} = \frac{\text{Mass of water absorped}}{\text{mass of sample}} \times 100 \quad (1)$$

Ignition time was determined by burning 200 g of briquettes in charcoal stoves. Since end-point of lighting was subjective and dependent on some judgment 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 in literature [6]

Combustion rate: Burning time is obtained by observing the mass changes recorded on mechanical balance and also by using stop watch. It is the time for the biomass combustion to be completed. With known amount of total burnt briquette and burning time, average combustion rate can be calculated using the following formula [12].

$$\text{Combustion Rate} = \frac{\text{Total Mass of Burnt Briquette}\,(\text{g})}{\text{Burning Time}\,(\text{min})} \quad (2)$$

RESULTS AND DISCUSSION

The proximate analyses results of the raw materials for the briquette studied are shown in Table 2. From the results, it shows that the coal sample had higher ash content (16.55% db), fixed carbon (29.85% db) and calorific value (22.66 MJ/kg) than the two biomass samples while melon shell had the highest moisture content (9.51db) and corn cob had the highest volatile matter (76.30% db). The higher calorific value of coal indicates that it will release more heat during combustion than the melon shell and corn cob, while the biomass will ignite more readily and burn relatively faster than the coal due to their higher volatile matter. Other results showed that the coal and corn cob had Total sulphur content higher than melon shell.

The results of the analyses briquettes are presented in Table 3 and Figures 1-5. The results of ash and sulphur showed that there content in the briquettes decrease with increase in biomass concentration (see Table3). Such decrease is expected since coal contains higher ash and sulphur than the biomass as observed from the results of the proximate analysis of the raw materials (see Table 2). By increasing the concentration of the biomass and correspondingly decreasing the concentration of coal would undoubtedly decrease the ash content of the composite, also note that the quantity of desulfurizer decreases with decrease in the coal content. The results of the sulphur content showed that 100% coal briquettes had the highest sulphur content (0.74%) with 100% melon shell been the lowest (0.35%) but with the briquetting of coal and biomass, increasing the amount of the sulphur fixing agent the sulphur content decreases.

The results of porosity of briquettes presented in Figure 1 revealed that the porosity of the briquettes increases with increase in the biomass concentration up to 40%. This could be as a result of its particle size been relatively bigger than that of coal; the fibrous nature of the biomass could also offer it the ability of increasing the pores in the briquette causing an increase in the weight of the sample immersed in water. The coal briquette had the lowest porosity value. This is because the particles were tightly packed together hence less volume of water was absorbed. Calorific value determines the energy content of a fuel. It is that property of biomass that depends on its chemical composition and moisture content. One of the important fuel properties is its calorific or heat value. The calorific value for the biocoal briquettes as shown on Figure 2 reveals that they can produce enough heat required for household cooking and small-scale industrial cottage applications. From the result, it was revealed that, as the quantity of biomass in the biocoal briquettes increases, and the quantity of coal decreases, their calorific value also changes. This means that biomass alters the calorific value of coal. Biocoal briquettes with 10% biomass had desired heating value 22.05 and 22.02 MJ/kg for corn cob and melon shell respectively, with 60% melon shell briquette having the least value of 21.42 MJ/kg. However, these energy values are sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. They also compare well with most biomass energy. For examples, groundnut shell briquette12600 kJ/kg [13], cowpea 14372.93 kJ/kg, and soybeans 12953 kJ/kg [14].

TABLE 2. The results of proximate analyses of raw materials

Parameters	Coal	MS	CC
Moisture content (%)	3.63	9.51	9.19
Ash content (%)	16	6.38	1.42
Volatile matter (%)	49.97	73.31	76.30
Fixed carbon (%)	29.85	10.08	12.76
Calorific value (MJ/kg)	22.66	20.64	21.89
Total sulphur content (%)	0.74	0.35	0.72

TABLE 3. Proximate analyses of biobriquette samples

Sample	AC%	VM%	SC%
C100	18.27	47.91	0.79
MS10	18.22	47.93	0.72
MS20	16.67	47.61	0.67
MS30	14.71	47.41	0.63
MS40	14.05	47.17	0.59
MS50	13.51	46.92	0.52
MS60	13.28	46.87	0.46
MS100	6.93	59.80	0.34
CC10	16.98	48.07	0.79
CC20	15.71	48.13	0.79
CC30	13.46	49.21	0.78
CC40	13.14	49.54	0.79
CC50	12.97	50.31	0.80
CC60	12.21	50.47	0.80
CC100	3.12	60.01	0.82

Note: MC = moisture content, AC = ash content and SC = sulphur content

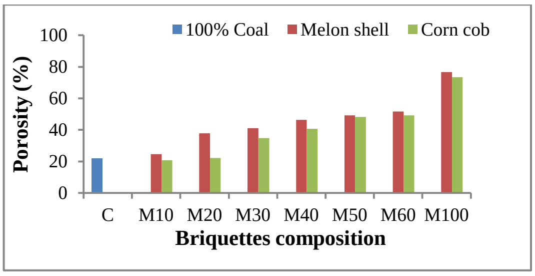

Figure 1. Porosity percentage of biobriquettes

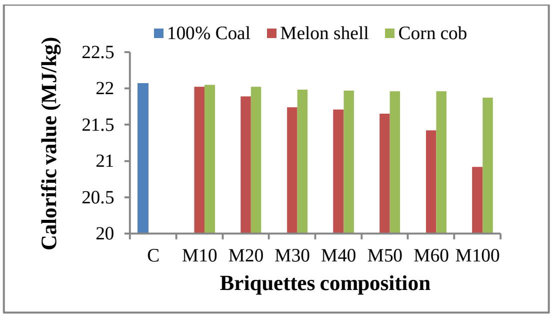

Figure 2. Calorific values of biobriquettes

From Figure 3, it can be seen that coal briquettes had the highest ignition time, while corn cob had the lowest ignition time. Results 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 corn cob-coal briquettes had shorter ignition time than their corresponding melon shell-coal briquettes. This is because corn cob had shorter ignition time than melon shell.

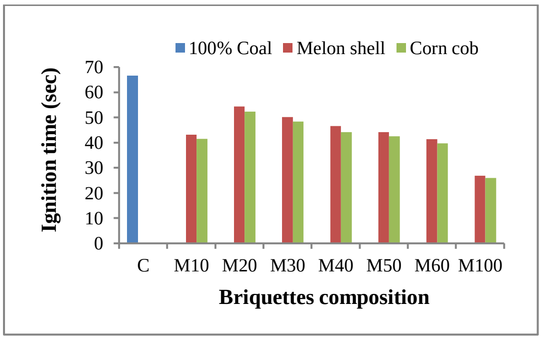

Figure 3. Ignition time of biobriquettes

Provision of sufficient heat for the time necessary is an important quality of any solid fuel. The results of burning time showed that the time required for each set of briquettes to burn an equal mass of briquette decreases with increase in the biomass concentration. A 100% coal took the longest time and 100% melon shell took the least time to burn as shown in Figure 4. However, the biocoal briquette containing 40% biomass have lower burning time than the 50 and 60% biomass is an indication that somewhere beyond 60% biomass concentration, burning time will eventually begin to decrease.

The combustion rate (how fast the fuel burns) is control by composition of the material. Biomass contains more volatile matter than the coal and more porous this allows for easy infiltration of oxygen and out flow of combustion products. Therefore, increasing the proportion of the biomass is expected to increase the combustion rate of the briquettes as indicated on Figure 5.

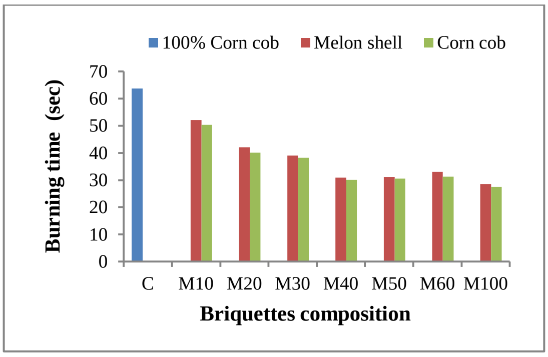

Figure 4. Burning time of biobriquettes

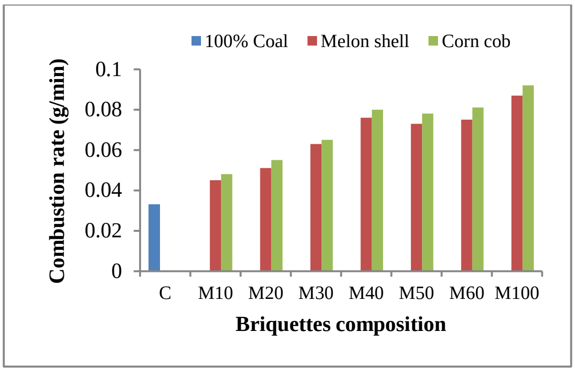

Figure 5. Combustion rate of biobriquettes

They biocoal briquettes are very efficient, providing sufficient heat as at time necessary, generating less smoke and gases (e.g.: sulphur) that are harmful to environment, generating less ash, as these have adverse effect during cooking. The biocoal briquette sample with 40% biomass gave the best combustible values when compared with the other biocoal briquettes. The properties were improved with increase in biomass concentration up to 40%. But for industrial heating that requires a long simmering phase, biocoal briquettes containing 10% biomass may be preferred due to its high calorific value.

CONCLUSIONS

They biocoal briquettes were very efficient, providing sufficient heat as at time necessary, generating less smoke and gases (e.g.: sulphur) that are harmful to environment, generating less ash, as these have adverse effect during cooking. The biocoal briquette sample with 40% biomass gave the best combustible values when compared with the other biocoal briquettes. The properties were improved with increase in biomass concentration up to 40%. But for industrial heating that requires a long simmering phase, biocoal briquettes containing 10% biomass may be preferred due to its high calorific value. Comparatively it can be concluded that though both melon shell and corn cob enhanced the properties of coal as demonstrated in this study; however, corn cob had a better attributes than other biomass.

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Persian Abstract

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چکیده

در این پژوهش تحقیق بر روی خواص ذغال قالبی بیولوژیکی تولید شده توسط واحد صنعتی ذغال اکابا که در نیجریه قرار دارد، انجام شد و تاثیر پوست هندوانه و چوب ذرت بر روی خواص ذغال قالبی بررسی شد. این پژوهش هم چنین شامل تولید ذغال قالبی از ذغال و بایومس با نسبت های ذغال سنگ به بایومس ۱۰۰ :۰، ۹۰ :۱۰، ۸۰ :۲۰، ۷۰ :۳۰، ۶۰ :۴۰، ۵۰ :۵۰، ۴۰ :۶۰ و ۰ :۱۰۰ می باشد که برای اینکار از نشاسته به عنوان عامل متصل کننده و از کلسیم هیدروکسید به عنوان عامل دی سولفوریله کننده (جدا کننده سولفور) استفاده شده است. تکه های ذغال به صورت مکانیکی و با استفاده از یک ماشین غالب زن مکانیکی که با فشار MPa ۵ کار می کند تولید می شوند. پژوهش انجام گرفته نشان داد که با افزایش غلظت بایومس سرعت احتراق افزایش یافته و دود منتشره کاهش می یابد. هم چنین یافته ها نشان می دهد که محتوی گوگرد تکه های ذغال با افزایش بایومس کاهش می یابد. تکه های ذغال حاوی ۱۰% چوب ذرت بیشینه ارزش گرمایی MJ/kg ۲۲/۰۵ و ذغال های حاوی ۶۰% پوست هندوانه ارزش گرمایی کمینه MJ/kg ۲۱/۱۴ را نشان دادند، هم چنین ذغال حاوی ۴۰ درصد چوب ذرت مقدار کمینه زمان احتراق به میزان ۳۰/۱ ثانیه و بیشینه سرعت احتراق را نشان داد در حالیکه ذغال حاوی ۱۰ % پوست هندوانه بیشینه زمان احتراق و کمینه سرعت احتراق را دارا بود. ذغال بیولوژیکی شامل ۴۰% چوب ذرت بیشترین مقدار احتراق پذیری را نشان داد اما برای فرآیندهای صنعتی که فاز طولانی مدت جوشاندن در آن مورد نیاز است، ذغال بیولوژیکی شامل ۱۰% چوب ذرت ترجیح داده می شود زیرا ارزش گرمایی آن بالاست.