# Enhancing the Properties of Coal Briquette Using Spear Grass (*Imperata Cylindrica*)

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**Abstract**

Studies have been carried out on utilizing agricultural wastes (spear grass) to enhance the properties of coal briquette. The proximate analysis of the plant material was carried out alongside with a sample of coal (sub-bituminous coal). Briquettes of different compositions were produced by blending the plant material with the coal at various concentrations: 0%, 10%, 20%, 30%, 40%, 50% and 100%, using cassava starch as a binder and calcium hydroxide ($Ca(OH)_2$) as desulfurizing agent. The properties of the briquettes were compared. It was found that the ignition, burning rate and reduction in smoke emission showed improvement with increase in biomass concentration. Compressive strength and cooking efficiency (water boiling time and specific fuel consumption) showed initial improvement and rendered to decrease with briquette containing 30% biomass.

**Keywords**

Agricultural wastes; Coal; Briquettes; Spear grass; Concentration

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## Introduction

Compaction of bulky combustible materials for fuel making purposes has been a technology widely used by many countries. There have been several researches carried out on production of fuel briquettes for both domestic cooking and industrial applications. One of the major driving forces behind these researches is the need to address the environmental consequences and health hazards associated with the use of solid fuels (such as fuel wood and coal) [1] and also an effective means of managing agro wastes. Among the common types of briquettes widely used in some countries are biomass briquettes, coal briquettes and charcoal briquettes, etc. However, more recently, it has been shown that blending coal and biomass (agro wastes) gives rise to a briquette with better combustion properties and pollutant emission compare to the conventional coal briquette. This type of briquette is known as bio-coal briquette.

Bio-coal briquette is a type of solid fuel prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent [2]. The high pressure involved in the process ensures that the coal and the biomass particles are sandwiched and adhere together, as a result do not separate during transportation, storage and combustion. During combustion, the co-combustion of the coal and the biomass gives a better combustion performance and reduces pollutant emission i.e. bio-coal briquette has a favourable ignition, better thermal efficiency, emits less dust and soot [3]. 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 be 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.

This technique has advantages over coal briquette in the sense that any grade of coal can be used without carbonization [4]. However, additional cost of carbonization of low grade coal before briquetting is saved. Furthermore, the presence of sulphur fixation agent otherwise 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 $SO_2$ [5]. This implies that, by this technology, the pollution problems associated with burning of coal is to a great extent taken care of.

Calcium hydroxide ($Ca(OH)_2$) and calcium oxide, ($CaO$), are common desulfurizing agent used for this purpose. For instance, when CaO is used, the reaction follows this equation [5]:

$$CaO_{(s)} + SO_{2(g)} + ½O_{2(g)} \longrightarrow CaSO_{4(s)}$$

The ash of bio-coal has been shown to be effective for soil treatment and enrichment [6]. However, preserving the forest resources by substituting fuel wood with bio-coal, 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. Therefore, bio-coal is considered to be a clean technology.

Nigeria has high potential for utilizing bio-coal technology as a measure to address its ecological problems associated with the rural household energy demands and as well, a means of managing agro wastes. This is because of large coal deposit in the country and numerous agro wastes generated annually during agricultural activities. Spear grass (*imperata cylindrica*) is among the agricultural wastes generated by farmers in a large quantity every year during farming activities. It is a noxious weed found abundantly in agricultural and non-agricultural fields especially in the forest/savannah transition zone where recurrent fire and farming activities prevent the natural vegetation from growing up to level that can shade out weeds [7]. Unlike leguminous crops, spear grass like other grasses of that kind does not decay readily when cleared. As a result, farmers prefer burning them off. By this act, the fertility of the soil is reduced and the environment polluted.

This research is aimed at investigating the properties of bio-coal briquettes as the concentration of biomass varies with hope of determining the optimum composition using sub-bituminous coal and also to compare the properties of bio-coal briquette with ordinary coal briquette.

## Material and Method

### *Sources and Preparation of Materials*

Spear grass (*Imperata cylindrica (L) Racauchel*) was collected from a farmland at Emene, Enugu East and Coal was sourced from Nigeria Coal Corporation Enugu, all in Enugu State. The samples were dried, pulverized with a mechanical grinder and sieved to pass through laboratory test sieve of 4mm (for spear grass) and 1mm (for coal) respectively. Cassava starch and $Ca(OH)_2$ (95.5% purity) were bought from Ogbete Main Market, Enugu State.

### *Proximate Analysis of the Materials*

The moisture content, ash content, volatile matter and the fixed carbon of the plant material and coal were determined in line with the ASTM D-3173 specification [8, 9]. The calorific value was determined using Oxygen Bomb Calorimeter of model-XRIA. The total sulphur content was analyzed using Eschka method [8].

### *Preparation of the Briquette Samples*

The briquettes were produced in the laboratory of National Centre for Energy Research and Development, University of Nigeria Nsukka, Enugu State. A manual hydraulic briquetting machine with six cylindrical moulds of 3.9cm diameter each was used. Briquettes of varied biomass concentrations were produced by blending the biomass at various concentrations; 0%, 10%, 20%, 30%, 40%, 50%, and 100% with the coal. For each set of briquette, 5% $Ca(OH)_2$ based on the mass of coal was used as the desulfurizing agent and 10% cassava starch based on the entire mass of the mixture was used as the binder. The pressure was maintained at 5MPa throughout the production. The samples were weighed using digital weighing balance.

### *Analyses of the Briquette Samples*

Ash content, moisture content, and calorific value of the briquettes were analyzed with the same procedure as in the proximate analysis of the raw materials stated earlier. The compressive strength was tested using universal crushing machine 781/2001/23.

Determination of porosity index: The following procedure was carried out to compare the porosity of the briquettes. Each briquette sample was immersed in a separate beaker containing a known volume of water for 20 minutes after which they seemed to have absorbed water to their full capacity. The porosity of the briquette was determined based on the amount of water each was able to absorb [10]. The porosity index was calculated as the ratio of the mass of water absorbed to the mass of the sample immersed in the water.

Determination of the ignition time: Each briquette sample was ignited at the base with a cigarette lighter in a drought free place. The time required for the flame to ignite the briquette was recorded as the ignition time using stop watch.

Water boiling test: This was carried out to compare the cooking efficiency of the briquettes. It measured the time taken for each set of briquettes to boil an equal volume of water under similar conditions.100g of each briquette sample was used to boil 100cm$^3$ of water using small stainless cups and domestic briquettes stoves [11]. During this test, other fuel properties of the briquettes like burning rate, specific fuel consumption were determined [12]. Also, the level of smoke evolution was observed. Burning rate is the ratio of the mass of the fuel (in grams) burned to the total time (in minute) taken. The specific fuel consumption indicates the ratio of the mass of fuel consumed (in grams) to the quantity of boiling water (in litres).

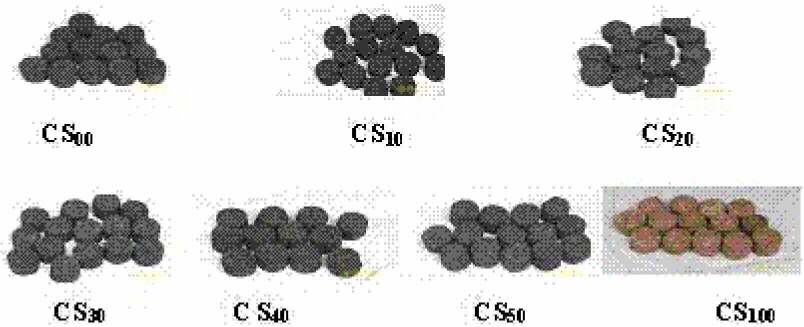


***Plate 1.*** *The briquette samples ($CS_{00}$, $CS_{10}$, $CS_{20}$, $CS_{30}$, $CS_{40}$, $CS_{50}$, and $CS_{100}$ are briquettes containing 0%, 10%, 20%, 30%, 40%, 50% and 100% spear grass)*

## Results and Discussion

The results of the analyses are presented in Figures 1-8 and Table 1.The results of moisture content did not show much variation but it appears that the moisture content of the briquettes tends to increase slightly with increase in biomass concentration as shown in Figure 1. Also, just as expected, there is a progressive decrease in the ash content of the briquettes as the concentration of the biomass increases, Figure 1. Since coal contains higher ash than the biomass as seen from the results of the proximate analysis of the materials shown in Table 1, decreasing the concentration of coal and correspondingly increasing the concentration of biomass would certainly decrease the ash content of the composite coupled that the quantity of $Ca(OH)_2$ (non-combustible material) used as the desulfurizer decreases with decrease in the coal content.

**Table 1.** The proximate analysis of coal and spear grass

| Parameter | Coal | Spear grass |
|---|---|---|
| Moisture content (%) | 7.64 | 9.26 |
| Ash content (%) | 18.27 | 6.18 |
| Volatile matter (%) | 43.44 | 69.10 |
| Fixed carbon (%) | 30.69 | 15.46 |
| Calorific value (KJ/g) | 20.64 | 14.66 |
| Total sulphur content (%) | 0.82 | 0.26 |

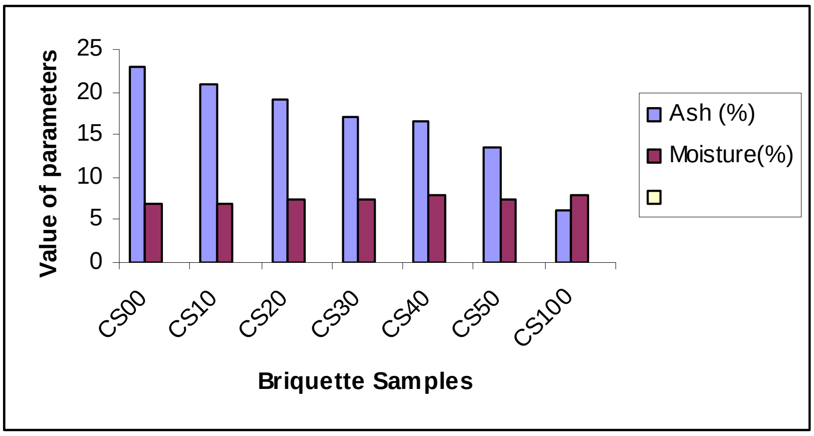


***Figure 1.** Results of moisture and ash contents*

Furthermore, the results of porosity index shown in Figure 2 revealed that the porosity of the briquettes increases with increase in the biomass concentration. Biomass has higher inherent porosity due to its fibrous nature coupled that after pulverization, its particle sizes were relatively bigger than that of coal. These two factors offered it the ability of increasing the number of pores in the briquette. The sample containing 0% biomass, $CS_{00}$, has the least porosity index, 0.560 while the one comprising 100% biomass, $CS_{100}$, has the highest porosity, 3.520. Low porosity will hinder mass transfer during combustion due to fewer spaces for mass diffusion. The higher the porosity, the higher the rate of infiltration of oxidant and out flow of combustion/pyrolysis products during combustion and the higher will be the burning rate of the briquette.

Again, from the results of compressive strength (i.e. the force required to crush the briquette), it is revealed that compressive strength showed initial improvement with increase in the concentration of biomass and reached maximum with bio-coal containing 30% biomass ($4.77N/mm^2$) before declining, Figure 3. Briquette containing 0% biomass, $CS_{00}$, has the least compressive strength, $0.92N/mm^2$. The increase in the compressive strength is attributed to the fact that, biomass because of its nature, has the ability to reduce the brittleness of the briquette but this effect reached saturation point at biomass concentration of 30%. A briquette with a higher compressive strength is safer for storage and transportation.

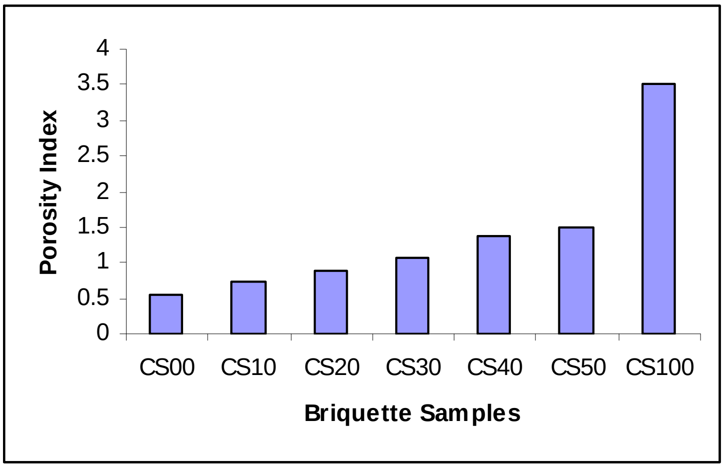


***Figure 2.*** *Results of porosity index*

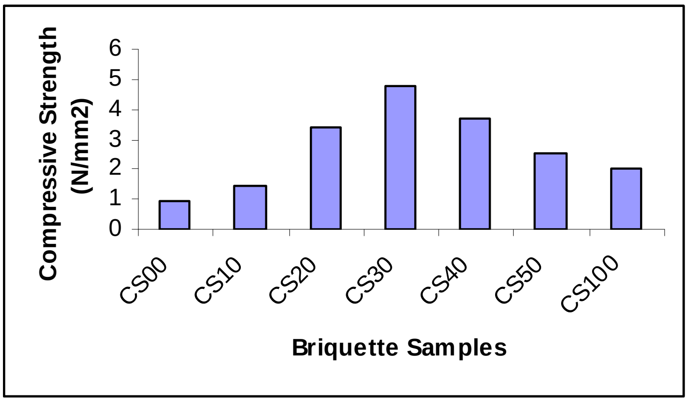


***Figure 3.*** *Results of compressive strength*

The results of ignition time in Figure 4 showed that the ignition time of the briquettes increases with increase in the biomass concentration. This can be explained from the fact that the biomass contains more volatile matter than the coal as shown in Table 1. Therefore, increasing its concentration in the briquette will definitely increase the ignitibility of the briquette.

Figures 5-8 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 the briquette to boil an equal volume of water decreases with increase in the biomass concentration up to 50%, Figure 5.

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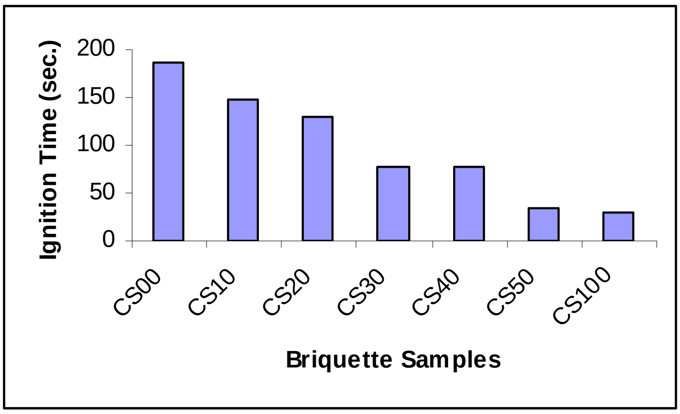


***Figure 4.*** *Results of ignition time*

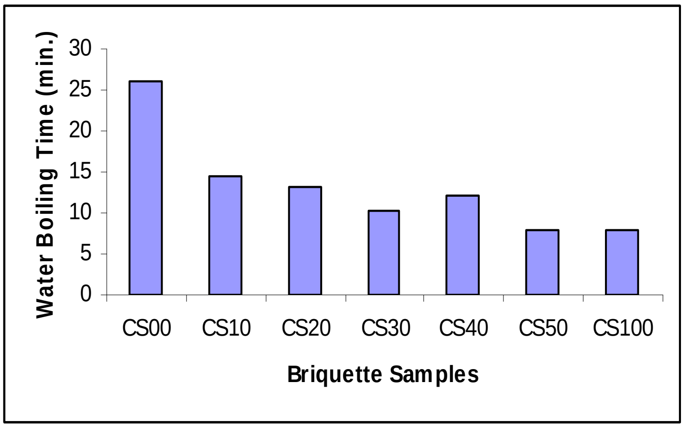


***Figure 5.*** *Results of water boiling time*

However, beyond this concentration, the water boiling time will eventually begin to drop as indicated by the fact that briquette comprising 100% biomass ($CS_{100}$) took longer time to boil water, 8.01min., than the one containing 50% biomass ($CS_{50}$), 8.00min. These results can be explained considering two factors; burning rate and calorific value. Owing to the fact that biomass increases the porosity of the briquette and as well its volatile component, increasing its concentration increases the burning rate of the briquettes as shown in Figure 6.

This increasing burning rate explains why water boiling time decreases with increase in biomass concentration. However, the fact that the briquette sample $SC_{50}$ boiled water faster than $CS_{100}$ even when the latter burns faster than the former is because two of them have close burning rate but with a substantial different heating values. $SC_{50}$ has calorific value of 18.09KJ/g and $CS_{100}$ 16.13KJ/g. This substantial difference in the calorific value offset the effect of burning rate. This equally explains why sample $CS_{30}$ (20.92KJ/g) was able to boil water faster than $CS_{40}$ (19.53KJ/g).

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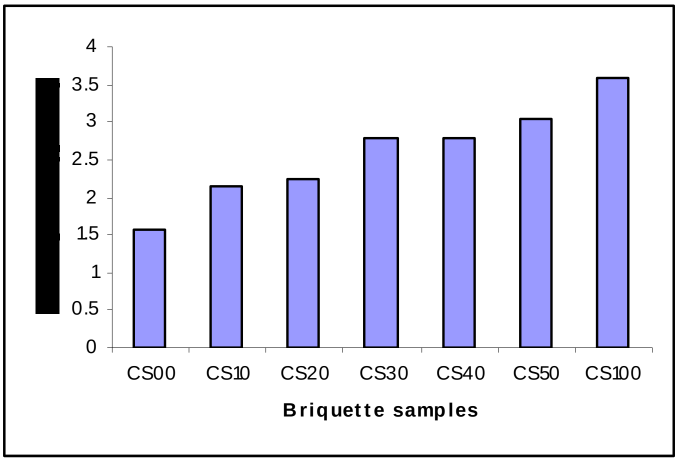


***Figure 6.*** *Results of burning rate*

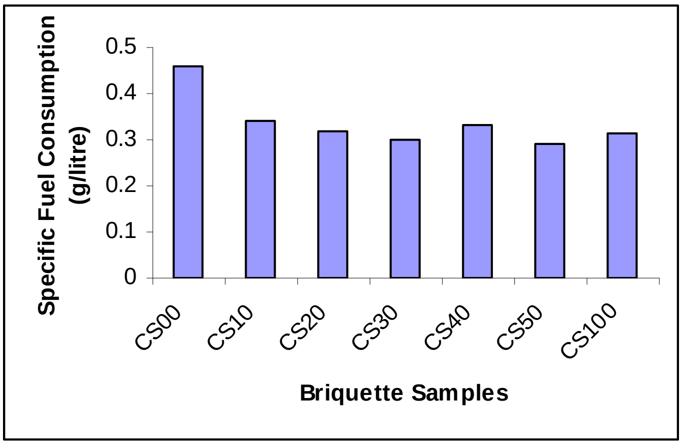


***Figure 7.*** *Results of specific fuel consumption*

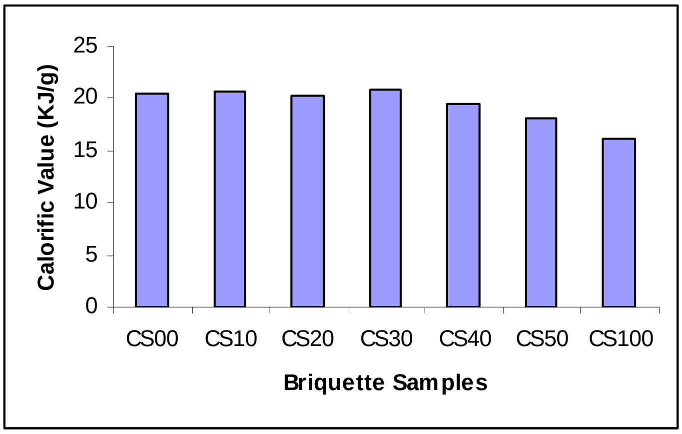


***Figure 8.*** *Results of calorific value*

Finally, comparing the water boiling time and the specific fuel consumption, Figure 7, it can be seen that the cooking efficiency of the briquettes improved with increase in biomass

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concentration up to 50% but beyond this biomass concentration, the cooking efficiency will eventually start to drop. The briquette sample $CS_{50}$ is considered to be most efficient followed by $CS_{30}$. They took shorter time to boil water and lesser quantity of than were consumed during the boiling phase-cold start.

## Conclusion

Since the quality of any fuel briquette depends on its ability to provide sufficient heat at the necessary time, to ignite easily without any danger, generate less dust (ash) as this will constitute nuisance during cooking. It is clear that bio-coal technique is an effective means of improving the properties of coal briquette using agricultural waste (spear grass). For normal domestic cooking, bio-coal briquette containing 50% was shown to be most efficient. But for industrial heating or cooking that requires a long simmering phase, bio-coal containing 30% biomass may be preferred due to its high calorific value.

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