

# Performance of Composite Sawdust Briquette Fuel in a Biomass Stove under Simulated Condition

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## Abstract

*In this research, composite sawdust briquette fuel were produced and utilized in order to simulate cooking. Within a time frame, a known amount of water was boiled to simulate cooking by burning composite sawdust briquettes in a biomass stove. The composite sawdust briquettes were produced using sawdust and charred palm kernel in percentage compositions of 50:50, 60:40, 70:30, 80:20 and 90:10, respectively. Starch gel was used as a binder. The boiling of water using the fuels was characterized into 3 namely the intermediate phase (initial boiling), high power phase (15 min after the initial boiling) and the low power phases (30 min after the high power phase). From the experiment, in respective of the percentage composition of the composite sawdust briquettes, the Percentage Heat Utilized (PHU) was found to increase from the intermediate phase through the low power phase. For other parameters like the Specific Fuel Consumption (SFC), Power Output and Burning Rate respectively, there was a sharp decrease from the intermediate phase through the low power phase.*

**Keywords:** *Intermediate phase, high power phase, low power phase, Percentage Heat Utilized, Specific Fuel Consumption, Power Output and Burning Rate.*

## Introduction

Renewable energy sources are been sought for domestic cooking in developing countries due to the fact that their non-renewable counterpart such as kerosene, LPG, etc., are not keeping up with peoples' demand. Also the high cost of non-renewable energy sources has made people to start deviating to the use of renewable energy sources for domestic cooking. The use of biomass fuel such as composite sawdust briquette has been proposed to be a good source of renewable energy for domestic cooking (Kuti and Adegoke 2008). This is due to the fact that sawdust, i.e., the chief raw material in the production of composite sawdust briquette is readily available in large quantities as wastes in majority of the wood processing industries. It has been proposed that the conversion of sawdust wastes through briquetting process will go along way reducing waste disposal problems in majority of the

wood processing industries. Furthermore deforestation which promotes pollution will be drastically reduced if the use of sawdust waste is enhanced.

Before promoting the use of any new type of fuel, it is expedient to have good understanding of its performance. The performance of any solid biomass fuel such as sawdust briquette can be evaluated effectively when it is combusted in a specially made biomass stove. Cook stoves which are internally lined with local clay of low thermal conductivity have been found to be more effective and efficient to burn sawdust briquettes in order to evaluate their performances (Adegoke *et al.* 1999; Adegoke 2002; Adegoke and Mohammed 2002). The reasons for carrying out performance tests are: to determine the comparative performance of fuel to the stove, to determine the potential and expected fuel savings offered by a stove and to obtain the data necessary for optimization of fuel in relation to its stove.

Stewart (1987) highlighted the three main

types of tests that can be carried out on solid fuel. These are field test, water boiling test (WBT) and controlled cooking test (CCT). These tests are meant to reveal quantitative and qualitative information about the fuel performance.

The WBT involves the simulation of standard cooking procedures that measures the fuel consumed and time required for simulated cooking. It is a well-developed test that measures the time taken by a given quantity of fuel to heat and boil a given weight or volume of water (Kuti 2003). Scientists or field workers, at the initial assessment and development stage, usually carry out WBT in a laboratory or a field station. It can be used for assessment of stove design and optimizations of stoves when a solid fuel is made to combust. In some cases where cooking tests or kitchen field tests cannot be undertaken, water boiling test can be used to give a rough approximation of relative fuel savings.

In this paper performance of composite sawdust briquette fuel in a biomass stove under simulated cooking conditions is carried out. The WBT is implemented to simulate cooking conditions when composite sawdust briquette is utilized.

## Methodology

Sawdust and charred palm kernel shell were collected from the dumping site, screened and converted into composite briquettes using a manually – operated hydraulic briquette making machine in percentage mixing ratios of 50:50, 60:40, 70:30, 80:20 and 90:10 (sawdust to charred palm kernel). Charred palm kernel shell of size 1.18mm was utilized. Starch gel was used as a binder. The composite sawdust briquette was left in the sun to dry properly. The calorific value, i.e., net energy content of the composite briquette, was determined using the Gallenamp ballistic bomb calorimeter. In conducting the water boiling tests, the following procedures were taken: Dry weights of experiment materials like pot and stove were taken and recorded. The pot was filled with an initial known weight of water and the same weight was maintained throughout the course of the experiment. The standard quantity of

water inside the pot is preferably two-thirds of the full pot capacity. The initial water temperature was taken about 1cm above the bottom of the pot. The initial weight of the sawdust briquette was taken before it was stacked in a round form inside the internally lined stove. A minimum of twelve pieces of briquettes was utilized during the course of an experiment. The fuel was ignited by adding a very small amount of kerosene to speed up the rate of initial combustion. One gram of kerosene is assumed to be about 2g of briquettes (Stewart 1987). The kerosene used can be considered as fuel consumed, however the energy involved is so small that it may be safely ignored in the calculation. Although kindling the fuel would have been preferable since it would not permit the use of another fuel apart from briquettes, the rate of initial combustion will not be faster. The lighting time was recorded. The fuel burns with fire during combustion. Immediately the fire went off, it started glowing with a red-hot flame having been fanned. The pot containing the known weight of water was placed on the stove with burning fuel. The temperature of the water was taken at 5 min-interval until boiling took place. The boiling time during the intermediate phase was recorded. The *intermediate phase* is that point when boiling is first noticed. During the intermediate phase, the weight of fuel remaining inside the stove at this point was recorded. Likewise, the weight of water remaining in the pot was recorded. The pot of water was left back on the stove burning with fuel and the whole process continued for the next 15 min. with rapid boiling. At the end of 15 min., the weights of fuel and water remaining were taken. This is the *high power phase*. The high power phase is that point when rapid boiling is achieved. Furthermore, the process continues for the next 30 min. and it was observed that the power is reduced to the lowest level needed to keep the water simmering. This is the *low power phase*. At the end of the low power phase, the water and fuel weight remaining were recorded. The stack temperature of fuel was taken. The weight of charcoal remaining was recorded. The values obtained during the experiment were used for analysis. The experiment was carried out in an

open space where the wind is under a calm condition. The open space was used since cooking using solid fuel such as composite sawdust briquette is usually done outside. Data were collected and analyzed.

The following parameters can be obtained during the water-boiling test:

**(i) Percentage Heat Utilized**

This is otherwise known as thermal efficiency or energy:

$$P.H.U = \frac{m_w C_p (T_b - T_0) + m_c L}{m_f E_f} \times 100 \% \quad (1)$$

The numerator gives the net heat supplied to the water while the denominator gives the net heat liberated by the fuel.

**(ii) Power Output**

This determines the available amount of energy released from the fuel in a given time:

$$P = \frac{m_f \times E_f}{t} \quad (2)$$

**(iii) Specific Fuel Consumption**

This is defined as the amount of solid fuel equivalent used in achieving a defined task divided by the weight of the task. It can be expressed as:

$$S.F.C = \frac{m_f}{m_w} \quad (3)$$

**(iv) Burning Rate**

This determines the rate at which a certain mass of fuel is combusted in air. It can be evaluated as:

$$B.R = \frac{m_f}{t} \quad (4)$$

where:

PHU = Percentage Heat Utilized;

P = Power Output;

S.F.C = Specific Fuel Consumption;

B.R= Burning Rate;

$m_w$  = Mass of water in the pot (kg);

$C_p$  = Specific heat of water (kJ/kgK);

$T_o$  = Initial Temperature of water (K);

$T_b$  = Boiling Temperature of the water (K);

$m_c$  = Mass of water evaporated (kg);

$L$  = Latent heat of evaporation (kg);

$m_f$  = mass of fuel burnt (kg);

$E_f$  = Calorific value of the fuel (kJ/kg);

$m_w$  = mass of water (kg);

$t$  = time taken to burn fuel (secs).

The Calorific values,  $E_f$ , for the different fuel composition have been determined in previous work (Kuti 2007).

**Results and Discussion**

From the experiment, as shown in Fig, 1 the percentage heat utilized in respective of the composition of the composite sawdust briquette increased from the intermediate phase (i.e. initial boiling phase) through the high power phase (15 min after initial boiling) to the low power phase (30 min after high power phase)

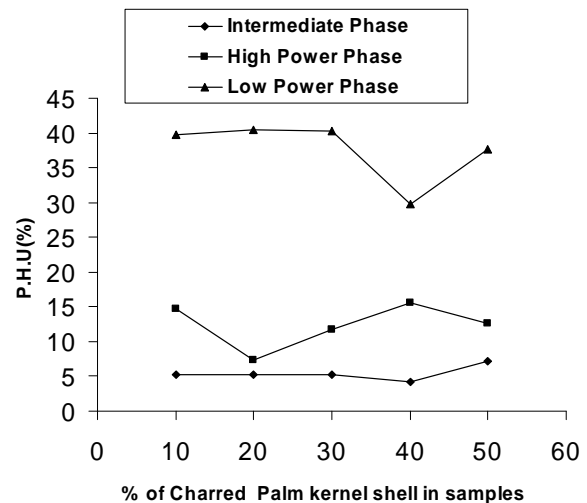


Fig. 1. Variation of percentage heat utilized with % of charred palm kernel shell in samples.

Fig. 1 indicates that with time, the net heat supplied to the water increases from the intermediate phase through the low power phase while the net heat liberated by the fuel decreases considerably from the intermediate phase through the low power phase. This shows that much energy was liberated by the fuel in bringing the water to the initial boiling (intermediate phase). When boiling was achieved less energy from the fuel is needed to keep the water boiling rapidly (high power phase) until it reaches a point where the boiling effect is reduced to simmering effect (low power phase).

On the other hand, Fig. 2 shows that in

respective of the percentage composition of the fuel, the power output decreased from the intermediate phase through the low power phase.

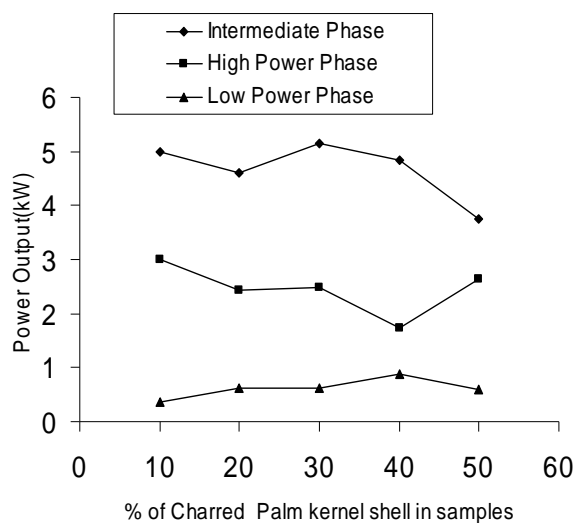


Fig. 2. Variation of power output with % of charred palm kernel shell in samples.

From Fig.2 it could be inferred that energy released from the fuel, i.e. heat in a given time decreases from the intermediate phase through the low power phase. This further confirms the result in Fig. 1.

Furthermore, the variation of the specific fuel consumption (SFC) with the composition of the composite briquette as shown in Fig. 3 decreases from the intermediate phase through the low power phase.

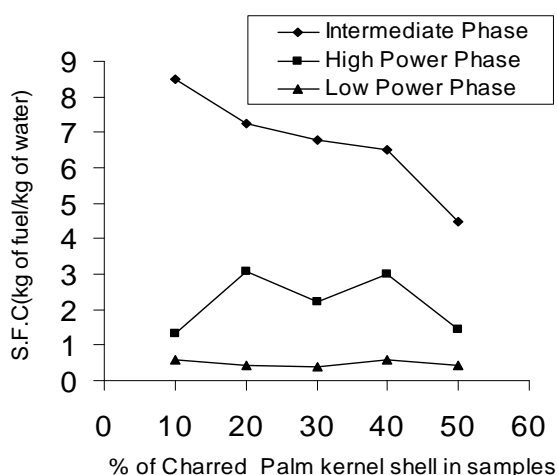


Fig. 3. Variation of specific fuel consumption with % of charred palm kernel shell in samples.

From Fig. 3, more mass of fuel is required to bring water into boiling during the

intermediate phase. The amount of fuel reduces from the intermediate phase until the low power phase is achieved.

Fig. 4 indicates that in respective of the composition of the fuel, the burning rate of the fuel decrease from the intermediate phase through the low power phase.

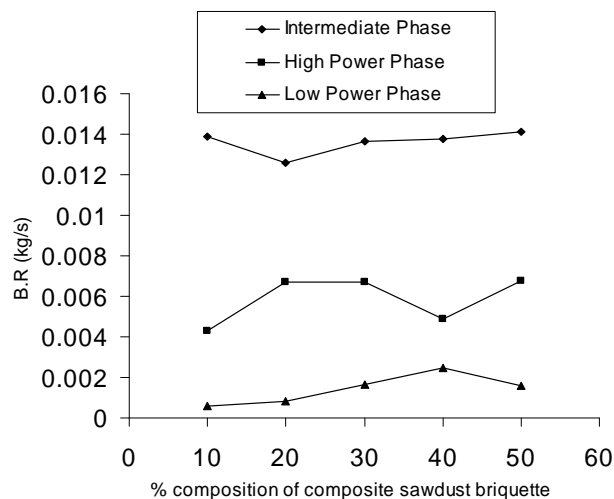


Fig. 4. Variation of burning rate with % of charred palm kernel shell in samples.

From Fig. 4 it can be inferred that the fuel burnt at a faster rate during the intermediate phase as compared to other phases.

### Conclusions

In this research performance of composite sawdust briquette fuel in a biomass stove under simulated conditions was carried using the water boiling test. The results obtained in this study are summarized as follows:

- The PHU in respective of the composition of the briquette increased from the intermediate phase through the low power phase.
- The power output decreases from the intermediate phase through the low power phase in spite of the variation in the composition of the fuel.
- In case of the SFC there was a decrease from the intermediate phase through the low power phase in respective of the of the fuel composition.
- Lastly, the burning rate reduces considerably from the intermediate phase

through the low power phase in respective of the composition of the fuel.

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