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Development of Electrically Aerated Stove for Pyrolyzed Briquettes

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Authors' contributions

This work was carried out in collaboration among all authors. Author OKF initiated and wrote the first draft of the manuscript. Authors MBU, OCA, Author UUE, DOA and DOO provided all the necessary supports for this research work. All authors approved the final manuscript.

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ABSTRACT

In this study, an electrically aerated stove was developed using locally available materials. The performance of the stove was evaluated by utilizing briquettes produced from pyrolyzed jatropha shell and *Eucalyptus camadulensis* wood shavings. Thermal parameters such as thermal efficiency, power output, specific fuel consumption and burning rate were determined. The mean values obtained for the thermal efficiency, power output, specific fuel consumption and burning rate were 7.62 %, 1685 J/s, 0.2377 g/g, 330.90 g/hr respectively. The performance of the briquette stove was considered to not be suboptimal. The thermal efficiency can further be improved by proper insulation and adequate utilization of the heat generated in the combustion chamber.

Keywords: Briquette; stove; burning rate and thermal efficiency.

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NOMENCLATURES

Ef = *Calorific value of the fuel (kJ/kg)*
PHU = *Percentage Heat Utilized (%)*
P = *Power Output (J/s)*
S.F.C = *Specific Fuel Consumption (kg/kg)*
B.R = *Burning Rate (g/h)*
mw = *Mass of water in the pot (kg)*
Cp = *Specific heat of water (kJ/kgK)*
To = *Initial Temperature of water (K)*
Tb = *Boiling Temperature of the water (K)*
mc = *Mass of water evaporated (kg)*
L = *Latent heat of evaporation (kg)*
mf = *mass of fuel burnt (kg)*
t = *time taken (h)*

1. INTRODUCTION

Energy is indispensable for survival of human race. It is applied in diverse areas of life. The demand for energy keeps increasing with exponential growth in the world population. The implication of rapid increase in energy consumption can be felt in global warming, resulting from emission of greenhouse gas. The European Commission [1] proffered improvement in efficient utilization of energy in order to achieve the goal in scaling down greenhouse gas emissions by 80–95% by 2050 compared to 1990 levels. However, the emission of greenhouse gas could be further reduced by adoption appropriate technology in the use of undesirable biomass such as forest and agricultural wastes as renewable energy source. Biomass has always been a veritable source of energy for mankind from time immemorial. Putun et al. [2] reported that biomass contributes around 10–14% of the world's energy supply. It is believed to be major source of energy in most developing countries [3]. It has been reported that efficient utilization of fuel wood is much more eco-friendly than the use of conventional fuels like kerosene and liquefied petroleum gas (LPG) which are not accessible in some developing countries [4]. The gaseous emission from biomass could be reduced through the process of pyrolysis and the solid particle made usable by conversion to bigger solid fuel through briquetting. Briquetting refers to densification or compression of loose particles of biomass such wood shaving, shell, pods, leaves to mention but a few, together into a larger, more compact form, with or without the use of a binder [5]. Briquettes are suitable for both industrial and domestic use as source of energy because the gaseous emission from combusted briquette is easily neutralized by vegetations [4]. Briquette stove provides domestic means to utilize undesirable biomass such as forest and agricultural wastes. However, stoves of this nature have been developed by some researchers [4,6,7,8]. One of the deficiencies of previously developed stoves is absence of regulator or control, which is necessary in increasing or reducing the flame intensity. This is very important in cooking. This is because heat requirement for various food materials differs, hence the need for an effective device to regulate the heat produced by the stove. The research was targeted at finding ways of reducing deforestation and providing an alternative to kerosine stove and Liquefy Natural Gas (LNG) which are not readily available and affordable to large percentage of Nigerian population. In this study, an electrically aerated briquette stove with a regulator was developed.

2. MATERIALS AND METHODS

2.1 Design and Construction of a Briquette Stove

The design of the briquette stove was based on some considerations which were factored in. These include the engineering properties of the briquette, ease of operation of the stove, safety/operational health hazard, hygiene/operational cleanliness, simplicity of design, durability, and affordability [9,10]. The design of briquette stove was based on some engineering properties of the briquette. The stove was designed having the thermal properties and stability of materials of construction in mind so as to meet up with the required standard. The briquette stove was fabricated in the department of Agricultural and Bio-Environmental Engineering using locally available materials while the standards and requirements were not compromised. The design drawings of the briquette stove are shown in Figs. 1 and 2.

2.2 Performance Evaluation of the Briquette Stove

2.2.1 Percentage heat utilized

This is otherwise known as thermal efficiency or energy. This was evaluated using equation 1 [8].

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

2.2.2 Power output

This determines the available amount of energy released from the fuel in a given time. This was computed using equation 2 as shown below [8].

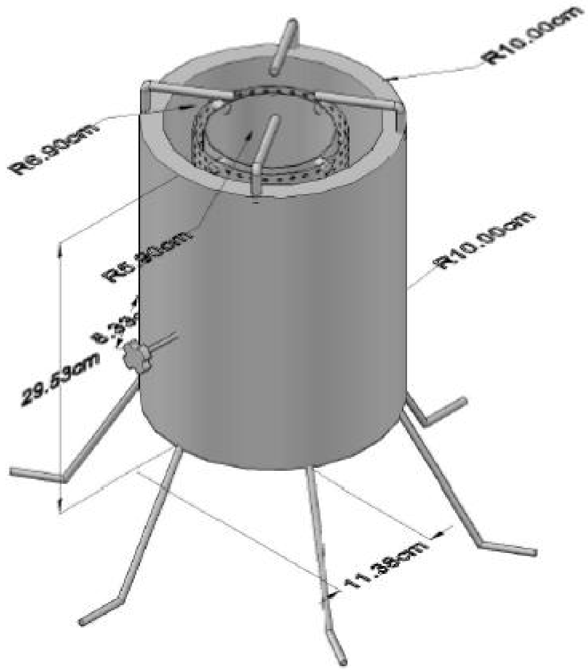

Fig. 1. Isometric view of the briquette stove

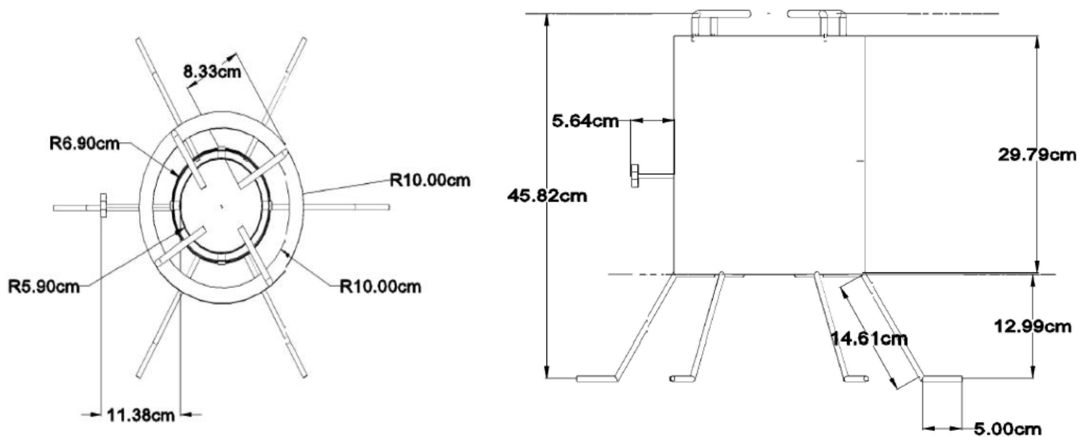

Fig. 2. Orthographic view of the briquette stove

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

2.2.3 Specific fuel consumption

This is defined as the amount of solid fuel used in achieving a defined task divided by the weight of the task. This was evaluated using equation 3 [8].

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

2.2.4 Burning rate

This determines the rate at which a certain mass of fuel is combusted in air. This was evaluated by applying equation 4 [8].

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

3. RESULTS AND DISCUSSION

3.1 Description of the Briquette Stove

The electrically aerated stove has some improvement over the stoves reported by other researchers [4,6,7,8]. This is as a result of some of the modification carried out on the stove; some components were incorporated to the stove. These components include fan, battery, charger and heat regulator. The features of the stove allows for easy replication, since the materials of construction are locally available. The compactness of the stove makes space occupied to be much lesser compared to other biomass stove [4,7]. The components of the briquette stove are as follow:

3.1.1 Regulator lever

This is the component of the stove which controls the exposure of the briquette to air during combustion. This component is also helpful in putting out fire from the stove. It aids the movement the combustion chamber longitudinally. The regulator lever enhances proper utilization of the briquette during combustion; this is unlike other biomass stoves which do not have regulators [4,6,11].

3.1.2 Fans

This component supply air to the combustion chamber. It aids the combustion of the briquette. The fan was designed in such a way that its speed can be easily controlled. The stove comprises of two axial fans which are powered by a 12 volts battery. The fans are adjacently located to the combustion chamber [12].

3.1.3 Air tunnel

This serves as a passage for air generated from the fan to the combustion chamber. The component is very important in conservation of the biomass during combustion.

3.2 Performance of the Briquette Stove

The performance of the briquette stove was evaluated based on thermal efficiency, power output, specific fuel utilized and burning rate. The results obtained for the performance of the stove are shown below:

3.2.1 Percentage heat utilized

This is otherwise known as thermal efficiency or energy. The maximum and minimum values obtained for the thermal efficiency of the stove were 13.23 and 4.41 % respectively while the mean value was 7.61 % as shown in Table 1. Kuti [8] reported a range of 5 – 40% while Panwar [4] reported 22 %. The range reported for the percentage heat utilized falls within the values obtained by other researchers. The low average value obtained could be as result of the inadequate insulation of the stove. Fig. 3 also shows the variation of thermal efficiency of the stove with the jatropha-eucalyptus proportions. The thermal efficiency followed a decreasing trend with jatropha-eucalyptus proportion. The latter is an indication that the higher the eucalyptus in the proportion of the mix, the greater the thermal efficiency of the stove.

3.2.2 Power output

This is the energy expended per unit time. The minimum and maximum values obtained for the power output of the stove were 845 and 2997 J/s respectively while the mean value was 1685 J/s as shown in Table 1. Kuti [8] reported a range of 800 J/s – 5300 J/s for power output. The value obtained for the power output falls within range reported by other researchers. The power output is dependent on the calorific value of the biomass used to evaluate the performance of the stove.

3.2.3 Specific fuel consumption

This is the quantity of briquette consumed in heating one kilogram of specific quantity of a material from a particular temperature to another. The maximum and minimum values obtained for the specific fuel consumption of the stove were 0.28 and 0.2 kg/kg respectively while the mean value was 0.24 kg/kg as shown in Table 1. The specific fuel consumption was found to increase with increase in jatropha-eucalyptus proportion as shown in Fig. 4. This is an indication that more jatropha proportion in the admixture would lead to higher specific fuel consumption. Kuti [8] also reported a specific fuel consumption of 0.4 – 8.5 kg/kg, which is in agreement with the range obtained for the stove. The specific fuel consumption depends on the nature of the cooked food materials.

Table 1. Performance of the stove using Jatropha-cum-eucalyptus briquette

Parameter	Minimum	Maximum	Mean	Std. Dev.
Percentage Heat Utilized (%)	4.41	13.23	7.617	2.661
Power Output (J/s)	845	2997	1685	645.4
Specific Fuel Consumption (kg/kg)	0.2	0.28	0.2377	0.02127
Burning Rate (kg/hr)	201.6	411.4	330.9	55.46

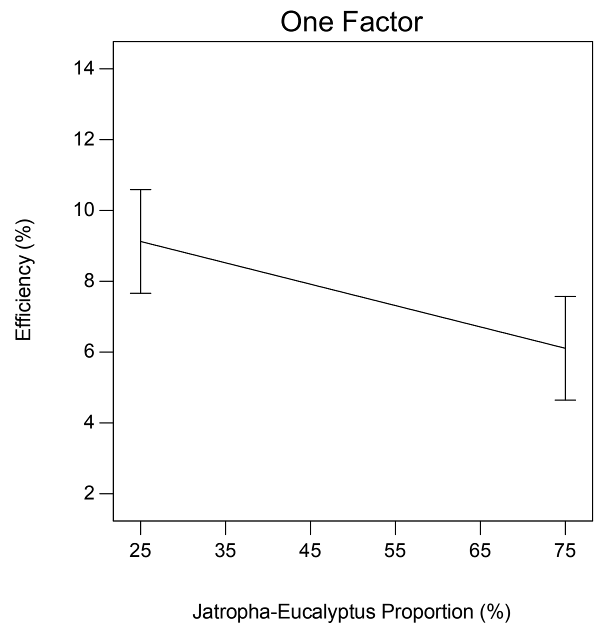

Fig. 3. Variation of thermal efficiency with jatropha-eucalyptus proportion

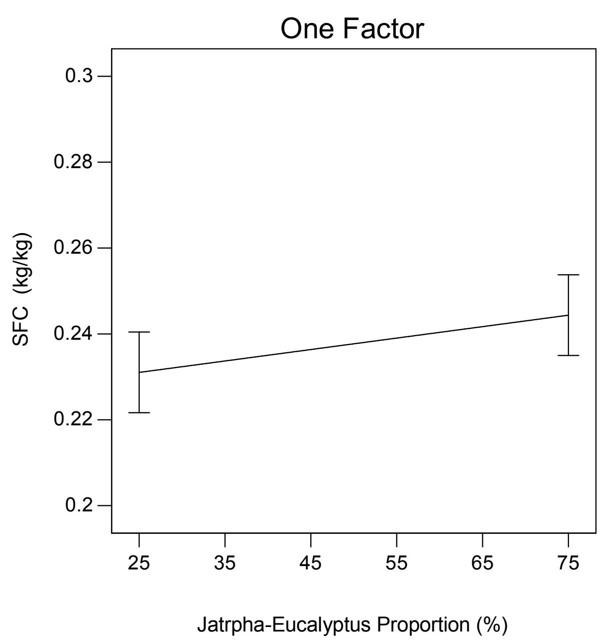

Fig. 4. Variation of specific fuel consumption with jatropha-eucalyptus proportion

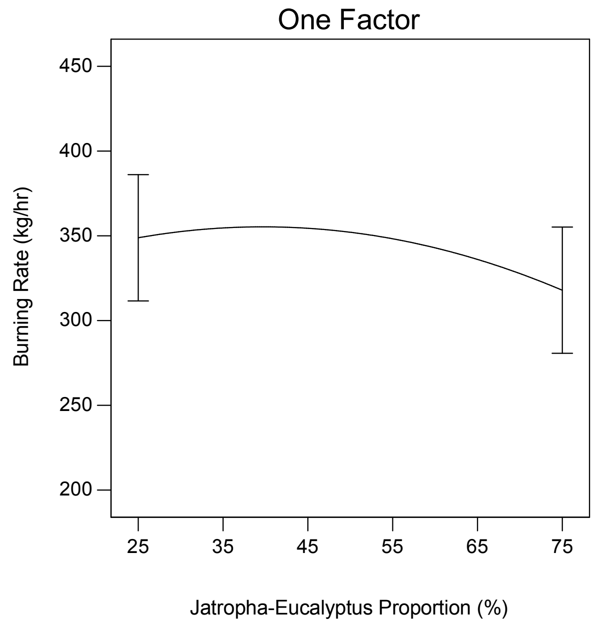

Fig. 5. Variation of burning rate with jatropha-eucalyptus proportion

3.2.4 Burning rate

This is the quantity of briquette consumed within a specific period of time. The maximum and minimum values obtained for the burning rate of the briquette during combustion were 411.4 and 201.6g/h respectively while the mean value was 330.90 g/h as shown in Table 1. The burning rate was found to decrease with increase in jatropha-eucalyptus proportion as shown in Fig. 5. This is an indication that greater quantity of eucalyptus proportion in the admixture would lead to higher burning rate.

4. CONCLUSION

An electrically aerated briquette stove was developed. The performance of the briquette stove was evaluated using briquettes produced from admixture of pyrolyzed jatropha shell and eucalyptus wood shaving. This was evaluated based on thermal efficiency, power output, specific fuel utilized and burning rate. The briquette stove had maximum and minimum values of 13.23 and 4.41 % respectively while the mean value was 7.61 % for the thermal efficiency. The maximum and minimum values obtained for the power output of the stove were 2997 and 845 J/s respectively while the mean value was 1685 J/s; the maximum and minimum values obtained for the specific fuel consumption of the stove were 0.28 and 0.20 kg/kg respectively while the mean value was 0.24 kg/kg and the maximum and minimum values obtained for the burning rate of the briquette during combustion were 411.4 and 201.6 g/h respectively while the mean value was 330.90 g/h. The briquette stove was adjudged to perform satisfactorily.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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