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Comparative study of the heating capacity of biogas and conventional cooking gas

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Abstract

A comparative study of the heating capacity of biogas and conventional cooking gas was carried out using a biogas stove was constructed from a 500 x 500 Ansun camping gas burner and one inch angle bar metal. The lumen of the gas supply jet was increased with a 3.5mm drill bit. The heating capacity of the biogas stove and conventional camping gas was done by heating 1000cm^3 of waster for 4 minutes, taking the temperature readings at 20s interval. The mean temperature rise of water heated, for 4 minutes, using biogas stove was 27.8^{o}C, giving an average of 0.12^{o}C rise per second. This compared favorably with that of the conventional Ansun 500 x 500 camping gas with an average of 0.13^{o}C rise in temperature per second. Statistical analysis using Mann-Whitney U test ($P<0.05$), indicate no significant difference between the heating capacity of the biogas stove and that of the camping gas. Performance evaluation of the biogas stove depict the stove was operating at a power rating of 486.5W. Comparing this with the estimated energy content of biogas feed, the efficiency of the stove was estimated to be 38.4%. This was based on the assumption that the methane content of the biogas was 45%. This efficiency assessment is the best the stove can obtain as higher methane content will mean a reduction in the present efficiency estimate.

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I. INTRODUCTION

The search for an alternative source of energy has enjoyed a tremendous number of research efforts in recent years. Many developing countries like Nigeria are still faced with energy problem especially in the rural environment were wood and kerosene is still being used. Biogas as a source of energy is popular in countries like India, China and Nepal. Amidst the large volume of waste being generated in the Nigeria, biogas is yet to be incorporated in the Nations energy generation mechanism. In Nigeria, as at 2001, the estimate of waste generated by cattle, poultry and piggery was put at 1.3, 6.4, and 5.2 million metric tons daily, respectively. These have an estimated gas generation value of 3.27, 0.01, and 0.21 million cubic meters of biogas respectively (Itodo, et al 1994). As at 2007, animal and agricultural wastes in Nigeria stood at 0.781 and 0.256 million tons per day respectively (Sambo, 2007). Ogwueleka, (2009) posited that from animal waste alone, Nigeria can generate 4.75 x 10^9 MJ per annum. This which is expected to rise depict that large proportion of the country’s energy mix can be sourced from biogas. It has also been reported that an average Nigerian generates about 0.48kg of municipal solid waste daily (Ugwuh, 2009). Ovueni (2010) projected the municipal solid waste generation in Nigeria to reach 58 million tons daily by 2050. In spite of this great potential in energy generation, Nigeria has not being able to harness this alternative source of energy adequately. This may be attributed to the numerous varieties of energy sources in the country.

Biogas is a methane-rich gas that is produced from the anaerobic digestion of organic materials. It is a colorless blue burning gas that can be used for cooking, heating and lighting. It has a heating value of 22MJ/m3 (Itodo, Agyo and Yusuf, 2007). It is odorless and can be obtained from various feedstock such as cattle dung, poultry and piggery wastes. Typically a kilogram of cow dung yields about 0.09m3 of biogas per day (Sasse, 1988). The quality of biogas (its methane content) depends on production factors such as the carbon-to-nitrogen ratio of the feedstock, pH of the slurry from which the gas is produced, retention time of the slurry in the digester and the loading rate of the slurry into the digester. Other factors include temperature, total solids content of the feedstock and the presence of materials toxic to the anaerobes (Itodo et al, 2007).

The main influencing factors in using biogas as a combustible gas are gas/air mixing rate, flame speed, ignition temperature and gas pressure. Compared to liquefied petroleum gas, biogas needs less air per cubic meter for combustion (Sasse, Kellner and Kimaro 1991). The gas jet needs to be larger in diameter than that of the LPG gas stove when using biogas. About 5.7 litres of air are required for total combustion of 1 litre of biogas, while for butane it is 30.9 litres and for propane 23.8 litres (Sasse et al, 1991). Efficiency of a stove could be categorized as burning efficiency and overall efficiency. Burning efficiency of a stove accounts for the capacity of that stove in terms of combustion of fuel. In other words ability of the stove to change the energy from fuel to heat energy is related with burning efficiency. The ability of the stove to change the energy from fuel into the energy gained by the specimen such as water, rice. milk etc is termed as overall efficiency of the stove (CES/IOE, 2001).

The use of biogas for cooking and heating begins with an efficient stove. This research work was a comparative study of the heating capacity of a constructed biogas stove and an Asun 500 x 500 camping gas stove.

Materials and Method

Construction of biogas stove

The stove frame and stand was constructed using a one inch angle bar metal. The angle bar was formed into a rectangular frame of length 30cm, breadth 25cm, and height 15cm.

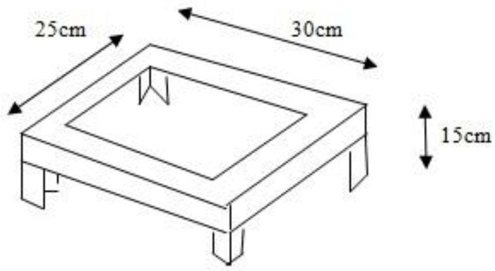

Figure 1: schematic diagram of the biogas stove frame work

A 500 x 500 Asun gas burner was used for uniformity of burner. The valve nipple of the Ansun camping gas model used in this construction was removed and the diameter of the lumen of the gas supply jet was increased using a 3.5mm drill bit. This increased the volume of biogas entering the burner at the same time reducing the amount of air mix to make for an efficient burning of the biogas. The burner was then screwed back without the valve nipple. A 4cm length of a one inch pipe was soldered to the base of the gas inlet pipe of the gas valve unit using oxygen acetylene flame, and the other open end blocked with metal sheet (1.2mm). To this end was attached (by tack-welding) 15cmm of the 3/8 inches pipe bent into an "L" shape. The shorter part (5cm) attached to the one inch pipe at the center of its base. This served as gas supply pipe to the burner.

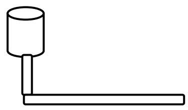

Figure 2; schematic diagram of the gas supply pipe

The gas burner and the pipe were the fixed to the original Asun 500 x 500 metal stove head which was then tack welded to the biogas stove frame.

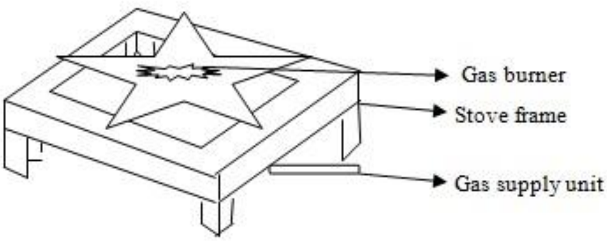

Figure 3: Schematic diagram of biogas stove

Powering the Biogas Stove

The biogas stove was powered with biogas from the storage tank by applying pressure into the tank through a flush tank.

The pressure (P) at which biogas flowed into the stove is equal to the pressure of water in the on the base of the tank ();

$P = \frac{\rho \pi r^2 hg}{\pi r^2}$

Where $\rho = density\ of\ water$ = 1000kgm^{-3}

r= radius of flush tank = 0.0797m

$g = acceleration\ due\ to\ gravity = 10ms^{-2}$

P = ρhg = 1000 x 0.5 x 10 = 5000N/m^2

Comparing the heating capacity of biogas stove and conventional camping gas (Ansun 500 x 500 burner)

This was done by calculating the heat transferred to 1000cm^3 of water for 4 minutes, recording the temperature readings from a digital thermometer, at 20 seconds interval. Duplicate records were taken for both biogas stove and the camping gas, and the mean temperature rise for both recorded. Length of the flame was regulated to 4cm from the burner to the base of the flask holding the water for both cookers (CES/IOE, 2001).

Performance Evaluation of Biogas Stove

This was determined by estimating the efficiency of the biogas gas stove.

Efficiency = P_o/P_i

Where P_o = power produced by the stove (output)

P_i = power put into the stove (input)

Power of the stove was be determined by estimating the rate of energy transfer to water.

P = Energy expended/time taken = $mc(\theta 2 - \theta 1)/t$ (Itodo et al, 2007).

Result and Discussion

Table 1: temperature readings taking at 20s interval, using the biogas stove to heat 1000cm^3 of water For 4 minutes

Time(s)	$\theta 1$(Biogas stove)	$\theta 2$(Camping gas)
0	0.0±0.0	0.0±0.0
20	0.75± 0.07	0.95±0.21
40	2.4± 0.85	2.6±0.85
60	4.45± 0.64	4.75±1.63
80	5.85± 0.62	7.45±0.92
100	8.85± 2.76	10.2±1.7
120	11.5± 2.12	12.9±0.28
140	13.9± 2.47	16.95±0.07
160	15.4± 3.25	19.1±0.99
180	18.5± 3.54	21.8±1.84
200	21.65±3.32	24.35±1.91
220	24.85±2.62	27.6±1.98
240	27.80±3.11	30.6±3.39

$\theta 1$and $\theta 2$ are the mean temperature rise of the duplicate determination for biogas stove and camping gas ± standard deviation

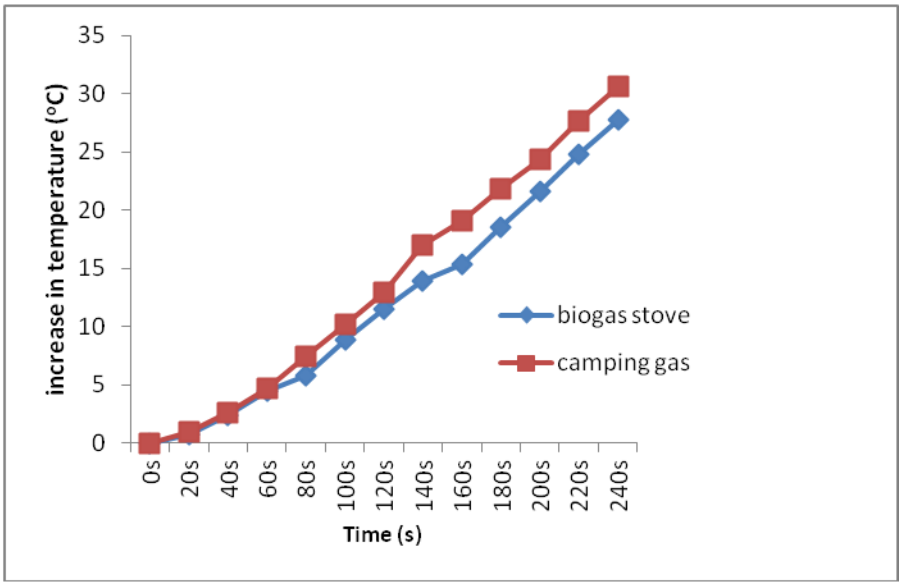

Figure 4: Plot of temperature increase for biogas stove and camping gas against time

Discussion

Mean temperature rise of water taken for the biogas stove and the Ansun camping gas is shown in table 1. The mean temperature rise of 1000cm^3 of water heated, for 4 minutes, using biogas stove was 27.8^{o}C, giving an average of 0.12^{o}C rise per second. This compares favorably with that of the conventional Ansun 500 x 500 camping gas with an average of 0.13^{o}C rise in temperature per second (table 1). The plot of temperature rise against time, (figure 4) depicts a correlation between the heating capacity of the constructed biogas stove and the camping gas. Statistical analysis using Mann-Whitney *U* test ($P<0.05$), indicate no significant difference between the heating capacity of the biogas stove and that of the camping gas. Nominal combustion efficiency of biogas and LPG has been reported to be 99.4 and 97.7 respectively (Joshi. Ramussen and Khalil, 1998). Performance evaluation of the biogas stove depict the stove was operating at a power rating of 486.5W. Comparing this with the estimated energy content of biogas feed, the efficiency of the stove was estimated to be 38.4%. This was based on the assumption that the methane content of the biogas was 45%. This efficiency assessment is consistent with assessment of Tata Energy Research Institute **(**TERI**),** on efficiency of different types of stoves which estimated that of biogas stove to be 45% and LPG 60% (CES/IOE, 2001). It is important to note that the low efficiency rating is not unconnected to the fact that overall efficiency of a stove depends upon different conditions such as temperature, pressure, wind speed, specific heat capacity of the vessel, bottom and overall shape of vessel, weight of vessel, size of vessel and amount of specimen (CES/IOE, 2001). The

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