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Production of biogas and greenhouse implication of its combustion device

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ABSTRACT

Biogas was produced using cow dung and poultry droppings as substrates and its green house effect during combustion was examined. The biogas plant was operated using these substrates (cattle dung and poultry droppings) as feedstock in the ratio of 1 part of dung and dropping to 2 parts of water at a retention time of 30 days. A total of 1.197m^3 of biogas was produced from cow dung biomass within a period of 30 days. Average daily production was 0.04m^3/day from an average of 1.167Kg of dung. Peak gas production was observed at day 17 ***with*** *production of 0.075m^3 of biogas. Total gas produced using poultry droppings as substrate was 1.659m^3 equivalent to 0.06m^3/day from an average of 1.167Kg of Poultry droppings. Peak gas volume of 0.092m^3 was observed at day 20. The results show that Poultry droppings has higher gas yield than cow dung. Furthermore, flue gas analysis was carried out to establish the emissions of the burners. The results show that solid biomass fuels are typically burned with substantial production of PIC (products of incomplete combustion). As a result, the emissions of CO_2 and PIC per unit delivered energy are considerably greater in the biomass burners.*

Key words: Biogas, Burner, Greenhouse, Cow dung, Poultry droppings.

INTRODUCTION

Biogas is a versatile gas used for cooking and lighting. Biogas is a relatively clean gaseous fuel produced mainly from cattle dung and other animal waste in anaerobic digesters. It typically consists of about 60% methane, 30% CO_2 and 2% H_2 with traces of ammonia, nitrogen, and hydrogen sulfide. Widespread dissemination of biogas plants began in 1981 through the National Project on Biogas development [1]. Since several animals are needed to supply for each biogas plant, biogas stoves are mainly found in rural areas where, overall, somewhat more than 1% have such devices [1]. Biogas does not contribute to increase in atmospheric carbon dioxide concentration because it comes from an organic source with a short carbon cycle and is the green solution in the devolopment of sustainable fuel [2].

Household stoves, although individually small, are numerous and thus have the potential to contribute significantly to inventories of greenhouse gases (GHG), particularly in those many developing countries where household use is a significant fraction of total fuel use. In addition, the simple stoves in common use in such countries do not obtain high combustion efficiency, thereby emitting a substantial amount of fuel carbon as products of incomplete combustion (PIC) - such as carbon monoxide (CO), methane (CH_4), and total non-methane organic compounds (TNMOC) - as well as carbon dioxide (CO_2). This is true for fossil fuels, such as coal and kerosene, but is particularly important for unprocessed biomass fuels (animal dung, crop residues, and wood), which make up the bulk of household fuel use in developing countries. [1]

Many greenhouse analyses of human fuel use assume that renewably harvested biomass fuels do not contribute to global warming, i.e., have no global warming commitment (GWC), because the released carbon is entirely recycled through photosynthesis in growing biomass that replaces the burned biomass. Even under renewable harvesting, however, the gases released as PIC contribute to global warming because of higher radioactive forcing per carbon atom than CO_2 [3]. Thus, such fuels have the potential to produce net GWC even when grown renewably.

It is estimated that biomass combustion contributes as much as 20-50 percent of global GHG emissions [4,5]. Though the major fraction of the emissions is from large-scale open combustion associated with permanent deforestation, savannah fires, and crop residues, combustion in small-scale devices such as cook stoves and space-heating stoves also releases a significant amount of GHG. A more accurate estimation of emissions from biomass combustion would require an inventory for GHG from different types of biomass combustion as well as better estimates of amount of biomass burnt.

A study of the biogas production potential of paper waste (PW-A) and its blend with cow dung (PW: CD) in the ratio 1:1 was investigated [6]. The two variants were charged into 50*l* metal prototype bio digesters in water to waste ratio 3:1. They were subjected to anaerobic digestion under a 45 day retention period and mesophilic temperature range of 26^0C - 43^0C. Results obtained showed that PW had a cumulative gas yield of 6.23 ±0.07dm^3/kg of slurry with the flash point on the 2nd day even though gas production reduced drastically while the flammability discontinued and resumed after 14 days. Blending increased the cumulative gas yield to 9.34±0.11 dm^3/kg. Slurry represents more than 50% increase. The onset of gas flammability took place on the 6^{th} day and was sustained throughout the retention period. The emissions of non-CO_2 greenhouse gases from small-scale combustion of biomass are not well characterized [7], but are known to be different from open large-scale combustion, such as forest and savannah burning, which have been the focus of more research.

Therefore, this paper aims to investigate the potential of producing biogas from cow dung and poultry droppings and evaluating its combustion’s greenhouse emissions. It is also an objective of this paper to provide the means by which people can improve their measure of health when utilizing biogas for domestic use. The specific objectives are;

i. Production of biogas.
ii. Analyzing the produced biogas.
iii. Analyzing greenhouse emissions.

MATERIALS AND METHODS

A 0.1m^3 Batch Operated Portable Biogas Digester was designed and constructed for loading the substrates i.e. cow dung and Poultry droppings [8], also, a combustion device (burner) was designed and developed [9]. A conventional liquefied natural gas (LNG) burner was used alongside the prototype burner and the Modified burner for this study. This was done to establish suitability of these stoves to the combustion of the generated biogas.

Brief description of all the stoves are as follows, LNG stoves are commonly used by urban families which are of two types, those with single and those with double burners, for household cooking. The stove used in the present study is a double-burner model. The main components of the developed biogas stove (prototype and modified) are the injector, the air/gas mixing chamber and the burner. The injector tapers into a nozzle of about 0.01mm^2 which enters into the air/gas mixing chamber. The air/gas mixing chamber opens into the burner head. The burner head has 207 and 32 jets, each of 5mm and 2mm for prototype and modified stoves respectively from which the gas can be ignited.

The biogas produced was analyzed qualitatively using gas chromatography. Biogas produced was evacuated from the gasholder bottles (cylinders) and taken to the laboratory for analysis. The biogas was passed through solutions of lead acetate and potassium hydroxide. Hydrogen sulphide (H_2S) and carbon dioxide (CO_2) were absorbed respectively, leaving methane (CH_4) gas to be collected at the exit.

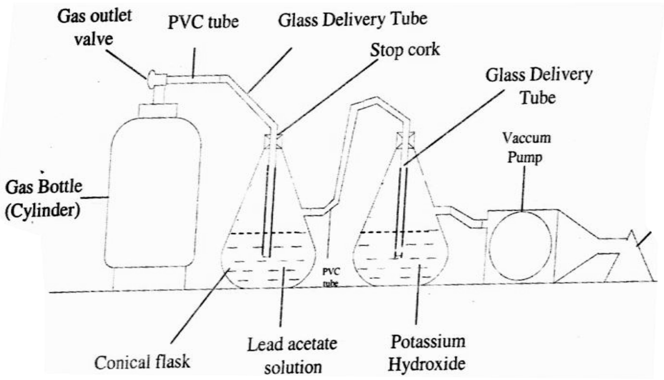

Fig. 1: Diagram of Experimental Set Up for Biogas Analysis [7]

2.1 Flue Gas Analysis
A flue gas analyzer is an instrument that monitors flue gases for emission and efficiency purposes. The gas analyzer is equipment used to analyze emissions directly from the combustion chamber. There are different versions of the analyzer available, however, IMR 1400 PL model was used for this study. Figure 3 below shows a pictorial view of the gas analyzer.

Fig. 2: IMR 1400 Gas Analyzer PL model

The gas analyzer measures and calculates the following parameters from the flue gases. These include:
- Combustion efficiency.
- Excess Air.
- Carbon monoxide (CO).
- NO_x.
- SO_2.
- Carbon dioxide (CO_2).

2.2 Experimental Design
All stoves were placed under a hood and gas samples were collected through a probe placed inside the hood exhaust duct. The hood method (sometimes called the “direct” method) has been used in studies of unvented cook stoves and kerosene space heaters [10-12]. The flue gas emissions for the three (3) different stoves used were analyzed.

RESULTS AND DISCUSSION

3.1 Biogas Production
Figure 3 below shows the daily monitoring of biogas production from cow dung biomass. A total of 1.197m^3 of biogas was produced within a period of 30 days. Average daily production was 0.04m^3/day from an average of 1.167Kg of dung. Peak gas production was observed at day 17 **w**ith production of 0.075m^3 of biogas.

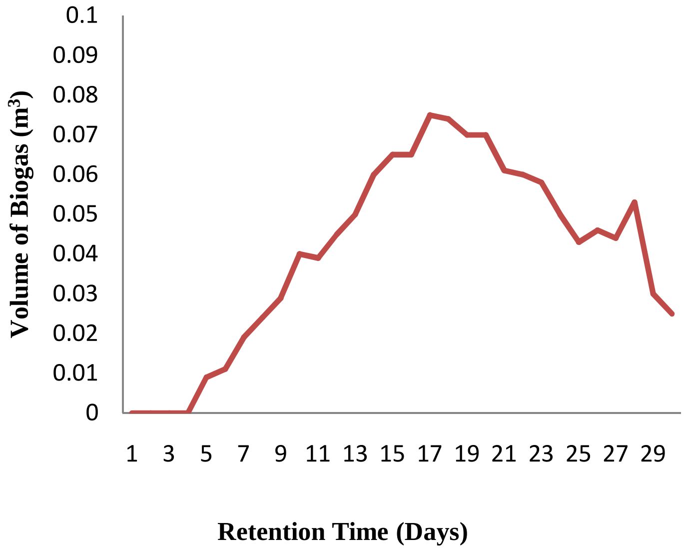

Fig. 3: Biogas Generation from Cow Dung

Also, Figure 4 below shows the biogas production using Poultry dropping. Total gas produced was 1.659m[3] equivalent to 0.06m^3/day from an average of 1.167Kg of Poultry droppings. Peak gas volume of 0.092m^3 was observed at day 20. The results show that Poultry droppings has higher gas yield than cow dung.

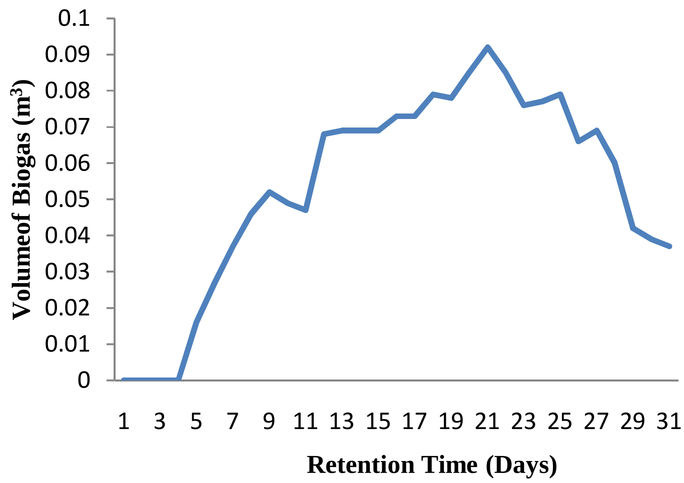

Fig. 4: Biogas Generation from Poultry Droppings

3.2 Qualitative Analysis of Biogas Produced

The laboratory analysis of biogas gave the following percentage constituents compositions of biogas produced as summarized in tales 1 &2 below, assuming that water vapour and other trace gases are negligible.

Table 1: Percentage Compositions of Biogas produced from Cow Dung

Component	Composition (%)
Carbon Dioxide (CO_2)	39.0
Hydrogen sulphide (H_2S)	3.0
Methane (CH_4)	58.0

Table 2: Percentage Compositions of Biogas produced from Poultry Droppings

Component	Composition (%)
Carbon Dioxide (CO_2)	37.5
Hydrogen sulphide (H_2S)	3.0
Methane (CH_4)	59.5

The results show that poultry droppings had higher percentage of combustible gas compared to cow dung produced within the same fermentation period (Tables 1 & 2).

3.3 Flue Gas Analysis

The constituent of the flue gases were measured. Major constituents like carbon monoxide (CO), Nitrogen Oxide (NO_x), Sulphur Oxide (SO_2), Carbon dioxide (CO_2), and excess air were measured in parts per million and percentages by the gas analyzer used. The results obtained were recorded in Tables 4 – 6 below.

Table 4: Flue Gas Constituent for Prototype Burner

Gas Constituent	1st Reading (%)/ppm	2nd Reading (%)/ppm	Average (%)/ppm
O_2	20.90	20.90	20.90
CO	33.00	37.00	35.00
CO_2	11.80	11.80	11.80
SO_2	0.00	0.00	0.00
NO_x	3.00	1.00	2.00
Excess Air	1.00	1.00	1.00

Table 5: Flue Gas Constituents for Modified Burner

Gas Constituent	1st Reading (%)/ppm	2nd Reading (%)/ppm	Average (%)/ppm
O_2	20.90	20.90	20.90
CO	4.00	6.00	5.00
CO_2	11.80	11.80	11.80
SO_2	0.00	0.00	0.00
NO_x	2.00	1.00	1.50
Excess Air	1.00	1.00	1.00

Table 6: Flue Gas Constituents for LNG Burner

Gas Constituent	1st Reading (%)/ppm	2nd Reading (%)/ppm	Average (%)/ppm
O_2	20.90	20.90	20.90
CO	8.00	10.00	9.00
CO_2	0.00	0.00	0.00
SO_2	0.00	0.00	0.00
NO_x	0.00	0.00	0.00
Excess Air	1.00	1.00	1.00

The percentage composition of O_2 and SO_2 were the same for all the burners, variations actually were observed in the percentage composition of carbon monoxide (CO) and NO_x for the burners. The charts below show the variations in the percentage composition for carbon monoxide (CO) and NO respectively.

From the charts, it can be seen that the prototype burner, produced a high percentage of CO, this was as a result of the numerous burner ports which made the stove to produce unstable flames. This makes it unsafe to use domestically and if it is to be put to use, a high amount of ventilation needs to be put in place.

Improved stove, as can be observed from the chart, produced less percentage of carbon monoxide (CO), this was as a result of the stable flame it produced when put to use. The reduced number of burner ports using flame stabilization theory was instrumental to the reduced percentage of CO emitted, which makes it saver to use domestically and requires minimum amount of ventilation during usage.

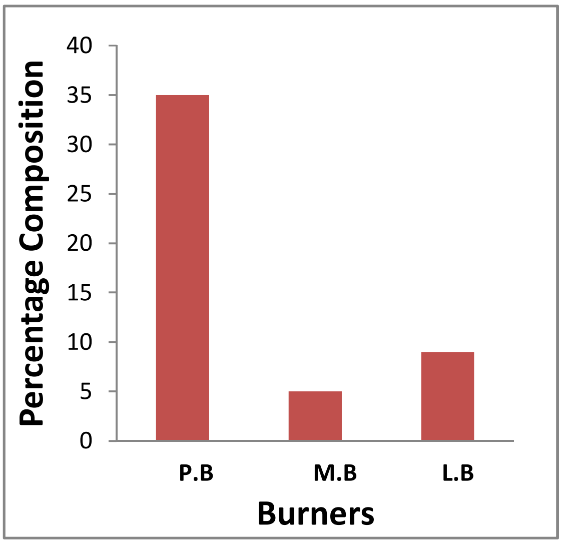

Fig. 5: CO Emissions for the Burners

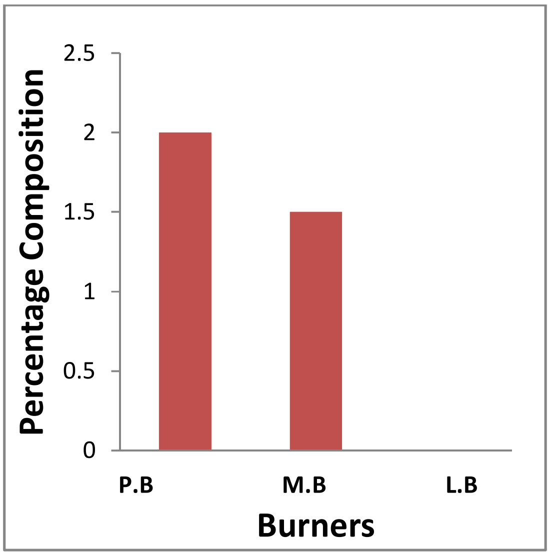

Fig. 6: NOx Emissions for the Burners

NOx and some impurities were not present in the LNG burner as recorded by the flue gas analyzer, but were 2% and 1.5% in the prototype and improved burners respectively as shown in Fig. 6. This percentage is relatively small compared to the CO emissions recorded. However, ventilation is still needed in terms of its domestic use.

3.6 Efficiency of the improved burner

The efficiency of the combustion device (burner) in terms of flue gas emissions and combustion efficiency are analyzed below:

Table 7: Reduction in Emissions

	PROTOTYPE	MODIFIED	LNG
CO	35	5	9
NO_2	2	1.5	-

$$\text{Reduction modified (COx)} = \frac{35-5}{35} x\ 100 = \frac{3000}{35} = 85.7\%$$

$$\text{Reduction modified (NOx)} = \frac{2-1.5}{2} x\ 100 = \frac{50}{2} = 25\%$$

The combustion efficiency of improved stove was recorded as 86.9% by the flue gas analyzer used in this research.

CONCLUSION

The following conclusions are made from the green house tests carried out on the burners, more specifically the improved burner, which include;

i. The combustion efficiency was recorded as 86.9%, and the percentage reduction in emission for both carbon and nitrogen oxides were 85.7% and 25% respectively.
ii. The potential of this stove can be maximized by improving the air/gas regulating mechanism
iii. Biogas is an affordable energy source for in-situ application on Nigerian farms and villages where over 50% of the population lives and the use of this technology depend on an efficient combustion device.
iv. The percentage of O_2, CO_2 and excess air were constant for the flue gas analysis done on the three (3) burners tested. This was because the analyzer worked on some preset values inputted during calibration for different kind of fuels.
v. The improved burner produced less harmful emissions as compared to the other two burners used in this study. This was significant in their carbon monoxide emissions which is harmful to both the user and the vicinity of usage.

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