Refining Biogas Produced from Biomass: An Alternative to Cooking Gas

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Abstract

Our life is completely dependent on a reliable and adequate supply of energy. In other to reduce dependence on fossil fuels, the use of animal dung in producing a renewable alternative source of energy has been proved using cow dung. This work is aimed at produced and refined bio - gas from animal dung by reduces the H_2S and CO_2 content of bio - gas in other to improved the quality of the bio - gas to be used as an alternative to the petroleum based produces in use now. The sample of gas produced was passed through the gas chromatography to determine the percentage composition (mol % dry basis) of the bio - gas contents. The results of the bio - gas before refinement were 54.09% mole dry CH_4, 40.02mole % dry CO_2 and 0.80mole % dry H_2S which conformed with the literature values of 50 - 65 % mole dry CH_4, 35 - 50 % mole dry CO_2 and 0.1 - 1.0 % mole dry H_2S. After refining, the composition of bio - gas on dry basis were 54.09% mole dry CH_4, 4.01% mole dry CO_2, 0.02% mole dry O_2, 0.05% mole dry NH_3, 0.01% mole dry H_2S, 0.5% mole dry H_2 and 2.54% mole dry N_2. Analysis of the remnant indicated that it could be used for plant nutrient.

Keywords

Biomass, Biogas, Cooking gas

Introduction

Biogas is a mixture of gases mainly hydrocarbon (methane) and carbon dioxide used in domestic cooking [1]. Nigeria is blessed with natural resources that comprise fossil fuel e.g. natural gas and coal i.e. (petroleum). Biomass energy is renewable source to the future energy bank. Since ancient times, biogas is produced by the decay of vegetable and animal waste, and was early identified as a combustible “swamp gas” [2, 3]. The highly desirable fuel was obtained by fermentation of sewage as early as 1934 and was used for heating and initial combustion engine for pumping [4]. Attention is currently focused on biogas generation from cattle waste distribution to towns and it is being used on the farm. Several large demonstration plants are functioning well and many small units are in daily use [5]. The total amount produced is small but of great significance locally.

Biogas as an alternative source of energy is renewable. But petroleum is non renewable and it has been confirmed that non renewable source of energy could only last for about another 25 years or there about [6]. This uncertainty has created a lot of anxiety for industrialized and developing nations and they are now look back to the past methods of using biomass as one of the most viable remedy with purpose of improving it and eventually making it an alternative to the current methods. In the production of biogas, the biomass (cow dung) are allowed to decompose an aerobically at room temperature, producing a gaseous product which contains methane, carbon dioxide and hydrogen sulphide. This biogas which is mainly methane has to be refined of CO_2 and H_2S in other to improve its efficiency and thermal content which can be used for cooking and generating power. At present, countries like India, United States, Pakistan and China have actualized this idea and are still thriving well [6]. The merit of turning to this alternative source of energy especially for those countries listed above are labour intensive, low cost and its decentralized source for supplying energy in rural households or communities. It is easily controlled and reduces emission of gases into environment since there is no smoking or ash from the stock. The raw materials for biogas include most agricultural and other organic wastes. In Nigeria biogas can be produced from animal and human excreta, crop residue, poultry droppings, cow, pig, and horse dung. The product yield of cattle, poultry and pig are given in the table 1 below [7].

Table 1. Methane yield of animal waste

Animal	Typical experimental yield/Kg of manure	CH_4 (%)	CO_2 (%)	Thermal content Mj/m^3
Cattle	200 - 350 L	57.5	46.5	23
Poultry	550 - 650 L	70.0	30.0	28
Pig	400- 500L	65.0	35.0	26

Although the table above shows that the CH_4 yield from the pig waste is the second highest, but considering the fact that other factors such as population of animals and physical conditions of animal waste militate against its choice, it is therefore obvious that cow dung and poultry dropping are the better choice in Nigeria content. The objective of this paper is to investigate the potentials of biogas obtained from animal waste and to refine the gas. This can be achieved via the realizations of the following aims:

- Refining and production of a biogas that is environmentally friendly and that can be used as an alternative to petroleum based products in use now.
- Determine whether the slurry can be used as fertilizer for crop production.

Methodology

Preparation of Reactor

Known total solid concentrations of 50,65and 80 g/l of solution were prepared using the sieved cow dung. Each of the 4 litters laboratory sized batch digesters having working capacities of 3.5 litters were filled with each one of the concentrations to maximum working capacities, after slurries were warmed using steam bath to remove air bubbles with constant stirring. The pH was measured and adjusted to 7.6 ± 1; the overlying air was removed by aspiration and subsequent application of pressure to compress the plastic digesters. The outlet was immediately closed tightly to prevent re - entry of air into the digesters. Delivery tubes were connected from the digester to three 1000ml conical flask containing 300ml potassium hydroxide for CO_2 absorption and potassium permanganate ($KMnO_4$) for absorbing the H_2S. The gas collection bag was connected to the flask containing water for gas collection over water. The digester was maintained at room temperature, the contents were shaken daily and pH was monitored through a pH meter connected to a sampling point.

Total Solid Analysis

The evaporating dish was washed clean with a detergent solution rinsed and ignited for one hour in an oven at 100°C. It was allowed to cool at room temperature and then weighed using an electronic weighing balance and kept until ready for use. 25g of the animal waste was transferred to the pre - weighed evaporating dish, and weighed altogether and recorded. It was then dried at 105°C in the drying oven for two hours. The dish with its contents was then cooled at room temperature and weighed using the electronic weighing balance. This cycle of drying was repeated every 5 days for a period of 25 days.

Volatile Solid Analysis

The dried sample was transferred to the muffle furnace and ignited at 500°C for two hours. The loss in weight was calculated after weighing which, represent the volatile solids.

Analysis of Gaseous Products

2000cm^3 of biogas was collected and passed through a gas analyzer (model P7450gas analyzes system) to determine the percentage composition of the gaseous constituents. Also, analytical analyses were carried out on the slurry after the collection of the gas to determine the nutrient contents of cow dung slurry.

Results and Discussions

Biodegradation of biomass (cow dung) in a controlled technological condition produces bio - gas, which are mainly methane and other gases. The energy obtained during biodegradation of biomass could be described as having modest thermal content [8], and thus could comfortably serve as cooking gas since energy requirement for domestic heating is in small scale compared to industrial usage [9]. Empirical observations of sewage sludge digestion have shown that biodegradation can be measured using the amount of volatile solids and total solids.

It could be observed in table 2 that as residence time increases, moisture content in the digester also increases progressively, this is because water vapour is also a product of digestion process. The volatile solids and total solids removed as a result of biodegradation as shown in table 2 of results increases with increase in time, this could be attributed to the loss of moisture content as degradation proceeds.

Table 2. Rate of biogas production from cow dung (cm^3/day)

Time (days)	Concentration of feed slurry g/l		
	50	65	80
9	-	-	31.25
10	2.78	11.00	66.67
11	10.00	25.00	80.00
12	36.36	38.60	118.18
13	68.75	58.33	166.67
14	84.62	111.54	192.31
15	92.86	133.35	231.55
16	100.00	152.22	265.56
17	106.25	169.75	295.30
18	113.24	176.47	382.35
19	125.00	188.89	451.40
20	126.32	201.32	526.32
21	135.00	222.50	532.50
22	134.92	228.60	558.73
23	134.85	234.10	582.28
24	134.78	239.10	604.32
25	138.54	284.33	655.21
26	140.00	334.00	668.00

From the rate of gas production shown in table 3, it is shown that as the concentrations of slurry increases, the rate of production also increase. It could also be observed from the graph of rate of production plotted against time as shown in figure 1, that the rate is constantly increasing with time and at a point or the other, there is a point of inflexion, this is said to be a case of multiple lag phases. It is attributed to the presence of multiple carbon sources in the substrate, after one carbon source is exhausted, the cell must divert its energies from the growth to re - tool for new carbon supply [9].

Table 3. Results of Moisture contents, total solid and volatile solid contents of the cow dung

Time (days)	Moisture content (g/l)	Total solid	Volatile solid
1	19.82	5.18	4.57
5	19.84	5.16	4.40
10	20.91	4.09	4.33
15	21.00	4.00	3.5
20	21.65	3.48	2.73
25	21.83	3.17	2.37

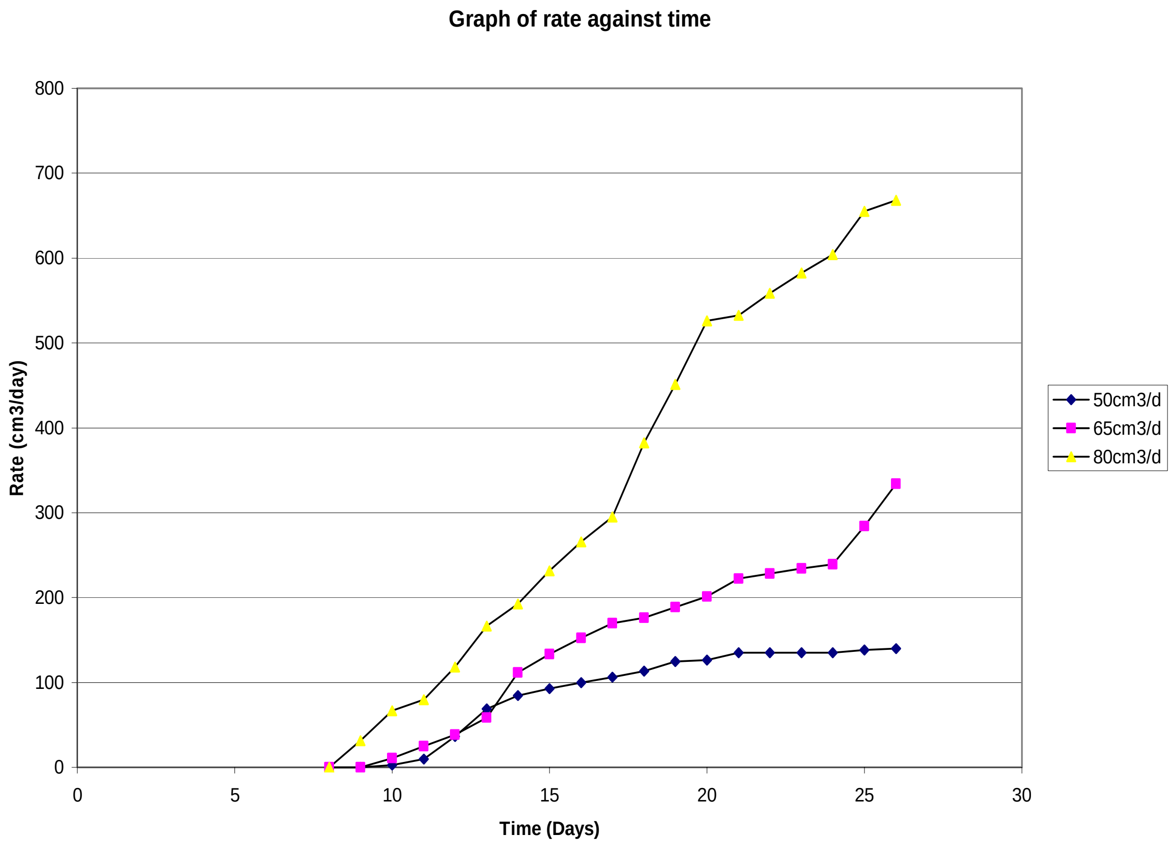

Figure 1. Graph of rate against time for feed slurry at different concentration

In so doing, no population increase occurs and hence rate of production will remain constant for a while. It could also be observed, from the graph that as feed concentrations increases the lag time decreases, which could be attributed to the adaptation of micro organisms in high slurry concentration due to increase in available substrate.

Analysis of the gases produced before and after refinement was presented in table 4.

Table 4. Results of gas analysis

Source of gas	Composition of gas mixture (%)		
		Before refinement	After refinement
Cow dung	CH_4	54	54.09
	CO_2	40.2	4.01
	O_2	0.05	0.02
	NH_3	1	0.05
	H_2S	0.8	0.01
	H_2	0.5	0.5
	N_2	3.29	2.54
	Others	0.16	38.78

It could be observed from the results that the percentage compositions of CH_4, CO_2 and H_2S before refinement are 54, 40.2 and 0.8 mole % dry gas respectively. These values conform to the literature values of 50 - 60, 30 - 50 and 0.1 - 1 mole % dry gas for CH_4, CO_2 and H_2S respectively [10, 11]. The gases i.e. H_2S and CO_2 produced along with the methane need to be removed as it affects the quality of the cooking gas. The two gases are corrosive and dangerous. Quantity of CO_2 in high proportion in cooking gas is highly undesirable. It reduces the thermal content of the cooking gas. Results of gas analysis after refinement shows serious reduction in the CO_2 and H_2S present in the gas produced. The percentage compositions of the product after refinement are 54.09, 4.01 and 0.01mole % dry for CH_4, CO_2 and H_2S respectively. The CO_2 is absorbed by concentrated potassium hydroxide solution forming the soluble carbonate as shown in the equation 1 [10]:

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O \quad (1)$$

Also, it could be observed in the table of results that percentage composition of hydrogen sulphide is quite low. But despite its low concentration, it is very toxic. It is absorbed by the acidified potassium permanganate solution as shown in equation 2 [10]:

$$5H_2S + 2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5S\downarrow \quad (2)$$

Finally after biodegradation of the dung in the digester, the remnant could still be use as manure [11]. The percentage composition of nitrogen, phosphorus and potassium are 0.08, 0.43 and 0.7 respectively as shown in table 5.

Table 5. Results of the nutrient percentage in the slurry after bio - gas production

Element	% Composition
Nitrogen	0.08
Phosphorus	0.43
Potassium	0.70

Conclusion

Based on the results, it can be deduce that the quality of biogas produced is improved by reduced the H_2S and CO_2 content of the biogas to a considerably low concentration after refinement and can be serve as a substitute for petroleum based cooking gas. The remnant could be used in supplementing plant nutrients readily available for crops.

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