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PRODUCTION OF BIOGAS FROM KITCHEN WASTE AND COW DUNG

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ABSTRACT
Biogas is a mixture of colorless, flammable gases obtained by the anaerobic digestion of organic waste materials. It is an alternative source of energy. The major composition of biogas is methane (CH_4) 50-70%. It can be used for cooking and power generation, while the residues from the process are used as fertilizers. In this experimental work, an equal ratio of 2.5kg kitchen waste and 2.5kg water with small amount (1.75kg) of cow dung was weighted. The 1.75kg of cow dung was mixed with 1.5kg of water fed into 13.5 liter constructed digester and after some days, 2.5kg kitchen waste was mixed with 1kg of water and also fed into the digester. Then allowed to ferment for period of 22 days and a pressure range of 0psi-70.5psi was obtained. A graph of pressure (psi) against time (hrs), volume (liters) against time (hrs) and Pressure (psi) against volume (liters) of gas shows increase in pressure (psi) with time (hrs) and an increase in pressure with decrease in volume. A combustion test was also carried out which showed that for every 1 minute the temperature of water increases. The result from analysis of biogas composition done revealed the following: CH_4 (67.58%), H_2 (5.16%), CO_2 (20.29%), N_2 (8.46%), O_2 (1.06%) and H_2S (2.36%) which has proved that really kitchen waste is a good raw material for production of biogas.
Keywords: Biogas, Kitchen waste, Cow dung, Anaerobic digestion.

INTRODUCTION
Fossil fuel provides the bulk of the world's primary source of energy. Since they are non-renewable natural resources with little to conserve the earth's supply, supplies of fossil fuel (especially oil and gas) may soon get completely depleted. Additionally, the rising cost of petroleum and allied products most especially in Nigeria has triggered a need to develop alternate sources of energy, one of which is biogas production. In Nigeria, majority of the population are rural dwellers without access to gas or electricity and therefore depend on firewood for cooking and lightening. Unfortunately, this has contributed immensely to the rapid rate of deforestation and desert encroachment. The establishment of biogas plants in these communities would greatly ameliorate these problems and help preserve the environment.
Biogas is distinct from other renewable energy source such as solar energy, wind energy, thermal and hydro sources of energy because of its characteristics of using controlling and collecting organic waste and at the same time producing fertilizer and water for use in agricultural irrigation. Anaerobic digestion process produces a higher biogas yield when running on a mixture of animal manure and vegetable/crop waste rather than animal manure alone, and biogas production is considered the most suitable bio energy technology in china (Wu CZ et al 2009). The slurry and residues from the biogas process can also be used as an organic fertilizer to replace the use of chemical fertilizer on the farm (HUGO 2008; Zhou Cx et al 2004; Liu y et al 2008 and chem. RJ 2007).
The composition of biogas is typically methane (50-70%), carbon-dioxide (30-40%) and the rest is made up of traces of elements of hydrogen sulphide. Biogas can be used in gas engine to convert the energy in the gas into electricity and heat. Biogas is characterized based on its chemical composition and the physical characteristics which result from it. It is primarily a mixture of methane (CH_4) and inert carbonic gas (CO_2). However the name 'biogas' gathers a large variety of gases resulting from specific treatment processes, starting from various organic waste-industries, animals or domestic organic waste etc.

Different sources of production lead to different specific compositions. The presence of H_2S or CO_2 and water make biogas very corrosive and require the use of adapted materials. The composition of a gas issue from a digester depends on the substrate, of its organic matter load, and the feeding rate of the digester.
According to its composition, biogas presents characteristics for comparison with natural gas propane. Biogas is a gas appreciably lighter than air, it produces twice as less calories by combustion with equal volume of natural gas.
The importance of biogas as alternative source of energy cannot be over emphasised. It is a sustainable, more environmentally friendly and cheaper source of energy.

MATERIALS AND METHODS

Materials used include: kitchen waste, cow dung and water.
Apparatus used include:

i. Constructed digester
ii. Mortal
iii. Pressure gauge
iv. Funnel
v. Hand glove
vi. Measuring cylinder
vii. Bunsen burner
viii. Mask
ix. Stirrer
x. Beaker
xi. Electronic weighing balance
xii. Hose
xiii. Clip
xiv. Poly filler

Experimental Method

In this experiment, 1.75kg of cow dung was weight and mixed thoroughly with 1.5kg of distilled water using hand, then fed into the 13.5liter air tight constructed bio digester as it contains the required microorganism for anaerobic digestion. After some days, 2.5kg of kitchen waste was weighed and mixed with 1kg of distilled water. The mixture of the kitchen waste and distilled water inside the bio digester was then allowed to ferment. The reason why the kitchen waste was added after some days was to check gas emission.

Stages Involved In The Production Procedure

The stages involved in the procedure for producing biogas are:
Stage 1: The preparation of the substrate (slurry)
Stage 2: Substrate introduction
Stage 3: Decomposition process
Stages 4: Collection of data
Stage 5: Combustion test.
Stage 6: Analysis of the gas produced.

Stage 1: Preparation of the Substrate

In this stage, a total of 1.75kg of cow dung was weighed and mixed with water then fed into the digester. 2.5kg of kitchen waste was also weighed and mixed with water and added to the mixture in the digester. The addition of water to both cow dung and kitchen waste was gradual while there was continuous stirring until a suitable homogeneous mixture was obtained. The mixture was carried out in batch processes for convenience.
Total weight of substrate = 6.75kg
Volume of the digester = 13.5kg
Percentage of volume occupied by substrate = Total weight of substrate/volume of digester x 100
= 6.75/13.5 x 100 =50%

Therefore the substrate was fed to about half of the volume of the bio digester.

Stage 2: Substrate introduction

In this stage, the substrate was gradually fed into the bio digester in batches through funnel. This was carried out through the inlet cover (reducer). All the connections made were air tight and checked properly to avoid leakages. This set up was kept under room temperature of (25-35^{o}C) in the laboratory for the bacteria to act on the substrate.

Note: After the connection of the digester, it was pressurized with a vacuum pump and tested to make sure there is no leakage before the introduction of the substrate.

Stage 3: Decomposition process

In the decomposition stage, after the process undergoes decomposition for 3 days, the 1st gas production was observed. There was a deflection at pressure gauge of about 0.5psia indicating that there was a buildup in pressure. This buildup continued for 22 days and data of pressure buildup with time and volume was taken on daily basis.

Stage 4: Collection of data

This stage involved the method by which data is been collected on a daily basis. The pressure variation with time for every day was recorded at an interval of 24hours (i.e.11am daily). This method was adopted due to the limited time of accessibility to the laboratory.

Stage 5: Combustion Test.

The combustion test took place after the biogas production. The test was conducted by using Bunsen burner and the gas burned with blue flame without soot. Then a test tube containing 50ml of water was placed on the combusted flame to test for heat and at 1 minute, the water temperature increased.

Stage 6: Analysis of the gas Produced.

In this stage, the biogas produced was analyzed with the aid of a GC (gas chromatography) machine at Lighthouse Petroleum Engineering Co Ltd. The gas chromatography machine was turned on and the carrier gas was opened to flow into the machine. The machine was then allowed to stabilize.

Tests for methane composition

This test was carried out in the automatic gas chromatography machine which has been programmed and stabilized for detecting only composition of hydrocarbon in gas. Helium was used as the carrier gas.

The sample of biogas was pumped into the gas chromatography machine from a gas sampler bladder through a plastic tube and after the time duration of about 148 mins, a methane peak area of 97.92% was detected with a mole% composition of 67.58.

Therefore the CH_4 (methane) in the biogas =67 58%

Hazard statement: Gas and liquid should be under pressure, since over pressurizing or over heating may cause gas release or violent cylinder bursting.

Precaution

1. Biogas coming out was not inhaled.
2. There was adequate ventilation.
3. Do not tamper with valve /safety relief valves.
4. The valve / hose were air tight after use.
5. The temperature range for which the bio digester was kept is 35-40^{o}C
6. Sources of leakage were closely monitored.
7. There was no rough handling of the cylinder.
8. The carrier gas bio digester was ensure to be above 100psia before usage.
9. The use of a safety valve into the set up was ensured.
10. Ensured that the injected sample was in one column uninterrupted and a single stroke of the syringe was used.
11. The bio digester was kept away from damp area.

Observation

During biogas production, it was observed that due to the use of block hose in the bio digester, as the pressure builds up, the pressure force burst the hose and the gas escaped.

It was also observed that during combustion test for 1psia pressure of gas, it took 1 minute for it to combust. Therefore the ratio of the combustion rate is 1:1.
Also, after the addition of kitchen waste to the inoculums in the bio digester, it was observed that there was a great increase in gas produced with effect of 24 hours. This implies that kitchen waste produced more gas than cow dung.

Costing Analysis of the Practical
The cost analysis of materials used for experiment are as follows.

Table 1: COST OF RAW MATERIALS

No	Raw Material	Amount	Cost
1	Kitchen waste	2.5kg	
2	Cow dung (fresh)	1.75kg	#200
3	Water	2.5kg	#750
4	Transport	-	#500
5	Total		#1,450

Table 2: The Cost Analysis of the materials used in carrying out the project

No.	Materials	Uses	Quantity	Cost
1	Digester	Liter(kg)	1	#3,000
2	Hose	Cm	1	#300
3	Pipe	Cm	1	#1,500
4	Galvanized steel	Cm	1	#1,000
5	Clip	Inch	3	#300
6	Scale	Kg	1	-
7	Stirrer	-	1	-
8	Bowl	Liter	1	#320
9	Poly filler	-	1	#1,000
10	Pressure gauge	-	1	#1,500
11	Transport	-	-	#2,000
12	Total	-	-	#11,020

Conservation of Mass Balance
The general conservation equation for any process system can be given as followed. The material balanced around the digester is shown below.

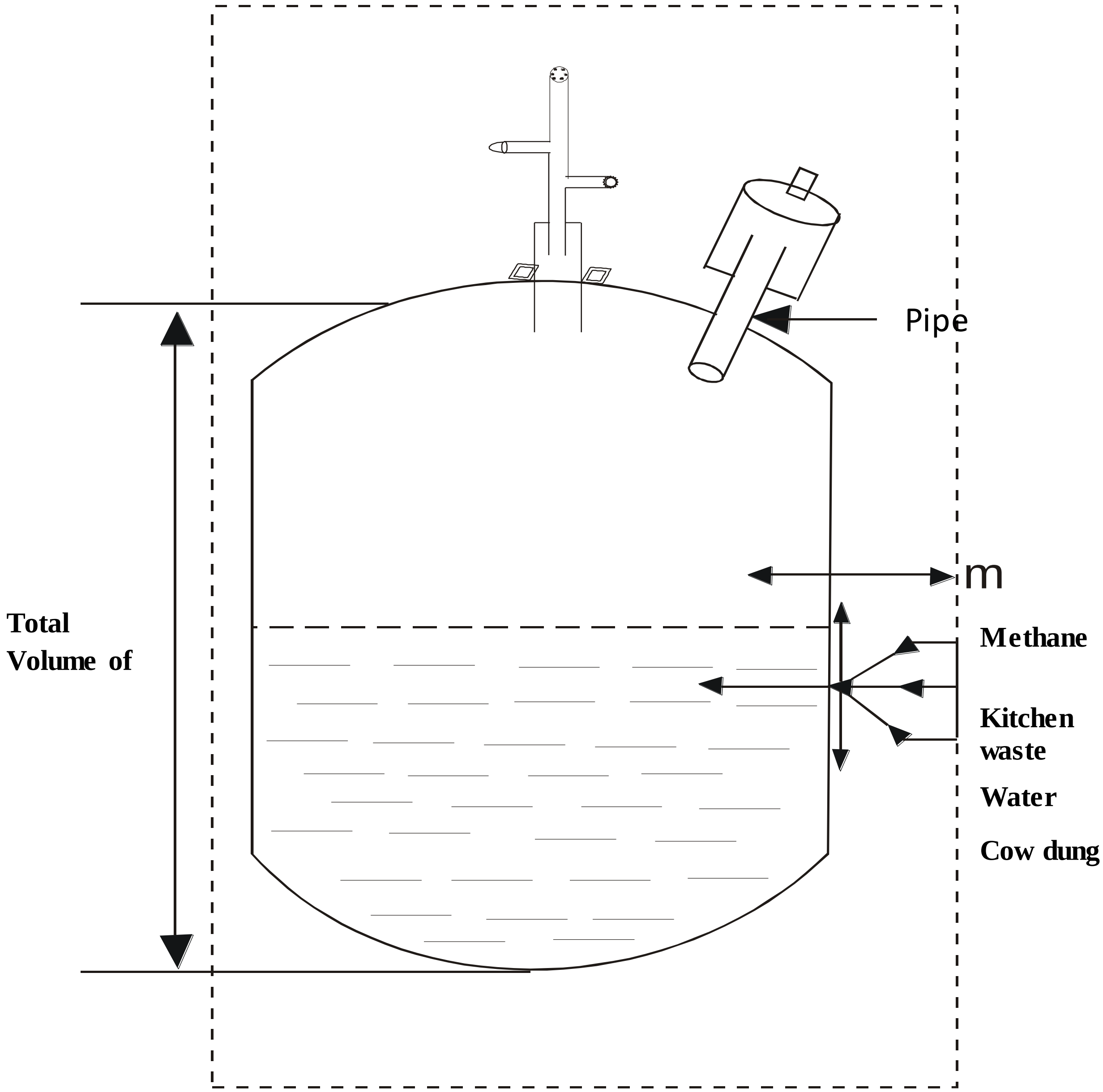

Fig. 1. The constructed digester

The bio digester is a major equipment which was used for the production process. This contains a connected metallic pipe, galvanized steel and a pressure gauge. The following are the specification of the constructed bio digester (fig. 1);
WC is 13.5kg =13.5 liters.
TARE Wt. =2.5kg
DT = 36 cm
WC = water capacity. This is the difference between the weight of a digester when filled with water and the weight of the digester without the pressure gauge, clip, and pipe (Tare weight).

Note:
1 volume of water =1 liter
This implies that 1kg
Tare wt. = the weight of the digester without pipe, gauge or clip.
DT = Diameter of the digester.
WP = this implies the pressure in which the cylinder should be filled to when it is used.

Materials composition

1. Kitchen waste =2.5kg
2. Distill water =2.5kg
3. Cow dung =1.75kg

Material Balance Calculation

Material out =Material in + Generation – Consumption-Accumulation.
Assume steady state process, the accumulation is taken as zero.
Material in = Material Out
Ram material specification
Kitchen waste =2.5kg
Water =2.5kg
Cow dung (inoculum) =1.75kg
Content of the digester =13.5kg
Content of the feed inside the digester = 6.75kg
Let the quantities (unknown) of 1.75% slurry be X and water be Y
Material balance on kitchen waste
Material in = Material out
X (6.75/100) = 6.75 x 1.75/100
X (0.0675) = 0.11813
X = 0.11813/0.0675
X = 1.75 --- 1
Material balance of water around the digester
X {(100-1.75)/100} + y = 6.75 {(100-2.5)/100}
X (98.25/100) + Y = 6.75 (97.5/100)
X (0.983) + Y = 6.75 (0.975)
Put X = 1.75 (from equation 1)
X (0.983) + Y = 6.75 (0.975)
1.75 x 0.983 + Y =6.75 x 0.975
1.7203 + Y = 6.58
Collect term
Y = 6.58 – 1.7203
Y = 4.86kg
Y ~ 5kg --2
Add equation 1 & 2
X + Y = 1.75 +5
= 6.75kg
Material in = 6.75kg
Material out = 6.75kg
M = mass of the digester

Energy balance around the digester

Heat energy is the energy generated from biogas production
Heat generated = Heat given Out

Heat energy =13.5*0.5537*40
= 298.998KJ/KG

RESULT AND DISCUSSION

The regular check of the result on the bio digester during the retention periods and the temperature condition of the environment where the digester was kept was outlined below:

Table 3: retention time / result

Days	Temperature	Findings
0-2	Room temperature	Lag period where there is no production of gas , that is no decomposition
3	Room temperature	A little defection was observed on the pressure gauge which indicates that bacteria decomposition has developed before the kitchen waste was added.
4-6	Room temperature 25^{o}C	Bacteria decomposition has developed proper and digestion has begun. The gas produced increase.
7-14	Room temperature	The rate of increase reduced which indicate low production and fall in temperature.
15-22	Room temperature	The rate of deflection of the gauge with time increase rapidly. This indicates high production of gas.

The table 4 shows the results of daily pressure buildup against time during the biogas production, while volume buildup against time is shown in Table 5, and pressure buildup against volume for 22 days is shown in Table 6.

Table 4: Pressure Buildup Against Time Using The Decomposition Process

Days	Date	Time	Pressure in (Bar)	Pressure in (Psi)
1	20th Oct	0	0.00	0.00
2	21st Oct	48	0.00	0.00
3	22nd Oct	72	0.03	0.40
4	23rd Oct	96	1.00	14.50
5	24th Oct	120	1.31	19.00
6	25th Oct	144	1.59	23.00
7	26th Oct	168	1.76	25.50
8	27th Oct	192	1.83	26.50
9	28th Oct	216	1.95	28.30
10	29th Oct	240	2.10	30.50
11	30th Oct	264	2.24	32.50
12	31st Oct	288	2.36	34.50
13	1st Nov	312	2.50	36.30
14	2nd Nov	336	2.68	38.90
15	3rdNov	360	3.12	43.20
16	4thNov	384	3.34	48.50
17	15thNov	408	3.59	52.00
18	6thNov	432	4.07	59.00
19	7th Nov	456	4.43	63.00
20	8th Nov	480	4.72	68.50
21	9thNov	504	4.79	69.50
22	10thNov	528	4.86	70.50

Table 5: Volume of Gas Buildup in the Digester against Time

Time (hrs.)	Daily volume of gas (L)	Cumulative volume of gas
24	0.00	0.00
96	2.08	2.08
120	6.71	8.79
144	7.43	16.22
168	12.24	28.46
192	29.71	58.17
216	17.33	75.50
240	13.87	89.37
264	14.86	104.23
288	14.86	119.09
312	17.33	136.42
336	11.56	147.98
360	4.73	152.71
384	9.45	162.16
408	8.32	170.48
432	4.33	174.81
456	7.17	181.98
480	5.47	187.45
504	29.71	217.16
528	29.71	246.87

Table 6: Pressure Buildup Against Volume

Pressure (Psi)	Volume (L)
0.00	0.00
14.50	2.08
19.00	6.71
23.00	7.43
25.50	12.24
26.50	29.71
28.30	17.33
30.50	13.33
32.50	14.87
34.50	14.87
36.30	17.33
38.90	11.56
43.20	4.73
48.50	9.45
52.00	8.32
59.00	4.33
63.00	7.17
68.50	5.47
69.50	29.71
70.50	29.71

Pressure buildup against time during biogas production

Production of biogas varies with time and is directly proportional to time. During the gas production, there was no production of gas from day 1 till day 3. The pressure gauge remained stagnant for a period of 2 days which indicates no detectable production until day 3.

Gas production was first observed on day 3 from the pressure gauge. The optimum production was observed on day 20 while there was a decline in the gas production level from day 21 which indicate that the retention time for the biogas is 22 days. From the results and plot of the pressure buildup against time (hours in a day) of production, it can be deduced that the rate of pressure buildup is directly proportional to the days of production.

As explained by literature, it could be as a result of high acidic concentration of substrate at the initial stage and as the bacteria began to absorb the acid, the pH then, tend towards the maximum production range. Therefore increase in fermentation occurs and production increase as observed form the graph. From the graph the maximum production is observed on day 20 while day 22 and day 23 appear to be steady.

Since activities of bacteria decrease below $16^{o}C$ while rapid gas production occurs between $29^{o}C$ to $41^{o}C$, temperature can also be responsible for the production. The production rate can be determined by the trend line equation of the graph. Thegraph analysis of pressure build up against time is shown in figure 2.

Volume buildup against time

Volume buildup in biogas production is directly proportional with time. Substrate decomposition begins as from day 4 and gradually the volume increased with respect to time.

During the process of fermentation, the volume of the feed is gradually increased which indicates decomposition of the substrate that was put inside the digester. The outflow of biogas is clearly related to seasonal variation in temperature.

For the same retention time, the total volume of biogas obtained during the warm season is found from literature to be 1.8 times greater than the total volume of biogas obtained in cold season. Although biogas production began at day 3 from the graph, there was gradual increase as the fermentation process continues with respects to change in days. The production rate can be determined by the trend line equation of the graph. The graph analysis of volume build up against time is shown in fig 3.

Variation of Pressure with Volume

In the production of biogas, the pressure of the gas is inversely proportional to the volume of the container, which implies that as the pressure increase the molecules are confined to a smaller volume and gradually the molecules comes closer and closer together. With real gases there comes a time when the molecules stick together and the liquid droplet start to appear. From the graph analysis, as the pressure increase the volume decreases but at a particular pressure, we known that real gases will liquefy. If you were able to look inside the cylinder, you will see that tiny droplet of liquid appear.

The volume of the droplet will be very much smaller than the volume of the gas which decreases rapidly. This is what happens along the horizontal part of the graph. When all the gas is liquefied, it takes a huge increase in pressure to change the volume, then the molecules in a liquid are already very close together, so it is very hard to reduce the volume any further.

This stage is shown by the lines becoming almost vertical on the graph. This is shown in fig 5. Since liquid are very hard to compress, therefore little change in volume even for a large increase in pressure. This is a statement of Boyle’s Law in a simpler language, which says that if the pressure is increased, then the volume gets smaller and vice versa.

Therefore, we have

V & 1/P (T constant)

Alternatively, we can put PV = constant (Boyle’s Law).The law state that provided the temperature is kept constant, the volume of a fixed mass of a gas is inversely proportional to its pressure. So as the volume decrease will bring about increase in pressure and vice versa.

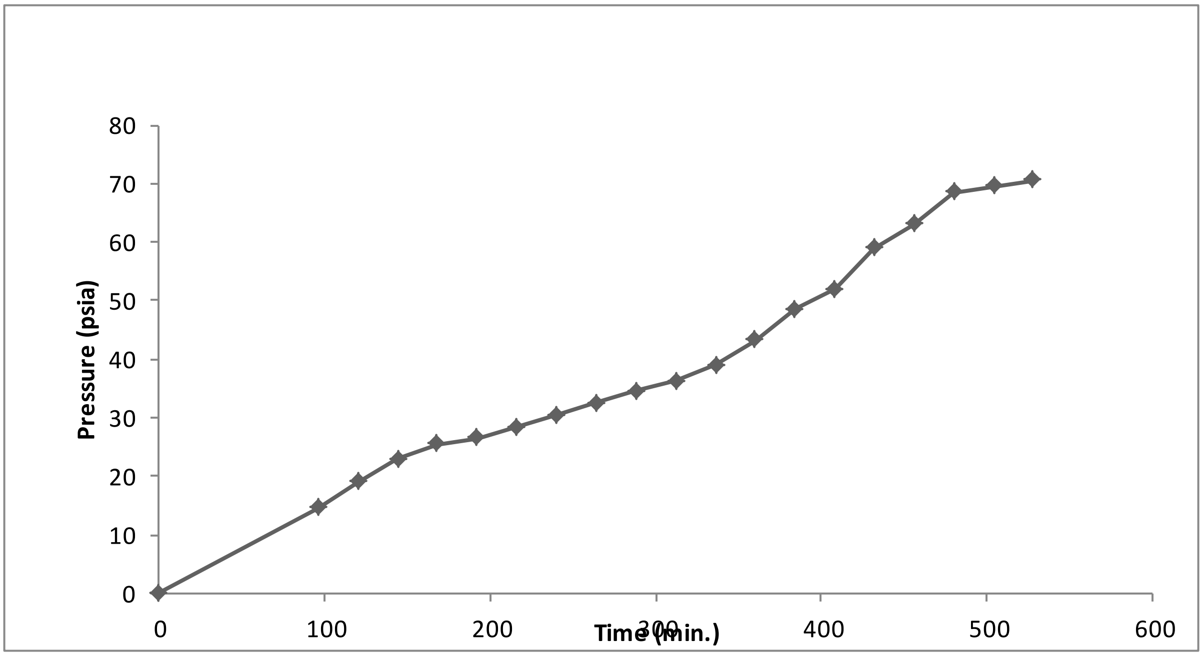

Fig 2: Plot of Pressure build up (psia) against Time (mins)

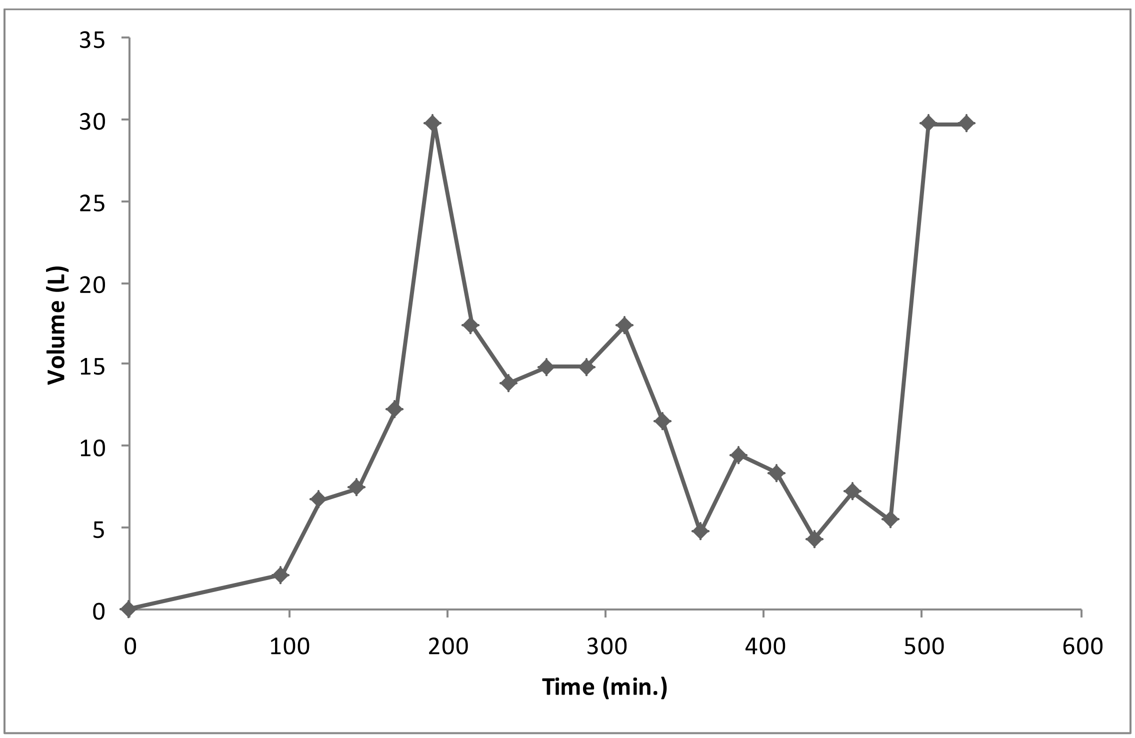

Fig 3: Plot of Volume build up (L) against Time (mins)

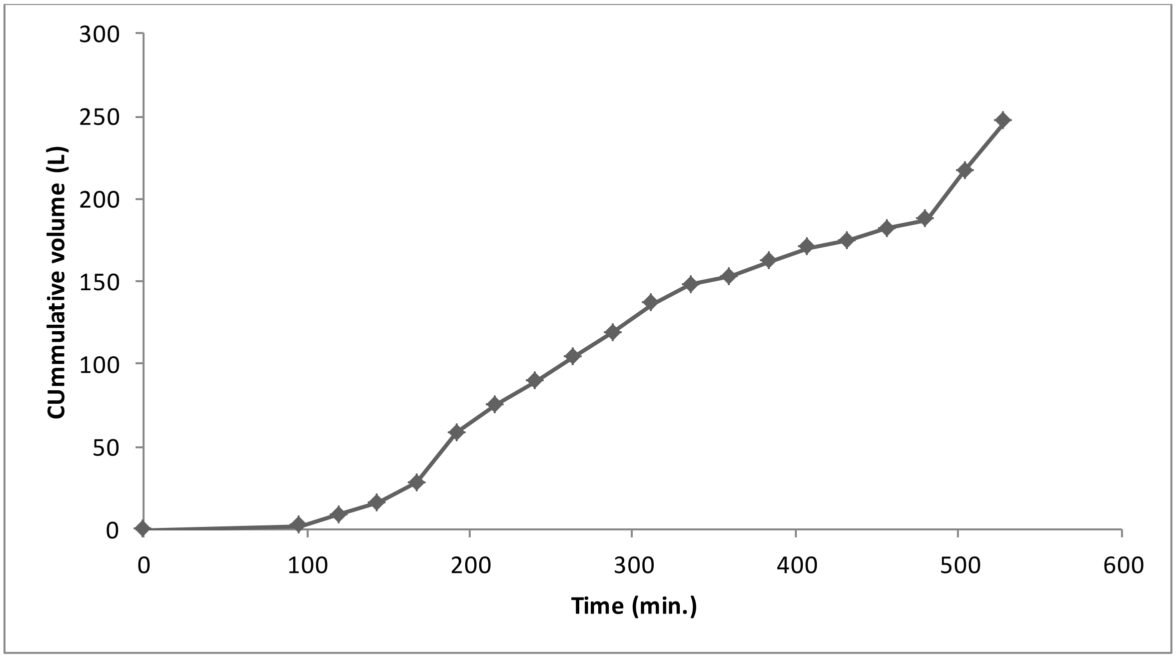

Fig 4: Plot of Cumulative Volume (L) against Time (mins.)

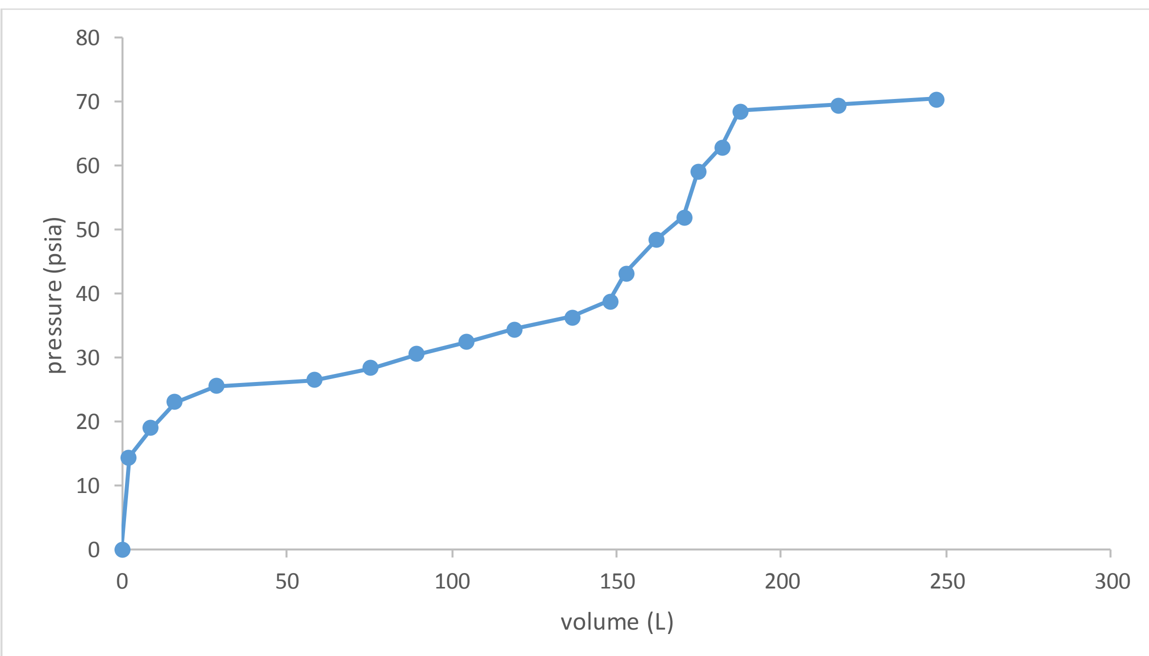

Fig. 5: Plot of Pressure build up (psia) against Volume (L)

Combustion Test Analysis

Combustion test analysis that was carried out showed that the gas produced is biogas and it burnt with blue flame without soot. The test carried out using a Bunsen burner and it was able to raise the temperature of 50ml of water from 28^{o}C to 80^{O}C in 4 minutes. When compared with Liquefied Petroleum

Gas (LPG) for the same volume of water and at the same time duration (4minutes), it raised the temperature from 28°C to 100°C. From literature it shows that LPG has a higher calorific value which is (22,457kcal/m^3) than biogas (5000kcal/m^3).

Analysis of Result

From the composition of biogas analysis using GC machine, the Methane produced was the leading component with about 67.58% composition which conform to literature (50-70%) and it is self-explanatory that Methane composition is optimal. However, from literature the percentage (%) composition of CO_2 is between (30-40%) but the percentage composition of CO_2 obtained from biogas produced is 20.29%. Although it is not the given range in literature but it is expected to be less than 30 since the composition of Methane is high and there are still other gas components present.

In conducting Hydrogen test, the result obtained from composition is 5.16% which was in line with literature (5-10%). The percentage composition of Nitrogen obtained from GC analysis is 8.46% which was higher than what is expected from literature (1-2%). This could be as a result of improper flushing of the GC machine with Biogas. Also Hydrogen sulphide (H_2S) was found to be 2.36 % and a trace amount of Oxygen (1.06%) was obtained in the biogas. The analysis of the result is given below.

Table 7: Lighthouse Petroluem Engineering Co.Ltd, Warri, Delta State. Quality Control Laboratory, LPG and gas

Source	
Sample	Biogas
Hour	
Methane	67.58
Propylene	
Ethylene	
Hydrogen	5.16
N-butane	
Propane	
Iso butane	
Trans-butane	
N-pentane	
Iso-butylene + I –butane	
Cis-butane	
Hydrogen Sulphide	2.36
Oxygen	1.06
Nitrogen	8.46
Carbon dioxide	20.29
Carbon monoxide	
Molecular weight	
Cal density	
Density at 15°C	
Schilling Density	
Total Sulphur (ppm)	
Water (ppm)	

CONCLUSION

The study revealed that it is possible to produce biogas from kitchen waste since it has more nutrient than cow dung. Therefore it could be stated that kitchen waste is a good raw material for biogas production as an alternative source of energy. The analysis carried out further confirmed that biogas produced indicate that methane is the major constituent (67.58%) while CO_2, N_2, H_2, O_2, H_2O and H_2S make up the remaining composition.

Without any further argument, the current disposal system for agricultural waste has created a negative effect through disease and pollution problems. The search for alternative sources of energy such as biogas from waste materials like kitchen waste, when increased would help in the elimination and control of deforestation and soil erosion. It should be noted that the development of biogas does not eliminate waste but it makes them easier to manage.

Therefore in developing countries of Africa especially Nigeria, where electricity and heat are sparse and biological waste are everywhere, the anaerobic digestion process could be a better option. Also, the use of kitchen waste due to its availability as waste in the production of biogas in developing countries like Nigeria, could allow for production of cheap, readily available and environmentally friend biogas which can be a suitable alternative to fossil fuel at all times.

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