Nig J. Biotech. Vol. 21 (2010) 1 – 11
ISSN: 0189 17131
Available online at
http://www.ajol.info/index.php/njb/index
and www.biotechsocietynigeria.org.

NIGERIAN JOURNAL OF BIOTECHNOLOGY

The Effect of Seasons Temperature and Nitrogen Release on Cow Dung and Pig Dung Treatment in Anaerobic Sequencing Batch Reactors

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Abstract
This study determined the rate at which nitrogen from cow dung and pig dung is released during decomposition and the effect of temperature on their rates of decomposition. The cow dung and pig dung were treated in anaerobic sequencing batch reactor or digester whose capacity was 0.971 m^3 and operated at 28.2^oC and 35.3^oC respectively as their maximum ambient temperature and 27.0 ^oC and 37.5 ^oC as their maximum slurry temperature. This digester could easily support volumetric organic loading rates of 220kg/m^3/d for cow dung and 173kg/m^3/d for pig dung. The maximum weekly rates of nitrogen release after digestion were 2.62 % for cow dung and 3.06% for pig dung. Temperature had a significant effect on the decomposition rate of cow dung and pig dung. The highest volume of Biogas was produced at 21.05 ^oC and 24.7 ^oC (mesophilic temperature). Total solids, volatile solids and C/N ratios of the wastes were also determined.

Key words: Decomposition; Nitrogen Temperature; Batch Reactor; Volumetric

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Introduction

Biogas is formed solely through the activity of bacteria. Bacteria have a temperature range in which they are most productive in term of production rates, growth rates and substrate degradation performance. Several groups of bacteria involved in anaerobic digestion have different temperature optimum. This results in two main temperature ranges at which digestion usually can be performed optimally and most economically. These ranges are 25.38^oC called the mesophilic range and 45-70^oC called the thermophilic range (BTG, 2003).

Biogas is made up of methane, carbon dioxide, nitrogen, hydrogen sulphide, ammonia and water vapour. The percentage composition of these gases varies depending on the substrates and the optimum conditions of biogas production (Ezeonu, et al., 2006). Temperature is one of the most important factors that affect biogas production. The rate of bacteriological methane production increases with digester temperature, with retention time and with the percentage of total solid in the slurry. (Jenangi, 2002). However, the amount of free ammonia also increases with temperature; the bio-digestive performance could be inhibited or even reduced as a result (Werner, et al., 1987). This is because temperature affects the enzymatic activities of the microorganisms (anaerobic) responsible for the conversion of organic materials into biogas *(*Philip et al., 2001).

There are usually two reasons why the mesophilic and thermophilic temperatures are preferred. First, a higher loading rate of organic materials can be processed; second; temperature increases the destruction of pathogens present in raw manure. The microorganisms are very sensitive to conditions in their environment such as temperature, acidity, and the amount of water. When the temperature is high, the activity of bacteria is simply more vigorous, so that the fermentation period becomes shorter. When the temperature is low digestion is slow, and the fermentation period is longer (Goodger, 1980). The anaerobic digestion process is carried out by a delicately balanced population of various bacteria. These bacteria can be very sensitive to change in their environment. Temperature is a prime example. It has been determined that 35^{o}C is an ideal temperature for anaerobic digestion (Ojolo et al., 2007).

To guarantee optimum biogas, production, it is very important to mix various raw materials in accordance with carbon to nitrogen (C/N) ratio requirements of the fermentation. The C/N ratio reflects the relative proportions of these two elements in the digester charge. Carbon (in form of carbohydrates) and nitrogen (as protein, nitrates, ammonia, etc) are the chief nutrients for anaerobic bacteria.

There are two major differences between the digested and undigested products. More volatile nitrogen is contained in anaerobically digested manure and nutrients are more uniformly distributed. The temperature of mesophilic fermentation is preferred worldwide because: it is easy to maintain the digester at this temperature. Mesophilic bacteria are more stable than thermophilic bacteria. They produced high quality sludge (Dioha et al., 2006). This study determined the effect of fermentation temperature on production rate of biogas from organic waste. This study also determined the rate at which Nitrogen accumulated in organic waste is released during decomposition.

Materials and Method

Apparatus: The bio-digester that was used for this study is 0.971 m^3 in capacity and made of polyethylene material. Batch operation method was used. Fresh cow dung and pig dung were used for this study. The cow dung was obtained from Nsukka Abattoir. Pig dung was collected from veterinary farm, University of Nigeria Nsukka.

Characteristics of the wastes used in this study: The slurry of cow dung was obtained by diluting the solid cow dung with water in the mass ratio of 1:2 (waste: water). This implies that a total of 220kg of cow dung was mixed with 440kg of water giving a total mass of 660kg of slurry. Those were measured using a weighing balance of 0-50kg ranges. Both waste and water were thoroughly mixed in a small drum ensuring that no solid (hard) material, which was not decomposable, was present before introducing the mixture into the digester. The waste occupied about 74% by volume of the digester, this is the loading rate. The remaining part was left for gas collection. After introducing the waste, all openings were closed. After one day from charging, biogas generation commenced. The biogas became combustible as from the fourth day to the end of digestion as show in table 1.

Table 1: Mixing Ratio and the temperature of samples.

Waste	Mixing Ratio	Quantity of Waste and Water (kg)	Ambient Temperature Range(^{o}C)	Slurry Temp Range(^{o}C)	Total vol. Biogas Produced (m^3)
Cow dung	1:2	660	19.3-28.2	21.1-27.0	1.510
Pig dung	1:2	549	22.0-35.3	21.4-37.5	4.835

The initially dry pig dung was pulverized and every hard stones were removed. It was dissolved in water in the ratio of 1:2. A total of 173kg of waste was mixed with 376kg of water in batches in a small drum after which it was introduced into the digester while keeping gas outlet open to exhaust trapped air. The fermentation and biogas production started after 1 day. The gas became combustible from the 19th day to the end of digestion.

Retention time and Flammability: Retention time is the period during which any organic matter is subjected to the anaerobic environment and reaction in a biogas digester. The length of time that the volatile solids remain in an anaerobic digester is an important factor in the digestion process. The solids retention time (SRT) represents the average time microorganisms spend in the system (Jenangi, 2002). Retention time is proportional to the temperature of the process. The retention time of cow dung and pig dung were 70 and 101 days. Too short a retention time does not allow sufficient time for anaerobic bacteria to metabolize the waste.

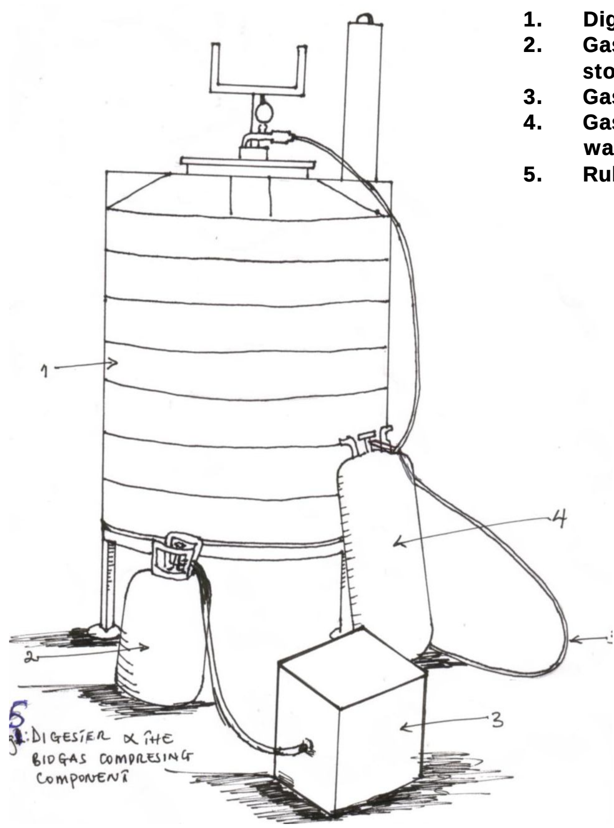
Flammability test was conducted on the biogas produced from cow dung and pig dung; it became combustible on the 4th and 19th day. The average daily gas production was calculated from the total volume of gas produced and the retention time. The total volume of gas produced by each waste divided by the product of retention time and volume of digester gives the specific gas production. The volume of gas produced was measured by downward displacement of water (table 2).

Table 2: Retention time and day of combustibility.

Waste	Retention time (days)	Flammable time (day)	Average daily gas production (m^3)	Specific gas production
Cow dung	70	4	0.022	0.022
Pig dung	101	19	0.048	0.049

Storage of Biogas: A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compression of a gas naturally increases its temperature. Compressors are closely related to mechanical pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas, whereas the main result of a pump raising the pressure of a liquid is to allow the liquid to be transported into cylinder (Ezekoye & Okeke, 2006).

Two cylinders were constructed; one of the cylinders had valves at the top and by the side of its base. The other cylinder had a valve only at the top. Two pipes of 1cm in diameter were welded to the two openings or pistons on the compressor's body. A base was fixed on one of the pipes and connected to the valve of one of the cylinders while another hose was connected to the second pipe and fixed on the valve at the base side of the other cylinder. The hose from the digester was fixed on the valve at the top of this same cylinder. Biogas is compressed in the storage cylinder by two pistogns (Fig. 2a). The biogas stored in the cylinders can be used at home or stored. Biogas was passed to a burner and it consumed or burnt with blue flame (Brodhed, 2006).



Key

1. **Digester**
2. **Gas Cylinder where the Biogas was stored**
3. **Gas Compressor**
4. **Gas Cylinder through which the Biogas was sucked out from the Digester**
5. **Rubber Hose**

Fig. 2a: Digester & the Biogas Compressing Component

Analysis of Samples: Anaerobic degradation efficiency strictly depends on the characteristics of the cow dung and pig dung used for charging the digester. Characteristics of the samples are summarized in table 3.

Table 3: Characteristics of Cow dung and Pig dung used during the experimental study

Sample Waste	Total solids (%)	Volatile solids (%)	Total carbon (%)	Total Nitrogen (%)	C/N	pH
Cow dung	84.00	74.23	3.98	2.62	4:1	7.20
Pig dung	78.20	71.65	1.88	3.06	3:1	7.61

About 0.05 kg weight of each waste was collected and analysed in the laboratory for determination of concentration of different components of the slurry before and after digestion. The instrument used for the analysis were flame photometer for potassium; pH meter for pH, oven for total solid, volatile solid, Ash and moisture; distillation for Nitrogen and titration for carbon and phosphorous. The method of Meynell was used for total solids and volatile solid determination (Meynell, 1982). The percentage contents of all these components mentioned above are recorded in table 4.

Table 4: Proximate analysis of Cow dung, Pig dung.

Parameters	Cow dung		Pig dung	
	Before Digestion	After Digestion	Before Digestion	After Digestion
Nitrogen	0.94%	2.62%	0.61%	3.06
Carbon content	3.98%	5.31%	1.88%	10.63
Ph	6.50	7.20	6.00	7.61
Ash	3.70%	3.50%	2.35%	6.00
Moisture	88.85%	8.4.00%	88.45%	78.20
Phosphorus	0.04%	0.37%	0.08%	0.54
Potassium	1.20ppm	46.80%	38.40%	78.1mg/100g
Volatile solid	64.99%	74.23%	71.65%	86.55
Total solid	89.23%	84.00%	96.45%	78.20

Results and Discussion

Correlation between ambient and slurry temperatures: From table 5, it is evident that the monthly gas production from cow dung has tended to fluctuate with season or temperature. The highest average gas production from cow dung was recorded in August (0.715m^3) while the lowest was recorded in October. The monthly gas production from pig dung has tended to fluctuate with the season. The highest average gas production from pig dung was recorded in February (2.229m^3) while the lowest was recorded in May. Figure 1 shows the change in ambient temperature during fermentation.The range falls between (17-37^{o}C). Figure 2b shows the daily change in slurry temperature during fermentation which falls between (20-38^{o}C).

High temperature was found to favour high yield of biogas from clean pig dung as show in table 5. Digestion at high temperature range supports higher rates of biological degradation and biogas production (Itodo et al, 2002).

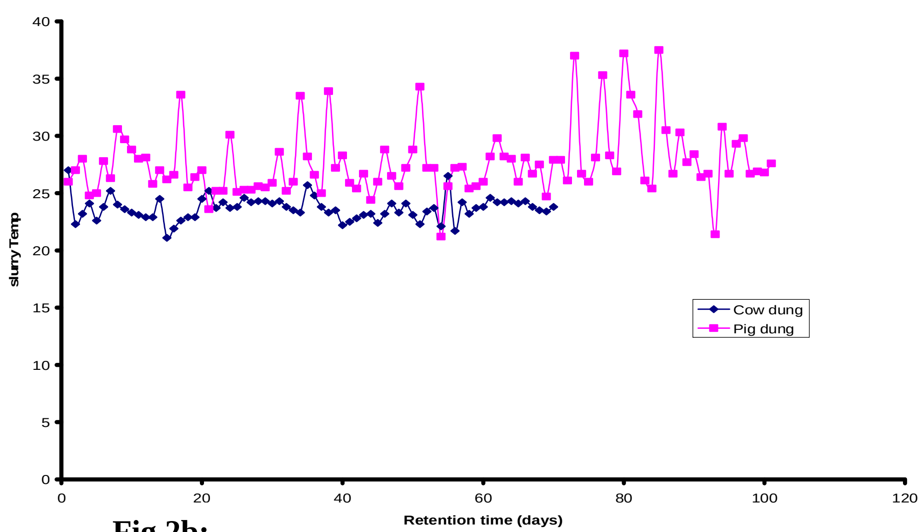


Fig 2b: Daily change in slurry temp. during fermentaton

Table 5: Gas production by Cow dung and Pig dung classified by month

Month for Cow dung	Average amount of gas produced (m^3)
August	0.715
September	0.635
October	0.160
Month for Pig dung	
January	0.204
February	2.229
March	1.392
April	0.940
May	0.070

Figures 3 and 4 are the graphs of the ambient and digester slurry temperatures respectively in which a linear relationship was established. If the measured maximum and minimum ambient temperature are known, the minimum and maximum temperature inside a digester can be determined from y = 0.8741 x + 3.158 for pig dung and y = 0.1109x + 21.06 for cowdung.

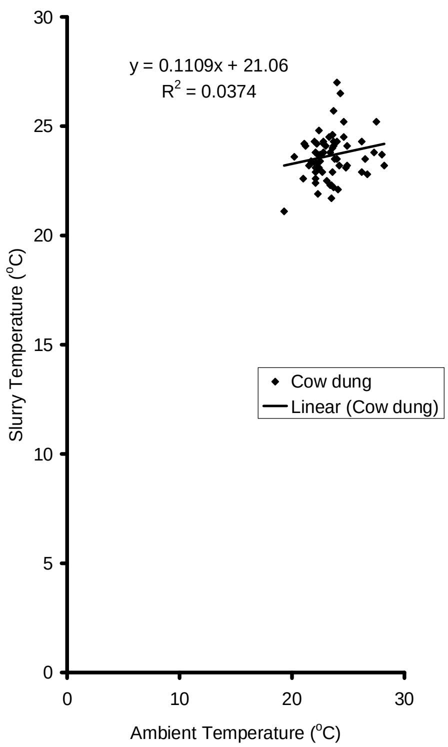


Fig 3: Maximum Ambient versus Slurry Tempreature

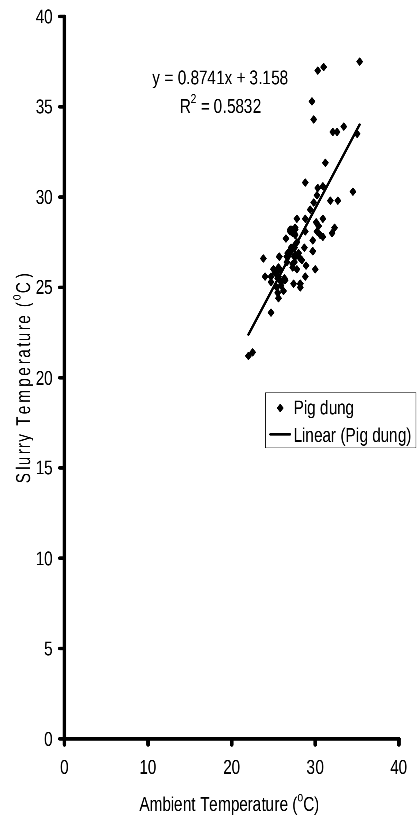


Fig 4: : Maximum Ambient versus Slurry Tempreature

For pig dung, substitute the values of x = 35.3°C for the maximum ambient temperature and x = 22.5 °C for the minimum ambient temperature on the prediction equation y = 0.8741x + 3.158. Their predicted maximum and minimum slurry temperatures were 34.01 °C and 22.83 °C. From figure 3 the equation y = 0.8741x + 3.158 means that y = 0.8741x is the slope of linear line while + 3.158 is the intercept on the y axis. The equation R^2 = 0.5832 shows the coefficient of determination which explains proportion of the two variables. In pig dung R^2 = 0.5832 shows that the straight line is a good line to explain the relationship between them, that is the relation is by 58.32% for pig dung and it is 3.74% for cow dung. The coefficient of correlation was deduced from the coefficient of determination R^2. So the coefficient of correlation for pig dung is the square root of R^2 that is $\sqrt{0.5832}$ = 0.76367.

The correlation coefficient between slurry temperature and ambient temperature for pig dung was γ = 0.76 and for cow dung was 0.1933 which was statistically significant $P \leq 0.05$ and was used to support the claim that increase in the ambient temperature could be attributed to cause increase in slurry temperature.

Proximate analysis of the treated dungs: From table 4 it was shown that the Nitrogen, potassium and phosphorus percentage content increased after digestion. This is because the complex molecules have been broken down to smaller units there by making the elements more available for utilization. The result of the proximate analysis of the waste shows that the sludge or affluent from anaerobic digestion contains more Nitrogen, Phosphorus and potassium. The sludge is rich in nutrients and is an excellent soil conditioner (Eboatu et al., 2006). This sludge helps in plant growth and productivity when added to the soil. The amount of methane to be produced depends on the quantity of the volatile solid in the anaerobic digestion. Nitrogen was determined by micro kjeldehl method as described by Pearson (1976).

Changes in pH during the treatment: From figure 5 it is observed that the pH of pig dung dropped below pH 7.0 within weeks 6 and 8. The reason is that the acid forming bacteria will be breaking down the organic matter and producing volatile fatty acid. As a result the general acidity of the digesting material will increase and the pH will fall below neutral (Garba, 1992). From figure 6 the pressure in the digester on the first 20 days for pig dung and cow dung was 0.43 bars and 0.14 bars.

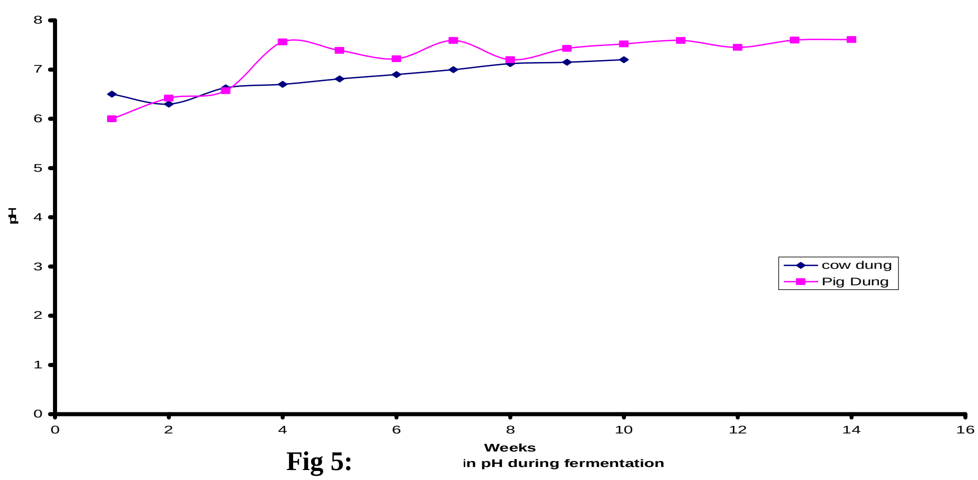


Fig 5:

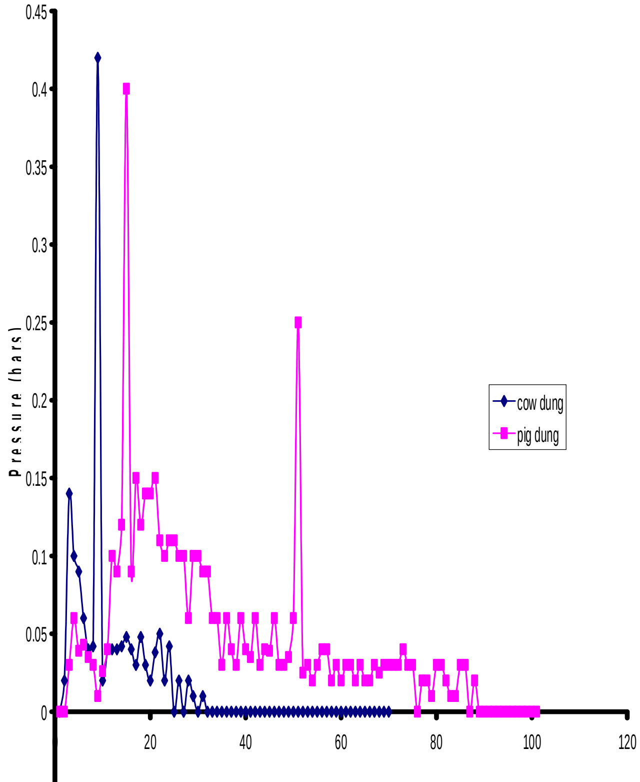


Fig 6: Change in pressure during fermentation

Gas production during the treatment: It is clear from table 1 and figures 7 and 8 that over the retention time of 101 days and 70 days the cumulative gas production was $4.835m^3$ for pig dung and $1.510m^3$ for cow dung. It can be concluded that pig dung produces significantly higher levels of gas than cow dung.

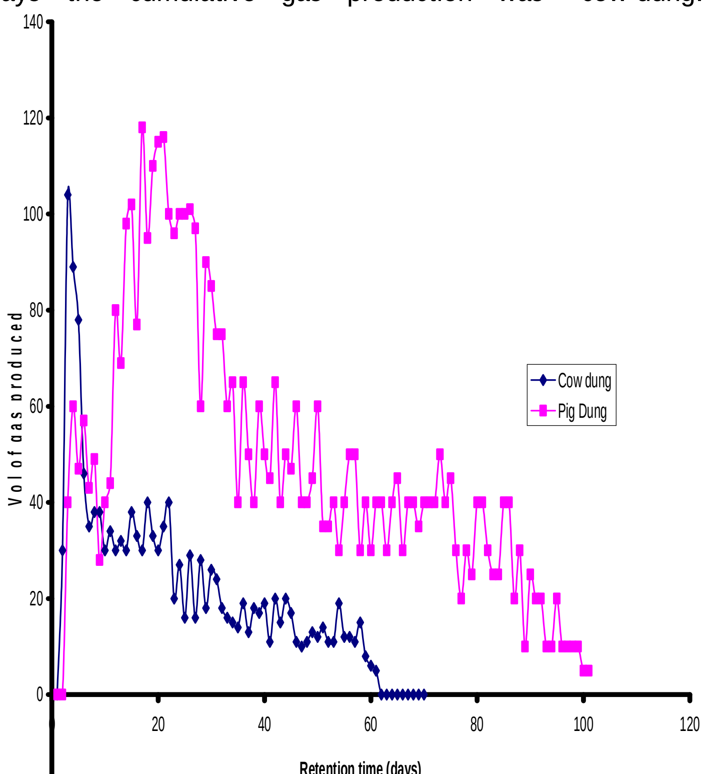


Fig 7: Change in daily volume of gas produced

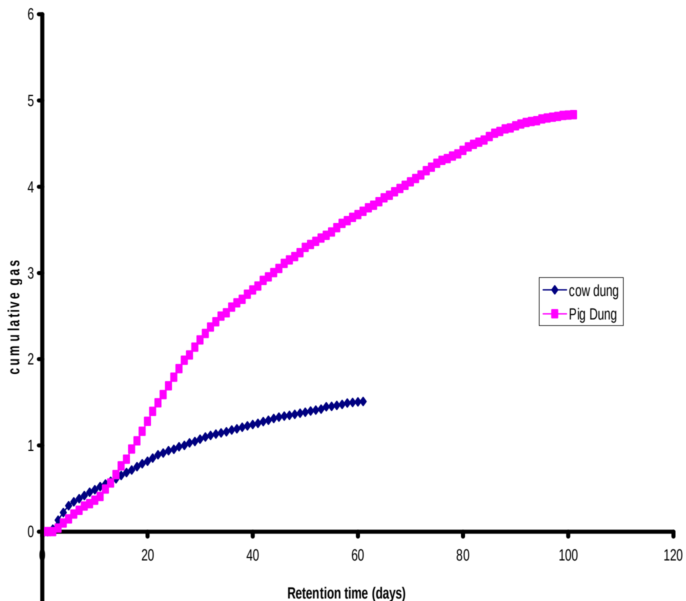


Fig 8: **Daily cumulative biogas generation**

Characteristics of the biogas produced

The biogas produced from the plant was passed to the burner for use and it burned with blue flame. The characterization of biogas components was done with biogas from cow dung using gas chromatography the percentage composition of methane is 63.29mole %, carbon dioxide is 28.20mole% hydrogen sulphide is 0mole% and nitrogen is 2.53mole%. Due to the high cost of Gas Chromatograph analysis,the percentage of the components of biogas, from pig dung was done using 0rsat apparatus. Methane and other components is 70.2%, carbon dioxide is 24.9% and hydrogen sulphide is 1.2%.

Conclusions

In this study mesophilic fermentation was employed. Digestion bacteria have a temperature range in which they are most productive in terms of production rates, growth rates and substrate degradation performance. An Instrument called Thermocouple Digital Thermometer was used to measure the slurry temperature and the optimum temperature range was 19.3 ^{o}C – 37.5 ^{o}C. It was mesophilic fermentation bacteria that initiated the anaerobic digestion in cow dung and pig dung. Cow dung yielded biogas faster than pig dung, while pig dung produced larger amount of biogas. Nitrogen content of pig dung after digestion was greater then that of cow dung. Both substrates have enough carbon and nitrogen elements that meet up the C/N ratio for optimum biogas yield. Pig dung was found to be better fertilizer because of the higher values of N.P.K in the digested wastes compared to those of the cow dung.

Acknowledgement

The authors are grateful to some staff of Energy Research Centre, University of Nigeria Nsukka for their assistance.

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