CONSTRUCTION OF BIO-DIGESTER AND THE ASSESSMENT OF ITS BIOGAS YIELD USING *Manihot esculanta* (CASSAVA) PEELS AND COW DUNG AS BIOMASS

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Abstract: This research work was undertaken to design and construct a workable bio-digester and assess its yield under several conditions. The constructed digester was composed of bio-digester vessel of 20 litres capacity, the pvc pipes which serves as inlet for the substrate and the bucket which serves as the gas collector. The funnel serves as guide for loading substrate, while the PVC valve made of (2 – 5 cm) in diameter was attached horizontally to the digester vessel which serves as collection point for slurry and the metal functions as a flame regulator. The digester was used in the production of biogas by co-digestion of cow dung and cassava peels as substrate (biomass). The yield between 3-30 days ranged from 200 – 11800 cm^3, respectively. The optimum yield was obtained on the 13th day with 11800 cm^3 of biogas yield. Further increase in the number of days, led to decrease in the quantity of biogas produced. Variation in the pH led to variation in biogas yield. The optimum gas yield was obtained at pH of 7.45. pH (2.0-6.4) affected the yield of biogas for the constructed digester due to the increase in the growth of acidic-phobic bacteria . Temperature also influenced the biogas yield. The optimum temperature for the operation of the digester was 34^{o}C with 11800 cm^3 of gas produced. The bio-digester is workable and adaptable to our environmental conditions.

Keywords: Bio-digester, biogas, biomass, cow dung, cassava peels, volatile solid

Introduction

Among the major environmental problems of our society today is the continuous increase in solid organic waste generation (Al Seadi and Holm, 2005). Many countries today, sustainable waste management, waste prevention and reduction are major political priorities and constitute an important share of the common efforts to reduce pollution (Al Seadi and Holm, 2005). Indiscriminate disposal is no longer tolerated today and even controlled landfill and incineration of wastes are no longer an acceptable practices, because current environmental standards and regulation is aimed at energy recovery and recycling of nutrients and organic matter (Moller, 2004).

The microbiological process of decomposition of organic materials in the absence of oxygen is known as anaerobic digestion. It is applied today to produce biogas in airproof reactor system commonly called digesters. Different types of micro-organisms are responsible for anaerobic process which has two major end products; the biogas and the digestate. Biogas is a combustible gas made up of methane, carbon dioxide and small fractions of other gases and trace elements (Adeoti *et al.*, 2000). The digestate is a decomposed substrate that is rich in macro and micro nutrients suitable for use by plant as fertilizer (Xiaohua, 2005). In Nigeria, only few bio-digesters are available. Most do not function and almost all of them available are not for commercial use. With the current crisis in our conventional fossil fuel source, the need to develop and harness alternative energy source has become imperative.

This study provides a method of constructing biogas digester for the production of alternative sustainable and renewable natural gas from waste products. It also provides a means of solid waste management and will serve as a form of reference to any research work on the construction of biogas digester.

Materials and Methods

Design/construction of biogas digester

Bio-digester design: The bio-digester vessel was made of about 20 liters transparent round bottom plastic container of diameter 20 and 37 cm height. The vessel was drilled in three places, one hole at the top center for $^1/_2$ inch metal connector, (1.27 cm) at same top left side a 2 inch (5.08 cm) hole was drilled on the digester vessel, and another hole of 1 inch (2.54 cm) was also drilled on the side of the digester vessel a little above midpoint.

The smallest size plastic bucket (5 litres) was also drilled in two places at the bottom ends. The 2 inch (5.08 cm) pipe was placed inside the digester vessel vertically close to the bottom and a funnel placed on top sealed with pvc glue. The 1 inch (2.54 cm) diameter PVC pipe was attached horizontally to the digester vessel with pvc valve/elbow glued to it using polyvinyl chloride (pvc) glue.

A pipe (hose) of 70 cm length was connected from digester vessel top ½ inch connector to meet the plastic bucket connector at one end down mid-way of plastic bucket height, while another hose of 30 cm length was connected to the other end of the plastic bucket bottom to meet metal valve/fittings using clips. The metal valve served as gas regulator, while the plastic bucket was the gas collector, inverted into another bigger plastic bucket containing water. All perforations were properly sealed with PVC glue and adhesive to make the bio-digester system airtight

Functions of the components

1) 20 litres container served as the digester unit, in which the anaerobic digestion of the substrate (biomass) took place.
2) PVC pipes served as inlet for the substrate.
3) The buckets served as the gas collector.
4) Funnel served as guide/direction for loading biomass.
5) PVC valve served as collection point for slurry.
6) Metal valve served as regulator for flame.
7) PVC cover cork to prevent substrate from smelling out.

Fig. 1: Diagram of digester constructed

Results and Discussion

The zone of inhibition (Fig. 1) of the goat bile against *S. aureus* was 28 mm at 100 mg/ml. The goat bile was also active against *S. typhi* and *E. coli* with a zone of inhibition of 35 and 29 mm, respectively at 100 mg/ml. The growth of *C. albican* was also inhibited with a zone of 25 mm at 100 mg/ml (Fig. 1). The MIC of the bile against *S.aureus* and *S. typhi* was 6.25 mg/ml and 50 mg/ml against *P. aeruginosa* and *E.coli.* The MBC was 25, 50 and 100 mg/ml against *S. typhi, S. aureus* and *E. coli*. The MFC of the bile against *C. albicans* was 100 mg/ml (Fig. 2).

Collection of biomass

Cow dung was collected from an abattoir (cow slaughter slab) at Obiaruku in Delta State, Nigeria. Cassava peels were collected from a Cassava mill in Abraka Delta State, Nigeria. The cow dung and the *Manihot esculanta* (Cassava) peels collected were pretreated separately by sun drying and thereafter crushed with a grinder into fine particle to ensure homogeneity of the dung and the Cassava peels and then weighed.

Assessment of the constructed bio-digester

In this study, 20 liters anaerobic plastic bio-digester was constructed and labeled. The Digester was fed with 50 kg slurry of fermentation substrates. Fermentation slurry was prepared by addition and vigorous mixing of dried cow dung and Cassava peels separately with an equivalent amount of water needed for maximum yield in the ratio 1:1 according to the method described by Itodo *et al.* (2007) (i.e. 25 kg of cow dung and cassava peels to 25 kg of water corresponding to a total solids concentration of 8-11 percent by weight in the slurry). Content above was inoculated with micro-organisms (media). After inoculation, the inlet of the biodigester (i.e. the 2 inch (5.08 cm) diameter hose) was immediately blocked with a PVC cork. Initial temperature and 3 in one pH meter readings were taken and found to be 27℃ and 6.8, respectively.

Fermentation was allowed for a period of 30 days under mesophilic (low) condition (temperature between 27 and 35℃). The pH of the medium was measured and found to be 5.8–6.8 which is within the pH range required for biogas production. During this period the digester was agitated twice a day (morning and evening) to enable digestion take place in the entire medium. The bio-digester was painted with black paint to prevent light penetration which can stimulate algae growth and also to trap the heat that has been absorbed in the day. Leakages in the bio-digester systems were checked by immersing the digester into a water-bath to check for air bubbles at intervals to prevent loss of medium and the gases generated.

Physical properties analysis

1. Total solid: The total solid (TS) was determined by weighing 0.001 kg of the sample and then oven dry at 378ºK for 24 h to allow for the removal of moisture and then the dried sample was re-weighed. TS % obtained by dividing the dry weight by wet weight and multiplying by 100.

$$TS = \frac{\text{dry weight (weight after drying}}{\text{wet weight (10g)}} \times 100$$

(Asiagwu, 2006)

2. Volatile solids: Volatile solids (VS) were determined by burning the dried TS sample at 70ºC with the aid of muffle furnace. This removes the "volatile components". The remaining component is the ash weight, which is subtracted from TS to determine VS.

VS =TS — Ash content (Asiagwu, 2006)

3. Non-volatile solid: A non-volatile solid (NVS) is what remains in the sample after the removal of the volatile solids. NVS% is determined by dividing NVS by TS.

$\%=\frac{NVS}{TS} \times \frac{100}{1}$ (Asiagwu, 2006).

Variation of temperature with biogas production

The funnel that linked to the drum through which materials were loaded was connected with a digital thermometer of about 50 cm length, such that it can sense the temperature of the digesting materials in the drum. It was also ensured that the exit of gas through the funnel was restricted three days after digestion has commenced, the daily changes in temperature and the corresponding gas yield were recorded until after 30 days of digestion (Adeoti *et al.*, 2000).

Determination of the effect ph on biogas yield

The influence of pH on biogas yield was measured by the use of a pH meter. The pH meter was firstly standardized by the use of a buffer solution before the probe was connected via the funnel into the drum so that it can sense the changes in the pH of the digesting medium. After a period of three days the changes in pH and the biogas yield were recorded for 30 days of digestion (Adeoti *et al.*, 2000).

Results and Discussion

The cumulative biogas production during the study period is shown in Table 1. It was observed that biogas production was actually slow at the commencement of the work and also towards the end. This is predicted because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria (Nopharatana *et al.*, 2007). During the first 3 days of observation, there was less biogas production mainly due to the lag phase of microbial growth. Whereas, in the range of 4 to 6 days of observation; biogas production increased substantially due to exponential growth of methanogens. Highest biogas production rate of 11.8 cm^3 was measured on day 13.

It is clear that cow dung and cassava peel are effective feedstock for anaerobic digestion and could significantly enhance the cumulative biogas production. It therefore shows that considerable amount of anaerobic bacteria in the cow dung and cassava peels function effectively to degrade the organic fraction from cattle manure and cassava peel even though pH was unregulated.

Table 1: Variation of biogas yield with days of digestion

Days (t)	Biogas yield (cm^3)
1	-
2	-
3	200
4	350
5	400
6	2200
7	4600
8	7400
9	8800
10	9800
11	11200
12	11400
13	11800
14	11300
15	10900
16	10600
17	10200
18	9800
19	9200
20	8700
21	8300
22	8000
23	7600
24	7100
25	6200
26	5600
27	5100
28	4200
29	2100
30	1400

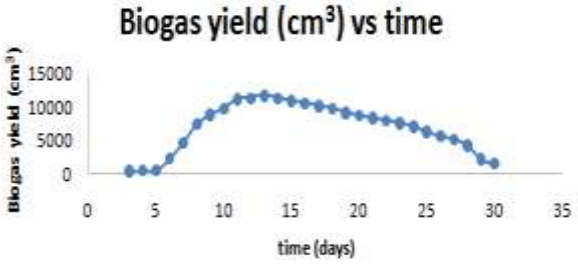

Fig. 2: Variation of biogas yield with number of days

Table 2: Variation of biogas yield with pH

Days (t)	Biogas yield (cm^3)	pH
1	-	6.3
2	-	6.4
3	200	6.6
4	350	6.8
5	400	7.0
6	2200	7.15
7	4600	7.18
8	7400	7.2
9	8800	7.25
10	9800	7.3
11	11200	7.35
12	11400	7.4
13	11800	7.45
14	11300	7.4
15	10900	7.35
16	10600	7.3
17	10200	7.3
18	9800	7.25
19	9200	7.2
20	8700	7.15
21	8300	7.1
22	8000	7.0
23	7600	6.9
24	7100	6.8
25	6200	6.6
26	5600	6.6
27	5100	6.5
28	4200	6.4
29	2100	6.4
30	1400	6.3

The influence of the digestion pH on biogas production is shown in Table 2 regardless of the temperature and retention time. Biogas production of about 11800 cm^3 which was the highest biogas yield was observed at the pH of 7.45, while 11.400 cm^3 was observed for the pH of 7.4. This may be attributed to the increase in growth of acidophlic (methanogenesis) bacteria, which are responsible for methane production, and their activity (Lazor *et al.*, 2010).

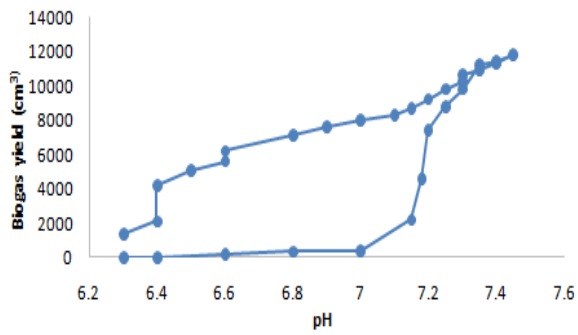

Fig. 3: Variation of biogas yield with pH

Table 3: Variation of biogas yield with temperature

Days (t)	Biogas yield (cm^3)	Temperature (°C)
1	0	27
2	0	27
3	200	27.5
4	350	28
5	400	29
6	2200	30
7	4600	30.5
8	7400	31
9	8800	31
10	9800	32
11	11200	32.5
12	11400	33
13	11800	34.
14	11300	33.5
15	10900	33
16	10600	33
17	10200	32.5
18	9800	32
19	9200	31.5
20	8700	31
21	8300	31
22	8000	30.5
23	7600	30
24	7100	29.5
25	6200	29
26	5600	28.5
27	5100	28
28	4200	28
29	2100	27.5
30	1400	27

Temperature also had a significant effect on the rate of biogas production; regardless of the pH (Fig. 4). According to the results, the biogas production rate was high at the temperature of 34°C, followed by the temperature of 33.5°C. It has been observed that biogas production decreased drastically at the temperature of 50°C (Asiagwu, 2006). This may be due to the annihilation of microorganism metabolism due to high temperature. Biogas production was 11800 cm^3, and 11400 cm^3 at the temperature of 34 and 33°C, respectively.

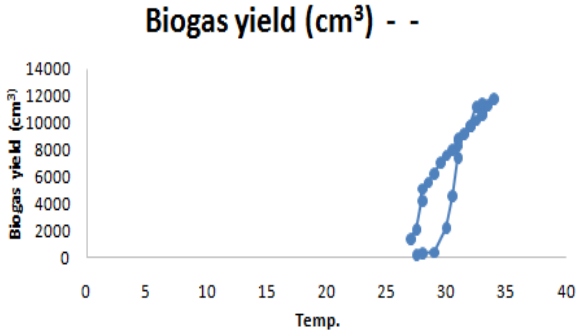

Fig. 4: Variation of biogas yield with temperature

Table 5: Total solids and volatile solids in the digester

Parameters	Cow dung (kg)	Cassava peels (kg)
TS	128	0.75
VS	1.02	0.6

Table 5 shows the TS and VS profiles of the bioreactor content during the experiment. TS and VS discussion is a vital aspect in evaluating anaerobic digestion performance. High total solid could lead to accumulation of inhibiting acids produced during digestion which could affect micro-organisms responsible for biogas conversion (Comino *et al.*, 2009).

Conclusion

The bio-digester constructed from the results of our findings is workable and efficient in the production of biogas for a period of within 30 days. The technology can be developed and the idea put together on a commercial scale to reduce this over dependence on fossil fuels as the only form of energy available. For the effectiveness of the process, an appropriate legal framework for bio-digester in Nigeria, should be adopted and also there should be increase in government spending to develop technical capacity for running and maintaining biogas digesters in Nigeria.

Conflict of Interest

Author has declared that there is no conflict of interest reported in this work.

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