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Manufacture of Biogas from the Anaerobic Treatment of Cow Dung from Federal University of Technology, Owerri Livestock Farm

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Energy from hydrocarbon compounds has over the years been expensive and also played a part in negative health implications amongst others, for this reason alternative sources of energy have been sort for. In the quest for a healthier, more cost-effective energy, cow dung as a renewable source has been proven to be very efficient. This study investigated the manufacture of biogas using cow dung from School of Agriculture and Agricultural Technology (S.A.A.T) livestock farm located in Federal University of Technology, Owerri, Imo State, Nigeria.

25 kg of the cow dung was used in this study. The digestion was carried out in a 50L anaerobic digester at a temperature of 30°C - 36°C and uncontrolled pH for a period of 40 days. The average quantity of biogas produced through the period was 10.39 liters, representing 46% of the total biogas production. The average temperature was 33.0°C. The utilization of cow dung as fuel will also help in the management of waste within the livestock farm. As an eco-friendly source of energy, the biomass generated after digestion can be utilized to improve soil fertility.

Keywords: Energy; environment; health; dung; biogas; sustainable; management; fuel; waste; safe; education.

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1. INTRODUCTION

Anaerobic treatment - The use of biological processes in the absence of oxygen for the breakdown of organic matter and the stabilization of these materials, by conversion to methane and carbon dioxide gases and a nearly stable residue has been a practice as far back as the 18th century. In the middle of the 19th century, it became clear that anaerobic bacteria are involved in the decomposition process.

Anaerobic digestion (AD), is one such well known and widely used method for bioconversion of wastes into fuel, it is regarded as the simplest technique due to its very limited environmental impact and high energy recovery potential [1].

According to National Non -food Crops center fact sheet, 2011; anaerobic digestion is a collection of processes by which micro organisms' breakdown biodegradable materials in the absence of oxygen. A biogas digester is an anaerobic tank which digests organic materials or waste biologically without the use of oxygen (Daisuke et al. 2013).

Agricultural residues and animal wastes are increasingly being diverted for use as domestic fuel to displace fossils fuel and reduce environmental pollution and reduce emission of greenhouse gases [2].

The use of fossil fuels as a primary energy source has led to global climate change, environmental degradation and human health problems. Also, improper waste management is one of the major problems confronting every development. This is because of increased industrial, commercial, agricultural and environmental activities that have resulted in the generation of large quantities of waste. These wastes, when not properly managed contribute to unhygienic environmental conditions that breed pathogenic microorganisms [3]. Apart from the health implications, wastes make an environment unpleasant and unattractive. However, these wastes can be managed properly by conversion into useful and more environment-friendly in the form of biogas for energy production.

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen [4]. It is a renewable energy source, like solar and wind energy.

The possibility of using such wastes for biogas production should be explored. The raw materials used in commercial methane generation include plant residues, animal waste like cow dung and various urban wastes which are available in quantity in Nigeria.

1.1 Problem Statement

The improper management of waste (organic and inorganic) is a very common environmental challenge in major cities and semi-urban areas of most developing nations.

The two enormous problems that are increasingly threatening the live in many nations include the task of waste management and inadequate energy supply. A nation's inability to dispose waste and to find enough energy greatly affects living conditions. The problem of fuel scarcity and sewage disposal in many developing countries including Nigeria is alarming [5]. Energy generation from waste is therefore important as it will serve the dual purpose of enhancing clean environment and providing a cheaper source of energy.

The increase in livestock farms has increased the rate of deposition of livestock droppings in the environment which could lead to the release of a large number of pathogenic bacteria that may be harmful in the environment. Livestock waste in addition with other biogas releases CO2 (an important greenhouse gas) upon its decomposition. This contributes to global warming. Utilization of these wastes and other bio-degradable materials are therefore essential for environmental sustenance, enhancing general health and harnessing/generating energy for general use.

1.2 Objective of the Study

Unlike other organic waste treatment technologies such as composting or wastewater treatment systems, anaerobic digestion can treat both solid and liquid waste together in one process. As the anaerobic digestion process is in an air tight container, vector, dust and odor issues are minimal as compared to utilizing a landfill or composting approach. Once built, the anaerobic digester requires relatively simple management with the main expenses being employing casual labor to oversee their operation and to feed them with waste daily.

This study explores the production of biogas from animal waste using an anaerobic digester. The specific objectives are;

1. To design and construct a biogas digester that will effectively digest animal waste.
2. To produce a renewable source of energy from organic waste.
3. To reduce greenhouse gas emissions from decomposition of organic waste.
4. To generate high quality compost for soil amendment.

2. MATERIALS AND METHOD

2.1 Materials

Every material used in the design and fabrication of this bio-digester was carefully considered and selected based on the knowledge obtained about the materials and their properties. These considerations were looked into in order to select the most optimum material in terms of the properties such as the strength, resistance to corrosion, rigidity, weight, and case joining and also the availability and cost.

The materials used in the construction of a biogas digester using local available materials are;

1. 50 Litre Plastic Tank (Digester)
2. Flexible Gas Pipe
3. PVC Pipe
4. PVC Pipe Cap
5. Thermometer
6. Gas Cylinder (Storage Tank)
7. Gas-Valve
8. Glue and Sand
9. Organic Waste (cow dung**)**
10. Water
11. Weighing Scale
12. Hand-Gloves and Nose-Masks
13. Pebbles, Black Paint and A Heating Stove
14. Gas Cylinder
15. The Purification Chamber

2.2 Method

Firstly, two openings will be made on the top and side of the digester to insert the PVC pipes which serve as inlet and outlet channels. The inlet pipe will be inserted vertically into the digester from the top, while the outlet pipe was inserted from the side of the digester 90 degrees to the inlet pipe. The point of insertion will be made airtight to prevent leakage of gas. Glue and sand will be used to achieve this. Then the pipe that transports produced methane gas will be connected to the top of the digester. The other end of the pipe will be connected to the T-valve which is connected to the storage tank and the gas valve.

The digester is painted black to prevent light from entering the digester. If light is allowed to enter the digester, green algae will grow in the digester. This will make the bacteria undergo aerobic respiration and oxygen gas will be produced. When painted black the bacteria in the digester will undergo anaerobic respiration, releasing methane gas. It is also painted black to maintain digester temperature.

When the construction of the digester is completed, the waste material was mixed with equal amount of water (10 kg of waste and 10 kg of water). The mixture was then poured into the digester. The PVC pipe (inlet and outlet channels) was corked with the PVC pipe cap to prevent escape of gas from them. The digester was left for about 40 days for the digestion to take place. In the absence of light, the bacteria in the digester was under anaerobic respiration and released methane gas through the flexible gas pipe to the storage tank (cylinder). The stored gas was then ready for use.

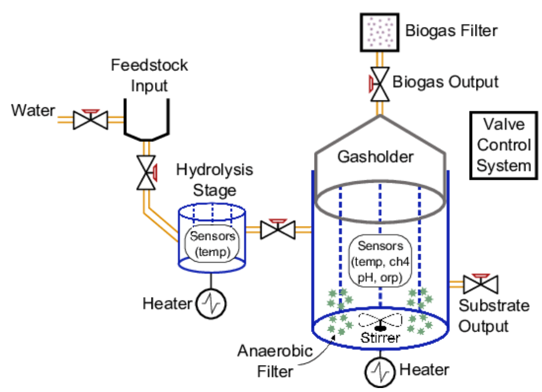

Fig. 1. Schematic of a typical domestic anaerobic digester for biomass
Source: www.researchgate.net

The purification chamber was then prepared by fitting in two tubeless valves on the lid of the chamber, one valve serving as input and the other as output. The input valve was fitted to a gas pipe with a gas control valve attached to control the flow of gas to-and-fro the digester. A gauge valve was also added on the lid to control the inflow of stripping limewater added to the chamber. A secondary outlet was included by the side of the chamber for gas measuring purposes such that the amount of water leaving through that outlet equals the amount of gas entering the system from the digester and this shows the amount of biogas produced per day.

The storage system consisted of a tube designed to withstand high pressure gas storage. A section of the tube was opened and a gas valve attached to serve as an outlet/flare zone, while the first opening serves as an inlet connected to the purification system to collect the upgraded biogas.

A fresh sample of solid cow dung was collected from the livestock farms, School of Agriculture and Agricultural Technology, FUTO Imo state at exactly 2:00 pm on the 30th of August, 2016. The sample was weighed and mixed with water at a ratio of 1 kg: 2 kg and fed into the biogas digester with the aid of a funnel and 30 liters of the mixture was fed to the digester. The resultant mixture was prepared to have high water content so as to increase the rate of biodegradation/ methane yield and was manually sieved to separate organic materials from inorganic hazardous materials that could disrupt the balance of the system with respect to the microorganisms' survival.

After the bio-digester has been fed, it was stirred (see Stirrer in Fig. 1) twice a day to ensure proper mixing and distribution of nutrients for the microorganisms. A little heat was applied to the bio-digester using a heater (see Heater in Fig. 1) for 30 minutes daily to help maintain temperature conditions above 25°.

3. RESULTS

The flammability of the gas was tested by flaring the resultant gas through the gas valves under controlled and safe conditions. The presence of methane was determined by the presence of a brightly burning blue flame, while the presence of carbon dioxide was reflected by the milky water found left behind in the purification chamber daily.

Table 1. Summaries of results for the waste stock

Items	Quantity
Mass of waste used(kg)	25
Mass of water used(kg)	50
Total mass of slurry(kg)	70
No of days of digestion	40
Total volume of methane(liter)	204.3
Minimum slurry temp. (°C)	22
Maximum slurry temp.(°C)	36
Peak volume of gas(liter)	15.4

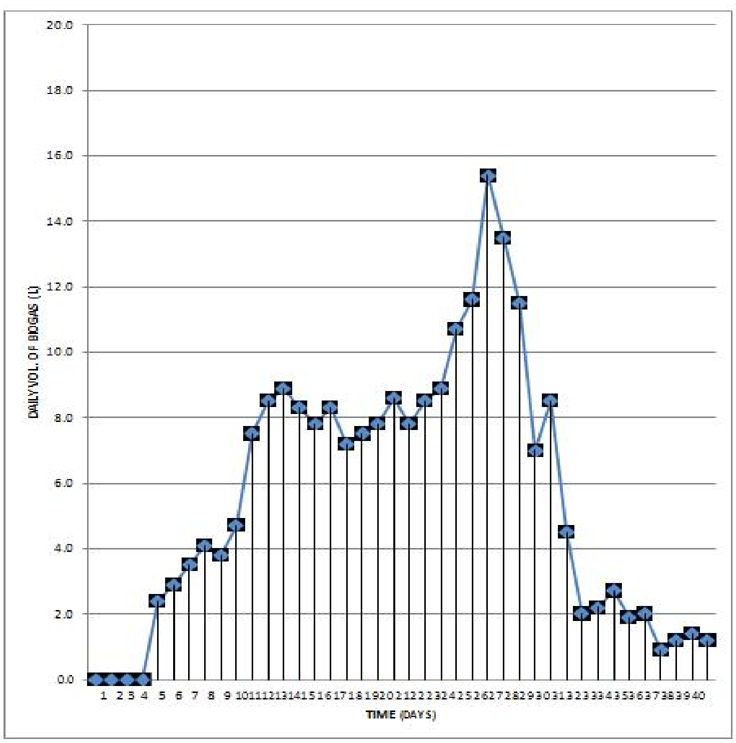

Fig. 2. Biogas volume Vs time (Days)

Table 2. Daily production of methane / slurry temperature

Days	Daily volume of gas(l)	Cumulative volume of methane(l)	Slurry temp(°C)
1	0.0	0.0	22
2	0.0	0.0	28
3	0.0	0.0	30
4	0.0	0.0	28
5	2.2	2.2	29
6	2.9	5.1	31
7	3.5	8.6	30
8	4.1	12.7	28
9	3.8	16.5	29
10	3.9	20.4	28
11	6.9	27.3	28
12	8.5	35.8	30
13	9.2	45.0	29
14	8.9	53.9	28
15	7.8	61.7	29
16	8.3	70.0	33
17	7.0	77.0	32
18	7.7	84.7	30
19	7.8	92.5	29
20	9.4	101.9	30
21	7.8	109.7	31
22	8.5	118.2	32
23	8.9	127.1	32
24	10.7	137.8	33
25	11.6	149.4	34
26	15.4	164.8	36
27	13.5	178.3	35
28	11.5	189.8	35
29	7.0	196.8	32
30	9.0	205.8	30
31	4.5	210.8	29
32	2.0	212.8	28
33	2.2	215.0	29
34	2.7	217.7	28
35	0.9	218.6	27
36	2.0	220.6	29
37	0.7	221.3	30
38	1.2	222.5	28
39	1.0	223.5	26
40	1.2	224.7	24

It was observed that biogas production was actually slow at the beginning and the end of observation. This is probably because biogas production rate in batch conditions is directly equal to specific growth of methanogenic bacteria. During the first 4 days observation, there was less biogas production and mainly due to the lag phase of microbial growth. Whereas, in the range of 5-7 days of observation; biogas production increased substantially due to exponential growth of methanogens. Highest biogas production rate of 15.4 liters was measured on the 26th day and the temperature was at a high level of 36°C which indicates a high range of activity and an increase in microbial population.

Towards the last quarter a decrease in temperature was recorded and the biogas production also depreciated drastically this is as a result of the decrease in nutrient (cow dung) available in the digester therefore leading to a decline in the microbial population. This is also reflected in the loss in temperature.

During the early stages of the study period the biogas production was delayed as a result of the commencement of the various stages of the anaerobic fermentation of methane which involves:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

At the early stages of the first quarter ranging from 1 – 5 days, the production of methane is mainly from the reduction of acetic acid by hydrogen gas. This continues through this period till methanogenic bacteria grow in order to breakdown the cow dung available.

The fermentation of cow dung during this study was divided into 4 periods based on the results obtained for both the biogas produced daily and the slurry temperature over the hydraulic retention time of 40 days starting from the 30th August to 8th September, 2016. These periods are:

1. The First Quarter: From day 1 to day 10. This quarter began from the day the bio-digester was loaded with cow dung slurry. It is in this quarter that hydrolysis, acidogenesis, acetogenesis and partial methanogenesis took place. The biogas production began on the 5th day and showed slow progression up till the 10th day. Most of the methane produced at this 1st quarter was through the reduction of acetic acid. The average biogas production during this period was 2.04 litres and this represents 10% of the overall biogas production while the average temperature was 28.5°C.

2. The Second Quarter: From day 11 to day 20. In this quarter the microorganisms were slowly increasing in population and began participating in the biogas production. The average biogas production was 8.5 litres representing 35% of the entire biogas production while the average temperature was 29.8°C.

3. The Third Quarter: From day 21 to day 30. This was the period in which maximum increase was recorded in temperature and biogas volume, which implies that it is the period of the highest growth in microbial population. The maximum biogas volume of 15.4(litres) and the maximum temperature of 36°C were both recorded on the 26th day (25th September, 2016). The average biogas produced during this period was 10.39 litres representing 46% of the total biogas production while the average temperature was 33.0°C.

4. The Last Quarter: From day 31 to day 40. This period was the conclusion of the fermentation process with diminishing nutrient available for the microbes. The biogas production showed a rapid decline due to the decline in the microbial population. A decline in temperature was also recorded due to the decline in activity of microorganisms. The average biogas volume recorded was 1.84 litres representing 9% of the total biogas production while the average temperature was 27.8°C.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study shows that cow dung holds a good promise in the cost-effective production of biogas. It is also important to note that biogas also can help to potentially reduce climate change as it is environmentally friendly. Therefore, Nigeria needs to harness this medium to boost its energy production as also reported by Ozor, et al. [6].

The study revealed further that cow dung as animal waste has great potentials for generation of biogas and its use should be encourage due to its early retention time and high volume of biogas yields.

Utilization of biogas in the transport sector is a technology with great potential and with important socio-economic benefits. Biogas is already used as vehicle fuel in countries like Sweden, Germany and Switzerland.

Bio-methane vehicles have substantial overall advantages compared to vehicles equipped with petrol or diesel engines. The overall carbon dioxide emissions are drastically reduced, depending on the feedstock substrate and origin of electricity (fossil or renewable) used for upgrading and compressing. Emission of particles and soot are also drastically reduced, even compared with very modern diesel engines, equipped with particle filters. Emissions of NOx and *Non Methane Hydrocarbons* (NMHC) are also drastically reduced.

Upgraded biogas (bio-methane) is considered to have the highest potential as vehicle fuel, even when compared to other bio-fuels.

4.2 Recommendation

Cow dung could be used as a suitable substrate for biogas production. If carried out at commercial scale, would not only provide an alternative source of energy but would also be a means of waste disposal for Nigeria. These wastes can be harnessed and used through conversion into biogas for energy production. The rampant use and locations of septic tanks in individual homes which characterizes mainly of human wastes can be pre-designed initially to function as a biogas digester which would anaerobically digest these wastes that are abundant and are convert them into biogas that can be channeled back into the kitchen of the household using the septic tanks.

Biogas production could be employed by Nigeria in the generation of electricity which has been a major problem for industries. This activity would definitely generate jobs and develop the agricultural sector for economy diversification.

It is also an effective way of reducing the emission of CO2 from decaying organic matter into the atmosphere. The bye product can be used as compost for soil enrichment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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