

DEVELOPMENT OF MODIFIED BIO-DIGESTER TANK FOR RENEWABLE ENERGY SOURCE USING URINE AND RAM DUNG

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Abstract

The high rate of fossil fuel depletion, its effects on the environment and the instability in crude oil prices has consolidated in the search for other alternative source of non-fossil fuels which are renewable, biodegradable and environmentally friendly. In this research a modified biodigester was locally constructed how to develop, using a steel drum, which have the capacity of about 20kg bio-methane gas storage tank of about a hundred litres of water displacement tank of 15 litres standard steel drum. It was used for the generation biogas (biomethane): Using ram dung and urine as the major feedstock. The major aim of constructing this bio digester tank was to use it to produce biofuel, by converting biodegradable biological waste into useful clean biodegradable fuel which will be safe for both human health and the environment.

Keywords: Bio-digester, Feedstock, Bio-methane, Biodegradable, Biogas.

1. INTRODUCTION

Energy is very essential to national development. It is the focal point around which industrialization of any country or nations revolves. Currently, there is a global paradigm shift from petroleum-based economy to bio-based universal economy. This means that on a daily basis, there is constant continuous research on transformation of biological waste into useful, and eco-friendly resources for home and industrial use. (Achinas et.;al 2018) Opined that Biogas is a renewable source of energy. (Adenikin et.;al 2017). Research has shown that the value of fossil fuel is declining on daily basis while the production of biogas from anaerobic waste is of growing interest in advanced and developing nations. (Adaramola and Oyewole 2011). Energy is therefore of great importance to the development in all sectors of economy. Ahmadu, (2009). Emerging nation like Nigeria should not be underrated as it is necessary to enhance development and self-reliance within the country. (Avicennaa, et.; al, 2015).Energy is a fundamental component of

national development and a key factor to eradicate and eliminate poverty in the world. (Barua and Kalamdhad, 2016). According to Milono et al.; (2017). Methane gas generally composes of hydrogen sulfide, hydrogen, nitrogen, carbon dioxide and methane. The composition of methane gas depends on the type and nature feedstock available in the digester. Natural or organic waste has been primarily used for biogas production. According to El-Saeidy, (2010). Raw cassava tubers, the cheap and abundant agricultural product in Thailand, are initially investigated to be used as a raw materials for the bio-energy. Production of ethanol from wood and all forms of agricultural waste. Hu et al., (2008), production of biogas from cow manure and food waste by Xing et al., (2020), production of biogas from hybrid Sea or aquatic weeds such as salvinia, water hyacinth and cabomba, other biodegradable wastes are kitchen garbage. Yuan et al., (2019). Mendoza et al., (2020) conducted research on the effect of lipid extraction method for biodiesel production and integrated recovery of biogas. Anaerobic digester is a valuable component or system for storage of decomposable waste to support production of gas and the process of production of methane gas through anaerobic digestion (AD) is quite complex since it requires biological and chemical procedures. According to Colorado et al., (2010). Starting up and set-up process for anaerobic digester require approximately 2 to 4 months. It also requires additional 2 to 4 months to analyze the efficiency of the process. Within the period of aerobic degradation, the carbon is transformed to carbon dioxide which is further released as a mixture of methane and carbon dioxide. Biogas is considered a useful product since it contains vital energy potential of approximately 50 MJ kg for methane, by (Wan B, 2004) and roughly 25 MJ kg for biogas at 75% methane content according to (Dasappa 2005). There is a common practice of burning waste materials in developing world. Biomass is seen to be capable of polluting the air during burning, but however, the rate of pollution is less compared with fossil fuel. During burning of biomass, carbon dioxide which is a greenhouse gas is released. The sustainable cycle of biogas was discussed in detail.

2. REVIEW OF LITERATURE

Production of biogas and its usage will greatly reduce global warming and offer an opportunity for extenuation of greenhouse gas emission. Biogas production has proven to be ecofriendly alternative energy source and a successful way of reducing pollution and greenhouse emission. (Eze & Onwuka; 2007). The major focus has been on efficient methods of harvesting biogas from biodegradable wastes of plants and animal origin and the application of the produced gas for generation of heat, light, electricity and power. Basically, the effectiveness of biogas production system is affected by the nature of the following: biodigester, the feedstock, characteristics and the bio-process operating conditions. Fulford (2011). Among the operating conditions, blends of the raw materials is easy to vary by optimization. The generation of biogas is an eco-friendly and a successful way of reducing pollution and greenhouse effect that is causing global warming. (Hadi, 2014). Hence, researchers and strategist in field energy tend to explore classical and global techniques to harvest large volume of biogas from decomposable plants, animals and other forms of municipal waste. (Gunja, et.; al). This has necessitated the exploration and exploitation of renewable energy alternatives (Owamah, 2020; Owamah et al., 2020; Onochie et al., 2021) and Okwu et al. (2020). Opined that the production of biogas from waste organic substances is a viable alternative energy as resulting digestates are also utilized as compost for farming. Anaerobic digestion improves agricultural productivity, generates bio-fuel and reduces environmental

pollution (Almomani et al., 2019; Almomani and Bhosale, 2020). Although bio-energy especially biogas has been established as a sustainable alternative energy source based on environmental impact assessment. (Igboro, 2011). And According to (Ignatus, 2016), the sustainability of the supply of the chosen biomass is an important factor for consideration in biogas production.

BASIC CONSIDERATIONS FOR BIO-DIGESTER DESIGN AND FABRICATION

A smaller unit of biodigester was developed at the College workshop and the gas production level was quite low. This necessitated the need to develop a larger digester with floating drum capable of producing large quantity of gas. The major factors put into consideration in the design of the modified digester include the design concept, models and calculation.

2.1 Calculation for the volume of the biodigester tank

The capacity of the tank designed for production of gas has an estimated volume of 150 litres. The height and volume of system were computed based on the estimated volume of the digester tank. The shape of the designed tank is conical and cylindrical. Let the volume of the digester be represented as

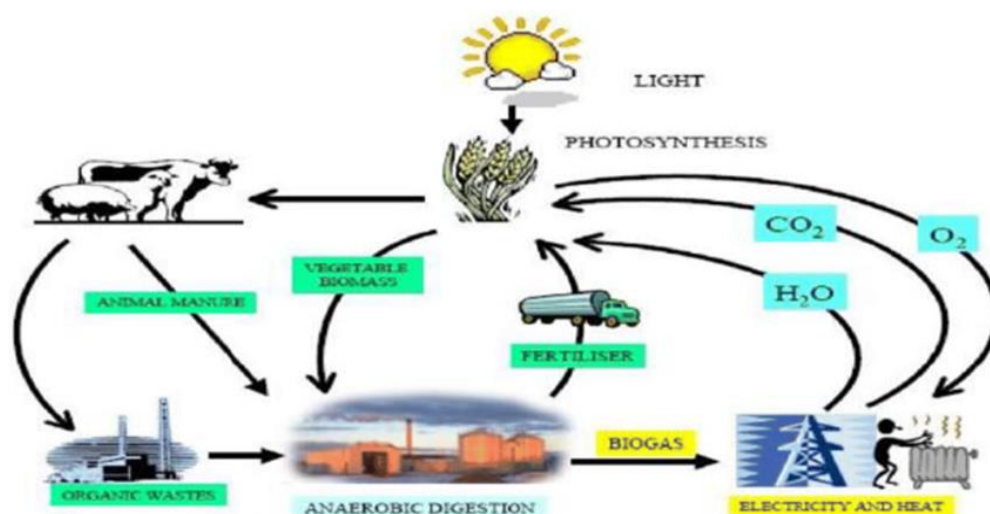
2.2 Calculation for the volume of the biodigester tank

The capacity of the tank designed for production of gas has an estimated volume of 270 l. The height and volume of system were computed based on the estimated volume of the digester tank. The shape of the designed tank is conical and cylindrical.

Let the volume of the digester be represented as V_d Volumetric capacity of bio-digester tank; $V_d = \frac{1}{4} \pi r^2 h$ (1)

where:

V_d volume (m^3),
 r radius (m),
 h height (m),
 π 3.142



Let the cylindrical volume of bio digester tank be represented as; (V_c) Cylindrical volume of bio digester tank ($V_c = \pi r^2 h$)

Let the conical volume of the bio digester tank be represented as (V_{cn}), The conical volume of the bio-digester tank $V_{cn} = \frac{1}{3} \pi r^2 h$ Therefore; the volume of the bio-digester tank $V_d = V_{cn} + V_c$

3 MATERIALS AND METHOD

3.1 Material sourcing

Poultry wastes and ram dung can be obtained Oko market slaughter.

When these wastes are collected, it can be kept in the clean polyethylene sacks, stored at room temperature (25 degrees) for two hours

No pretreatment is needed.

The wastes will be directly used to prepare slurry feed,

Materials for construction such as mild metals and welding diodes can be obtained tools market Onitsha Anambra State.

Analytical probes such as thermometer, pressure guage can be obtained from SAMKEZ Services and Mac-diamond Industries Limited, Warri, Delta State.

Digester design and fabrication process which includes metal cutting, rolling and welding. Followed by grinding and poly filler.

Sample preparation

1. A ram dung (7 days old) suspension was prepared by taking 300g of ram manure and 600g of urine (ration 1:2 of cow dung and urine).

2. Solid waste suspension was prepared by taking 150g of food waste (biotech culture. I.e. fermentation of food waste by microorganism) and 300g of water (ration 2:1 of food waste and water). Biogas (Bio-methane) Production Experiment Uses wastes during the biogas (bio-methane) production are: ram dung, urine and biotech culture (fermentation of organic waste). The reason for the choice is that the first step of prevailing of ecological thinking is predomination of the principles of sustainability, indeed the most effective environmental investment is recycling of organic wastes. Besides the biologically active thin manure in high concentration and quantity, which is a source of potential environment pollutant in animal breeding, the residues of distillation can also serve as the basic material of biogas production, which takes form on the course of the production of alcohol, and in distillery. The period of the experiments is 11 days. We loaded the experimental bio- digesters with 300g cow dung and 600g of the ram urine (slurry) and biotech culture, the bio-digesters.

3.2 Digester design and fabrication

Materials used for construction such as mild metals and welding electrodes were obtained from JIMCO Nigeria limited. Analytical probes such as thermometer and pressure gauge were obtained from SAMKEZ Services and Mac-diamond Industries Limited, Warri, Delta State. The design models used in this research include fabricated 2-mm-thick steel drum as the bio digester, the standard 217-L oil steel drum as the water holding tank, and a small steel drum as the inverted floating drum tank. The cylindrical digester chamber having an inlet pipe and two outlets for slurry collection and the gas collector tank (the floating drum tank which is inverted in the water holding tank). The floating drum is inverted and floats on the water tank as it captures the gas.

The generated gas from the gasp digester unit is trapped in the floating gas tank which displaces upward as guided by the frame and central rod for effective balance. The pressure generated by the gas greatly relies on the weight of the floating drum per unit area. The digester is made up of steel and PVC plastic for the inlet and outlet pipe. The structural design of the digester and the storage tank is shown in Fig. 2 and the model of full model is shown in Fig. 3.

3.3 Fabrication process of the digester

Different valuable materials sourced locally were used for the construction of the digester and floating drum tank. The materials include Flexible gas pipe, body fillers, 2 steel drums, steel pan cover, steel pans 2×, desulfurizer PVCs clips 2×, ½ inch elbow 5×, 1 ½ ball gauge 4×, PVCs glue 2×, auto weld sealant 3×, bearing 4×, Teflon tape, 1 ½ union 2×, reducer 2 in.—1 in. 2×, 1 in. pipe, 1 in. socket, ½ inch socket, reducer 1 in. by ¾ in., 1 ½ inch pipe, ½ inch adaptor, 1 ½ inch tee, 1 ½ inch cap, 6 bolts and nuts, washer 12×, 1 in. adapter, sealant 5×, 1 in. socket, 1 in. G.I pipe, ¾ G.I pipe, ½ in. center rod, steel rod. The design specification and bill of material for the digester are shown in Table 1 and Appendix 2 respectively.

Steel; The bio-digester tank and the floating drum tank were fabricated steel 2-mm thick. Steel was selected for the construction because of the following reasons: high strength; cheap and available; ductile and easy to work with; standard toughness; easily welded and durable.

Polyvinyl chloride (PVC) material; This is one of the most commonly used thermoplastics in the world. It has an amorphous structure with polar chlorine atoms in its molecular structure thus having high chemical stability. The purpose for selecting pvc pipes for this design includes the following: High fire retarding properties; high durability; high resistance to oil/ chemical reactions; high tensile strength; readily available and cheap; very dense.

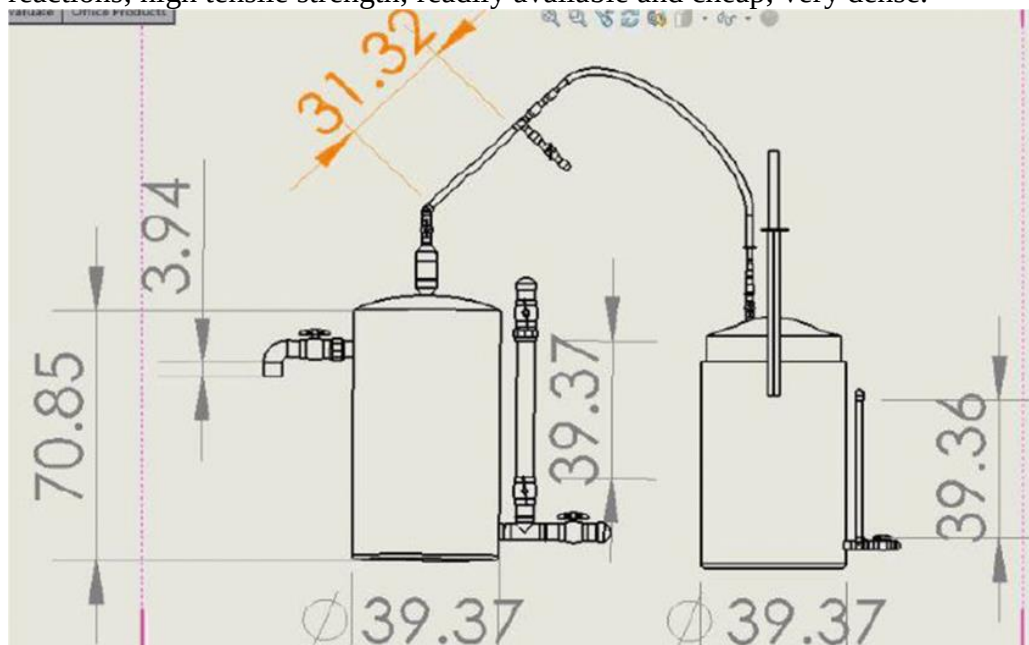




Fig. 3. Model of the digester and storage tank

Iron bearings: The bearings were made from iron to enable it withstand the total weight of the digester when fully loaded. They are three (3) in numbers and were welded to the base of the digester for easy movement of the system.

Auto sealant and abro gums: These sealants and abro-gums are mostly used when dealing with plastic and PVCS, due to their high water resistance, long life span, durability, and ability to withstand pressure. It is cheap and also readily available.

3.4 Feedstock choice and consideration:

The major feedstock used in this research is the dairy cow manure (cow dung). The secondary feedstock includes urine, food waste, and grasses. Cow slurry is a preferred inoculant "as a result of its availability in Delta State; it also has stable concentration of volatile acid forming bacteria (saprophytic bacteria) that feed on decaying organic matter and methane producing bacteria that feed on volatile acids (Mshandete & Parawira, 2009)

3.5 Procedure/analytical techniques

The sourced animal wastes were properly mixed with water at the workshop using 80-L plastic container in the ratio 1: 1. The slurry temperature and pH value were taken and recorded. The decomposable wastes were poured into the 2-mm-thick steel bio digester drum with the aid of a plastic funnel. The digester was filled to 80% of its total volume and left till retention time where methane gas was seen flowing into the cylinder. The gas slowly passes through the filtration chamber containing steel wool and activated carbon to filter the hydrogen sulfide (H₂S) from the gas. The gas further flows into the water holding tank where it bubbles through the water mixed with caustic water to dissolve the carbon dioxide from the biogas and then enters into the tank. As the gas flows into the tank, it displaces upwards, floating on top of the water. The full set up is shown in Fig. 4. The outlet valve opens as soon as the gas gets filled to allow easy flow of the filtered gas into a storage bag. From the storage bag, the gas is collected with a compressor which

was compressed into a modified cylinder. The cylinder was connected to a modified gas carburetor in a biogas generator for power generation.

3.6 Removal of impurities from biogas produced: The gas produced comes with impurities. It is appropriate to refine the gas to a standard methane gas. There are several methods of removing impurities like hydrogen and carbon dioxide from the biogas. In this research, desulfurization method was considered because it is cheap and effective and uncomplicated.

RESULTS

The table below shows the accurate volume of biogas produced from the feedstock used in the bioreactor for a period of 11 days, also some physiochemical parameters like moisture content, Ash content and Nitrogen content were analyzed.

Table 4.1: Volume of the biogas produced within the period of 11 days

Days	Sample A	Sample B
1	0.00	0.00
2	0.30	0.20
3	0.80	0.70
4	1.50	1.60
5	2.40	2.60
6	3.40	3.90
7	4.60	5.50
8	5.90	7.50
9	7.40	9.90
10	9.00	12.30
11	10.90	14.90
12	11.00	15.00
13	11.90	16.50
14	12.00	16.90
15	12.90	17.01
16	13.00	17.05
17	13.90	17.40
18	14.00	17.90
19	14.90	18.07
20	15.00	18.40
21	15.93	18.89
22	16.02	19.02
23	16.60	19.90

24	17.01	20.04
25	17.70	20.30
26	18.04	20.50
27	18.90	21.09
28	19.30	21.70
29	19.90	22.60
30	20.00	22.90

Table4. 2: Volume of biogas and Physiochemical Parameters of the sample.

Volume of biogas produced	Sample A (ml)	Sample B (ml)
Volume of biogas produced from the bioreactor	10.90	14.90
Volume of biogas produced after purification	15.00	16.00
Parameters	Composition % of Sample A	Composition % of Sample B
% Moisture Content	71.90	67.90
% Ash Content	24.50	24.45
% Nitrogen Content	4.34	3.43

DISCUSSION

From the experiment conducted in table 1 shows that the volume of gas collected through the downward delivery at the temperature between 28-32 degrees through the retention period, shows that gas yield started from day two for both samples, producing 10.90 and 14.90 respectively. As days increases so the yield also increases due to the presence of inoculum. This shows the effectiveness of the inoculum on increasing gas yield.

5. CONCLUSION

In the study, biogas was produced by microbial poultry wastes of ram dung and urine in the absence of air. These wastes were analyzed for use in the production. Bio-digester was developed and slurry was poured into the developed digester under strict monitoring. From the result of the experiment conducted using retention time of 4 weeks (30 days), it was deduced that the feed optimally generated biogas within the space of 4 weeks. Purification of the gas produced was actualized after which the gas was stored in a storage vessel; further storage was done using a tube from motor vehicle to achieve robust quantity of gas. Further analysis showed that methane had higher percentage in the biogas produced. After the purification, the result of the flame test showed that the methane burns with a blue flame. Furthermore, methane has the highest displacement in the response (mV) to time (min) graph which shows a percentage of 99.77% CH₄ in the gas produced after absorption of H₂S and water content. Conclusively, biogas production

technology has been proven to be a technology with great potential in the energy scene which is considered useful traditionally and globally. It is domestically and industrially useful with broad utilization for cooking, useful as source of fuel to power domestic generator and vehicles. The Federal Government of Nigeria through the Energy Commission Nigeria (ECN), Ministry of Science and Technology, and rural development organs could utilise this technology to curb the environmental menace of open defecation in Nigeria. Also, indiscriminate disposal of fecal waste matter can be effectively eradicated through enterprise development biogas production facilities to receive organic wastes, hence create employment for youths throughout the entire value chain.

RECOMMENDATIONS

Recommendations for the Production of Biogas from Biodegradable Feedstock:

1. **Feedstock Selection:** Choose biodegradable feedstock carefully based on local availability, cost-effectiveness, and its suitability for biogas production. Conduct feedstock characterization studies to understand its composition and potential for gas production.
2. **Optimize Process Parameters:** Continuously monitor and optimize key process parameters such as temperature, pH, and retention time to maximize biogas yield and quality.
3. **Digester Management:** Develop efficient strategies for digestive management, as the byproduct of biogas production can be used as a valuable fertilizer. Implement proper storage and application techniques to minimize environmental impact.
4. **Biogas Purification:** Depending on the intended use, consider biogas purification techniques to remove impurities like CO₂ and H₂S. This can enhance the energy content and quality of the biogas.
5. **Safety Measures:** Prioritize safety in biogas production facilities, including proper ventilation, gas leak detection systems, and employee training to ensure safe operation.

SUGGESTIONS FOR FURTHER STUDIES

Suggestions for Further Studies on Biogas Production from Biodegradable Feedstock:

1. **Feedstock Variability:** Investigate the impact of variations in feedstock composition and quality on biogas production. This can help develop strategies to handle different feedstock types effectively.
2. **Microbial Communities:** Study the microbial communities involved in the anaerobic digestion process. Understanding the microbial dynamics can lead to better control of the biogas production process.
3. **Enhancement Techniques:** Explore novel techniques to enhance biogas production, such as co-digestion with various feedstocks, pre-treatment methods, or the use of microbial additives.
4. **Biogas Utilization:** Investigate innovative and efficient ways to utilize biogas, including combined heat and power systems, upgrading biogas to biomethane, or using it as a transportation fuel.

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