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Development of an Improved Biogas Digester for Household Application

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***Abstract**: The efficient use of energy is crucial for various applications, particularly in households reliant on fuel. It plays a pivotal role in driving economic and social development. However, global energy shortages, including in Nigeria, highlight the need to explore alternative sources, such as biomass. A biogas digester, utilizing anaerobic digestion to convert organic waste into energy, emerges as a promising solution. This project aims to enhance household energy production by developing an improved biogas digester, using cow dung as a feedstock. The process involves developing and evaluating the performance of a bio digester constructed with a 120L PVC tank, a gas collector, dryer, rubber hoses, burner, and seals. While the results indicate the suitability of cow dung for biogas production through anaerobic digestion, challenges such as elevated moisture content and insufficient retention time affect the combustibility of the generated gas.*

***Keywords**: Biogas digester, biogas, cow dung, energy, anaerobic digestion*

1.0 Introduction

The importance of energy extends beyond domestic applications like cooking and lighting to industrial uses such as powering motors and electric furnaces, as well as serving as fuel for transportation. Its importance lies in being the fundamental driver of both economic and social development(Jamie & Susan, 2000). The expansion of energy is intricately tied to global well-being and prosperity. Safely and environmentally responsibly meeting the growing demand for energy poses a significant challenge. Amidst global market uncertainties, one certainty is the world's continuous need for increasing energy to foster economic and social advancements, ultimately striving for an improved quality of life. Renewable energy, derived from naturally replenishing sources like sunlight, wind, rain, tides, waves, and geothermal, plays a crucial role in addressing this demand(Omar, Haitham, & Frede, 2014). Energy shortages are a global issue, and Nigeria is no exception. Despite Nigerian refineries having a projected refining capacity of 445,000 barrels per day, the actual output falls significantly short of this capacity (Olusola, 2020). Moreover, the refineries fail to capture the gas emitted during the refining process, opting to burn it as flares instead.

Nigeria is experiencing a concerning and alarming pattern of deforestation, estimated at 300,000 hectares annually(Girod & Jacques, 1998).
The primary and predominant source of energy is fossil fuels, constituting 86% of the overall energy supply(Kaliyan & Morey, 2009). Agricultural residues and animal waste are increasingly being repurposed as sources of energy, leading to a reduction in pollution. These materials play a significant role in the production of biogas, generated through the anaerobic (no air or limited oxygen) bio-degradation process facilitated by bacteria acting on organic matter. In its unpurified state resulting from the anaerobic process, biogas theoretically consists of primary elements, mainly methane (CH_4) and carbon dioxide (CO_2), alongside other components like Hydrogen Sulfide (H_2S), Ammonia (NH_3), Hydrogen (H_2), Nitrogen (N_2), Carbon Monoxide (CO), saturated or halogenated carbohydrates, and Oxygen (O_2). The high methane content, approximately 55-65%, makes biogas a potent fuel. Generally, the composition of biogas is a blend of 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 5-10% hydrogen gas (H_2), and the remaining gases, including approximately 2% H_2S (Kardo & Arysca, 2019).
Biogas digester is energy-efficient and waste handling sustainable technique. The development of biogas promotes waste handling and reduces greenhouse gas emission. It also improves sanitation and energy for quality life in rural areas (Luana, et al., 2019). In Nigeria, the use of bio digesters is not wide spread but the abundant energy available from biomass can be meaningfully introduced into the nation's energy mix through the development of a comprehensive program on bio digesters, such sustainable programs exist only in Asia and East Africa. There is energy scarcity and fluctuation of prices of energy in Nigeria. Nigeria is an agricultural country that can use animal waste and food waste for biogas production so the large quantities of agricultural residues can be used in the production of biogas. There is also a serious and alarming trend of deforestation, indoor air pollution which causes serious health problems like chronic lung disease. The objectives of this work are to develop a biogas digester, to produce biogas for domestic utilization, to evaluate the performance of the digester.

2.0 MATERIALS AND METHODS

2.1 Materials

Cow dung, 120L capacity PVC tank, rubber motorcycle tyre tube, non-return valve, rubber seals, rubber hoses stirrer, dryer, thermometer, burner, Weighing scale, Air compressor

2.2 Methods

2.2.1 Sample of Feedstock

For this work, the selected feedstock is a fresh cow dung sourced from Maiduguri Abattoir in Borno state. The decision to use cow dung as the feedstock is based on its abundance in Maiduguri's cattle market (kasuwan shanu) and the various benefits associated with cow dung. It is considered the ideal substrate for bioreactors due to its non-acidic nature.

2.2.2 Feedstock Preparation

The preparation of cow dung involves a 1:1 ratio, where 40kg of fresh cow dung is combined with 40 liters of tap water. The mixture is then thoroughly stirred with a stirrer to create a slurry.

The specific loading rates can be determined according to (Arthur, 2004):

$$V_s = \frac{Mm}{Vd} \quad \text{...(2.1)}$$

Where;

V_s = Specific loading rate, kg/m^3

Mm = Mass of feedstock kg/day

Vd = Digester volume, m^3

But Vf is given as;

$$V_s = \frac{mass}{density} \quad \text{..(2.2)}$$

Where;

M=mass of dry input

ℓ =the density of dry material in the slurry

2.2.3 Fabrication of the bio-gas digester

The fabrication process for constructing a bio digester involves the following steps:

i. Acquiring a 120L capacity PVC tank.
ii. Sealing the top cover of the tank and creating a hole for the stirrer, ensuring a seal for efficient stirring.
iii. Drilling a hole on the upper side of the tank for the gas outlet, and each hole must be equipped with a clip to prevent leakage.
iv. Creating an additional hole for the gas outlet on the digester, connecting it to a rubber hose leading to the dryer, which contains silica gel to absorb moisture content in the biogas.
v. Introducing another hole for the gas outlet from the motorcycle tube tire, connecting it through a rubber hose to the burner.

Plate 1: biogas digester before gas Formation **Plate 2: biogas digester after gas formation**

2.2.4 Experimental Procedures

In executing this project, meticulous steps are taken to maintain precision and control in the experimental setup. The cow dung to water ratio is established at 1:1, ensuring a balanced and effective feedstock mixture. The introduction of the feedstock into the digester is conducted with care, and a thorough mixing process follows to homogenize the components. The preservation of anaerobic conditions within the digester is paramount for the success of the experiment. To achieve this, the digester's inlet is carefully padded with a clip, serving as a safeguard against any unwanted exposure to oxygen.

The intricate setup includes a rubber hose system. One end is strategically connected to the gas outlet located at the upper side of the digester. The other end of this hose embarks on a journey, linking to the gas inlet. This pathway involves passing through a dryer, designed to absorb moisture content, and ultimately storing the generated gas in a motorcycle tire tube. Another hose is then connected from the tire tube to the burner, where both the inlet and outlet are secured with rubber seals, ensuring a tight seal and preventing potential leakages. To maintain optimal conditions within the digester, stirring becomes a routine twice a day to prevent the formation of scum. The retention time is carefully set at 10 days, providing an ample period for the bio-digestion process to unfold.

Temperature monitoring is a critical aspect of the experiment. Using a thermometer, readings are taken twice a day, in the morning and evening, over a span of 10 days. This meticulous approach not only captures daily temperature variations but also contributes to the assessment of the digester's response to sunlight. Observations are keenly noted, aiming to discern patterns and fluctuations in temperature, which may unveil valuable insights into the experiment's progress and the impact of external factors.

2.2.5 COW DUNG AS FEEDSTOCK FOR BIOGAS PRODUCTION

Cow dung, sourced from a rumen animal, possesses inherent microbial flora that accelerates the biogas production process (Navneeth & Kiran, 2016). The digester maintained an average temperature of approximately 34.75°C, indicating a hydraulic retention time of 10 days. Gas generation commenced on the 7th day, reaching its peak at the 10th day with a maximum production of $0.031m^3$.

3.0 RESULTS AND DISCUSSION

The amount of gas produced was monitored the average temperature daily, which shows that;

i. The digester consistently maintained a temperature between 24-34.75°C throughout the period. Enhancing biogas production and quality can be achieved through uncomplicated modifications, such as elevating temperature, enhancing mixing, ensuring airtight conditions, and introducing additional substrate (Oumarou, *et al.,* 2017).
ii. The findings indicate a fluctuating pattern in the volume of biogas produced from the initial days.
iii. Although the gas generated during the first five (5) days was relatively low, a daily increase in production was observed.
iv. Following the peak gas production, there was a gradual decline in volume. This can be attributed to the microorganisms responsible for biogas production having consumed a substantial amount of the substrate, leading to a subsequent decrease in activity, this findings is the same as the one reported by (Navneeth & Kiran, 2016)

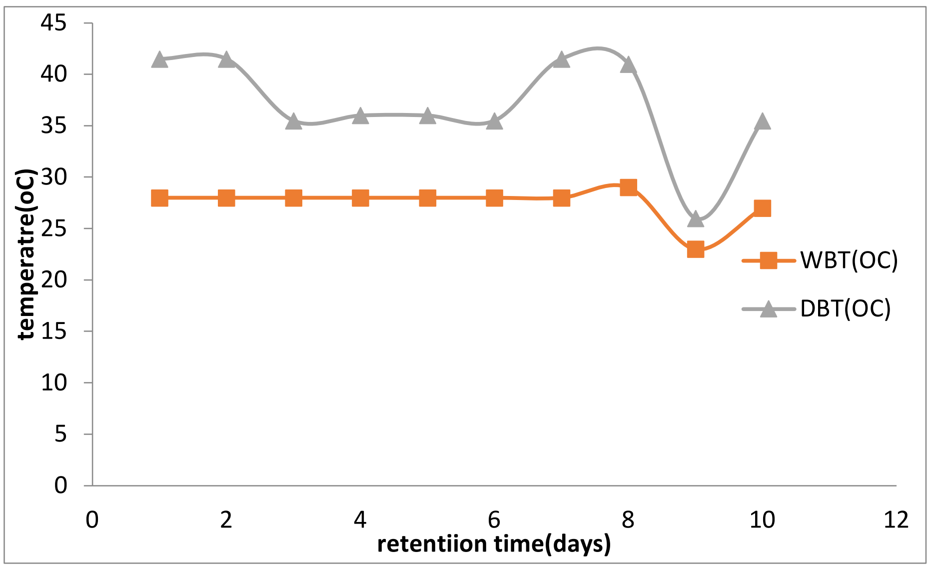

Figure 1: Temperature (°C) against retention time(days)

Figure 3.1 shows both the dry bulb temperature and the wet bulb temperature measured daily for the retention time of ten (10) days where for the first seven days the WBT was constant and it was taken to be 28°C. While for the last three days the WBT varied. Due to this the morning temperature is very low and the tube inflation was very negligible.

The DBT taken at 12:00 noon daily, at that time biogas production is very high, the tube inflates very well which shows that bioreactors depend on the effect of sunlight, the reaction is very high.

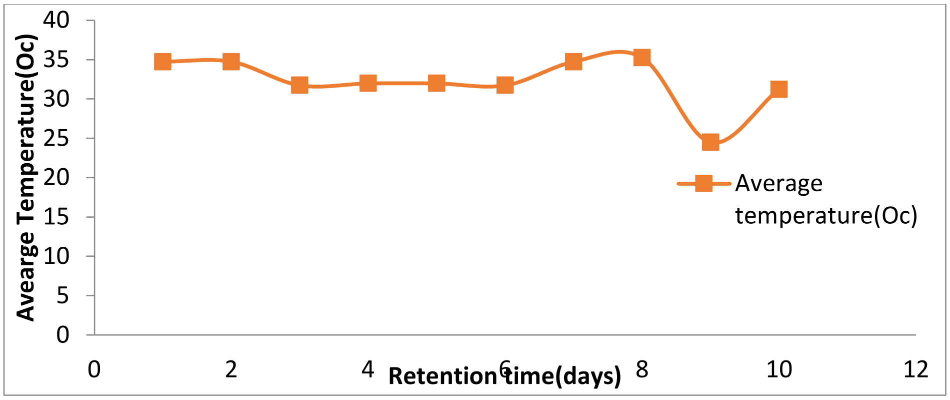

Figure 2: Average temperature (°C) against Retention time(days)

Observation shows that from fig 4.2, As, the temperature in increases so as the biogas production, the maximum point shows the increase in the rate of biogas production, and the temperature later falls which shows decreases in the volume of biogas production; that is, decrease in the production of the substrate (cow dung) because, the substrate has reached maximum biogas yield point.

During the production state, at a retention time of seven days, leakages were detected and so the slurry was offloaded and reloaded, after five days there was a blockage by moisture content in the dryer because the tube is no more inflating and so an air compressor was used to blow out the moisture content and then it was fixed back, the slurry was offloaded and reloaded again. The gas yielded was not combustible due to too much moisture content in the feedstock.

4.0 CONCLUSION AND RECOMMENDATION

From the study, the following conclusions can be made.

i. Polyvinyl Chloride (PVC) tanks can be used as bioreactors with less leakage occurrence than welded sheet metals.
ii. Biogas can be produced by the digestion of organic matter in the absence of air. Various waste such as municipal waste, kitchen waste, animal waste, crop residue can also be used in the production.
iii. Biogas production technology has established itself a technology with great potential which could exercise influence in the energy scene in both rural and urban area.

4.1 RECOMMENDATIONS

The following recommendations were suggested for future experiment:

1. To avoid leakages at junctions, gums should be used to seal them.
2. The combustibility obtained was very low, so more retention time should be increased.
3. Other types of dryer should be used for effective moisture absorption and one that cannot be easily blocked by moisture content.
4. The produced bio-fertilizer should be used as manure in farms as artificial manures cause's health hazards.

5. More research bodies and organizations should be created by the government.
6. A means of sustaining mesophilic temperature should be developed, as productivity of biogas is higher at this temperature.

REFERENCES

Arthur, M. (2004). *Biogas Production fromStillage (Scientific, Technical and Economic Aspects.* Germany: University ofLuneburg.

Girod, J., & Jacques, P. (1998). Reforms in sub-saharan Africa's power industries. *Energy Policy, 26*(1), 21-32.

Jamie, S., & Susan, H. (2000). *The cornerstone of development: integarting environmental, social and economic policies.* Canada: Lewis Publisher.

Kaliyan, H., & Morey, R. (2009). Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy, 33*(3), 337-359.

Kardo, R., & Arysca, W. S. (2019). Design of biogas purification to reduce carbon dioxide (co2) and hydrogen sulfide (h2s) . *Jurnal Teknik Mesin Universitas Bandar Lampung*.

Luana, C. G., Sâmilla, G. C., Bruna, S., Lucas, T. F., Arnaldo, S., & Kelly, J. D. (2019). Chapter 7 - New trends in biogas production and utilization. *Sustainable Bioenergy*, 199-223.

Navneeth, & Kiran, M. S. (2016). Comparative Study Of Biogas Production Using Kitchen Waste And Poultry Waste. *IMPACT: International Journal of Computational Sciences And Information Technology (IMPACT: IJCSIT), 2*(1), 1-10 .

Olusola, J. O. (2020). The legal sustainability of energy substitution in Nigeria's electric power sector: renewable energy as alternative. *Protection and Control of Modern Power Systems*.

Omar, E., Haitham, A., & Frede, B. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews, 39*, 748-764.

Oumarou, M. B., Y. B., Abubakar, A. B., & B. M. (2017). Design and Testing of an Optimized Anaerobic Digestion System. *Sustainable Energy*, 26-31.