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IMPROVEMENT ON THE DESIGN OF A SMALL SCALE ANAEROBIC FLOATING DRUM BIOGAS DIGESTER

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ABSTRACT

This project work is focused on improvement on the design and fabrication of a bio-digester and generation of biogas using cow dung and rumen fluid as substrate. A biogas digester with a capacity of 50litres was designed and fabricated, the substrate (cow dung and rumen fluid) were mixed in the ratio 3:2 and water to substrate ratio of 2:1 was used. The digester was stirred thoroughly to avoid scum formation in the digester and to allow for easy escape of the gas produced. The retention time used for this experiment was 42 days during which the daily internal temperature reading was taken in order to determine temperature variation and also to determine the effect of sunlight on the production rate. Result of this study showed that methane has the highest percentage and generally cow dung with rumen fluid easily subjected them to anaerobic digestion. From the project carried out on the improvement on the design and construction of the floating drum type bio digester (plastic) it was found out that the introduction of frames which prevent the gas holder from tilting and the black plastic drum and gas collector which has high heat absorption and retention have significant effect in the production of the biogas. It was found out that the initial PH value of the slurry is 8.5 and with the help of the heat adsorption and retention in 21days dropped the PH value to 6.5 which acidic and combustible. Recent research suggested that 1kg of cow dung will produced 0.264m^3 of gas, but with the improvement made, 0.305m^3 per 1kg of cow dung and rumen fluid was produced. This implies that for a design capacity of 25kg cow dung and rumen fluid it is expected that 8.75m^3 of gas would be produced.

Keywords: *biogas, digester, cow dung, rumen fluid, PH value.*

INTRODUCTION

The development and improvement of new techniques of production and utilization of renewable energy that is in line with economy and location of the developing countries is paramount with the view of solving the energy crisis and climate change problems. Climate change has been a source of international concern in recent periods, where it is tagged as one the leading problem that links international community and receiving much desired attention. Fossil fuel resources used to be a source of concern in the recent past. However, climate change issues have since over taken the centre stage. The trend has change, and it is very timely for much attention to be shifted to the renewable energy instead of the energy from the fossil sources. The anaerobic bio digestion process is not a new method of converting waste material into usable product. However, there is the need for continuous improvement particularly in this era of achieving sustainability in all ramifications. Traditionally, the anaerobic digestion (AD) process should be strictly taking place in an anaerobic environment with no free oxygen available. the presence of oxygen (aerobic) undermine the performance of the digestive system as reported by Hendrick (1991) as cited by Ramatsa (2014) therefore the best suitable condition for the production of biogas is oxygen deficient environment. Recent survey by Rinkesh (2009), suggest that non-renewable energy sources in terms of fossil fuels is fast degrading. This has led to research to new sources of energy like renewable energy sources such as solar energy, wind energy, thermal, hydro and biomass. Among these renewable energy sources biomass is more advantageous because of its characteristics of using, controlling and collection of organic waste for production of fuel and at the same time producing fertilizer for agricultural purposes. It does not have any geographical limitation nor does it require any advance technology for producing energy.

The term **"biogas"** is a renewable fuel provided by anaerobic digestion of organic material as substrate for bio-methanation. The gas is flammable, which is obtained through the action of methanogenic bacteria, which work in the absence of oxygen through a process of anaerobic digestion (Quaak *et al.*, 2001). It contains 50-75% methane, carbon dioxide, hydrogen sulphide and hydrogen. It can be used as fuel in boilers and dual fuel engines. It is made by fermenting organic wastes in biogas digesters.

The term **''Biogas digester''** is any structure that converts organic material (waste) into energy in the absence of oxygen. Various materials and geometric configuration have been used for the design of biogas digester system. Examples of the geometric configuration are horizontal, spherical, cylindrical and dome shape. The materials commonly used for its fabrication includes brick, cements, fiber glass for the dome shape and metal (stainless steel and mild steel). Biogas is a good source of renewable energy, composing of 50-70% of methane and 30-50% of carbon dioxide with other traces of gases. (Ranjeet *et al* 2008)

The term ''**Anaerobic digestion''** is an engineered methanogenic decomposition of organic matter under oxygen-free conditions and involves a mixed consortium of different species of anaerobic microorganism that transform organic matter into biogas. The process is successfully used for the treatment of municipal sludge, animal manure, industrial sludge, and industrial and municipal waste waters. Application of anaerobic digestion for waste treatment produce significant benefit beyond simple waste removal. These benefit include both energy production and energy conservation. In addition to waste removal, other environmental benefit result from anaerobic digestion including odor reduction, pathogen control, minimizing sludge production, conservation of nutrients, and reduction in greenhouse gas emissions. (Ranjeet *et al* 2008)

Replacement of fossil fuels also reduces atmospheric pollutants responsible for acid rain. Thus, anaerobic digestion is both a waste treatment technology, which enhances environmental quality and a suitable energy-producing technology. With these in mind, the research intends to improve on the design, construction and testing of a biogas digester to enhance its performance for efficient production of domestic biogas.

The scope and limitations of this research is to attempt to analyze and improve the existing biogas digester for their performance and will recommend measures to reduce the moisture content in the gas produced and obtain systematic approach for implementation

The problem with the existing plastic floating drum bio digester is when the biogas is produced, the floating gas holder tend to move up which facilitate the collection of the gas there by making the gas holder to tilt resulting to the escape of the gas produced and the material used usually not black in color which has less solar heat absorption, retention and has high moisture content in the gas produced.

The aim of this paper is to improve the design for functional production of biogas by improvement on the existing design of a bio-digester, to also minimize the moisture content in the gas produced and to evaluate the performance of the digester.

Sagagi *et al*. (2009) presented results of the study on biogas production from fruits and vegetables waste materials and their effects on plants when used as fertilizer (Using digested and undigested sludge). It has been observed that the highest weekly individual production rate is recorded for the cow dung (control) slurry with average production of 1554 cm^3, followed by pineapple waste which had 965 cm^3 of biogas, then by orange waste which had 612cm^3 of biogas, lastly, pumpkin and spinach wastes had 373 cm^3 and 269 cm^3 respectively. The results obtained shows that difference in the production of biogas to a large extent depends on the nature of the substrate. All the substrates used appeared to be good materials for biogas production and their spent slurries can be used as a source of plant nutrients.

Bhumesh *et al*.(2011) reported on biogas generation from dairy effluent and control of water pollution through treatment of dairy waste. All parameters however showed statistically gas generation fluctuated between 0.5m^3 /day to maximum 4.5m^3 /day with an average of 3m^3 /day was recorded.

Material and Method

Study site

Present study was carried out at the Federal Polytechnic Damaturu, Yobe State, North Eastern Nigeria.

Climate of the study area:

The climate of Damaturu is referred to as a local stepped climate. There is little rainfall throughout the year. The climate here is classified by the Kőppen-Geiger system. The average temperature is 25.0 ^{0}C with about 741mm of precipitation falls annually.

Choice of feedstock:

Cow dung and rumen fluid was used as co-substrate due to the excess abundance of cattle in Nigeria and its numerous advantages. Cow dung is the ideal substrate for bio digester because of it non-toxicity according to Onwuliri e tal (2013).

Materials	**Uses**
50-liters tank	Used as the digestion chamber
25-liters tank	Used as the gas collector (floating drum)
9mm diameter rubber hose	Used for the collection of gas
PVC pipe ($\frac{3}{4}$)	Used for inlet and outlet ports of the slurry
Weighing scale	Used to weigh the cow dung and the rumen fluid
Thermometer	Used for the measurement of the slurry temperature
Cow dung (raw material)	Used as the feedstock into the digester
Rumen fluid	Used asco-substrate
Silica	Used to absorb the moisture in the gas produced
Hack saw	Used to cut the digester tank
Meter rule	Used for measurement
90^0-elbow	Attached to the inlet pipe
PVC cap	Used to close the inlet pipe in order to avoid unwanted material getting into the digestion chamber
PVC adhesive	Used to seal the joints
Galvanized circular iron pipes	Used for the construction of the frame (guides)
Mass	Serve as weight to avoid the floating drum from tilting
Valve	Used for opening and closing of the outlet port
Cork	Is attached to the rubber hose which is Used for gas collection
Back note	Used as a sealer between the outlet pipe and the digester tank

Table 1. Materials and their uses

Methodology

The experimental setup includes the floating drum which serves as the gas holder which was fabricated from a plastic tank having a capacity of 25 litters, a hole was drilled into the bottom of the gas holder, about 1.5cm diameter for the gas outlet and a hose was fitted into it, a one-way metallic valve was attached to the hose for opening and closing. The joint between the hose and the tank was sealed with PVC adhesives in order to avoid leakages. The digester was fabricated from a plastic tank having 50 litters capacity, a hole was drilled on the side of the tank at its base, 6cm diameter and fit into it a PVC pipe of length 50cm and a 90^0 elbow, a pipe of 50cm length 5.5cm diameter was fitted into the elbow and all the joints were sealed with PVC adhesive; This served as the inlet pipe. Also, another hole was drilled at the base of the digester opposite to the inlet pipe ø3cm and a pipe of 12cm was fitted into the hole together with a unidirectional valve, all the joints were also sealed with the PVC adhesive; this will serve as the outlet pipe (for discharge of the slurry). A base was cast with three (3) 9-inch block were the frame will be fitted which is used to be a guide for the floating drum where the digester rest on top and a car tire which will help in making the floating drum not to tilt which causes gas leakage.

Once the digester was operational for several cycles and for several weeks after the initial filling, the pH value had reached the stable range of 6.5 and remained constant during the period of experimental cycles. The temperature was also recorded and was constant between 35-43^0C during the day and 25-33^0C during the night. Therefore, these two parameters were considered as the constants with respect to the model development. Based on the field data, those two parameters did not fluctuate significantly in Damaturu Climatic conditions.

Experimental Details

Step I: Finding the amount of total solid (TS) in the slurry

$$\mathbf{TS} = 8.5\% \text{ of slurry} = 0.085 \times 17kg = 1.445 \text{ kg}$$

Step II: Finding the amount of volatile solid (VS) in the slurry

$$\mathbf{VS} = 0.8TS = 0.8 \times 1.445 = 1.156kg$$

Step III: Finding the biogas yield in terms of per kg of VS

The total amount of degradable materials present in the VS is about 50% only, therefore,

$$VS \text{ used} = 0.5 \times 1.15 = 0.5575 \text{ kg}$$

Now,

0.5575 kg of VS gives 0. 17 m^3 of biogas

Therefore,

1.0 kg of VS will give 0.17/0.5575 = 0.305 m^3 of biogas

Thus, the biogas yield is **0.305 m^3/kg VS** from cow-dung and rumen fluid slurry

Hydraulic Retention Time HRT (Weeks)	Temperature (°C)
1	33.50
2	34.00
3	33.50
4	34.50
5	33.50
6	32.50
Average	33.58

Table 2: Average Weekly Temperature Readings for Biogas Production

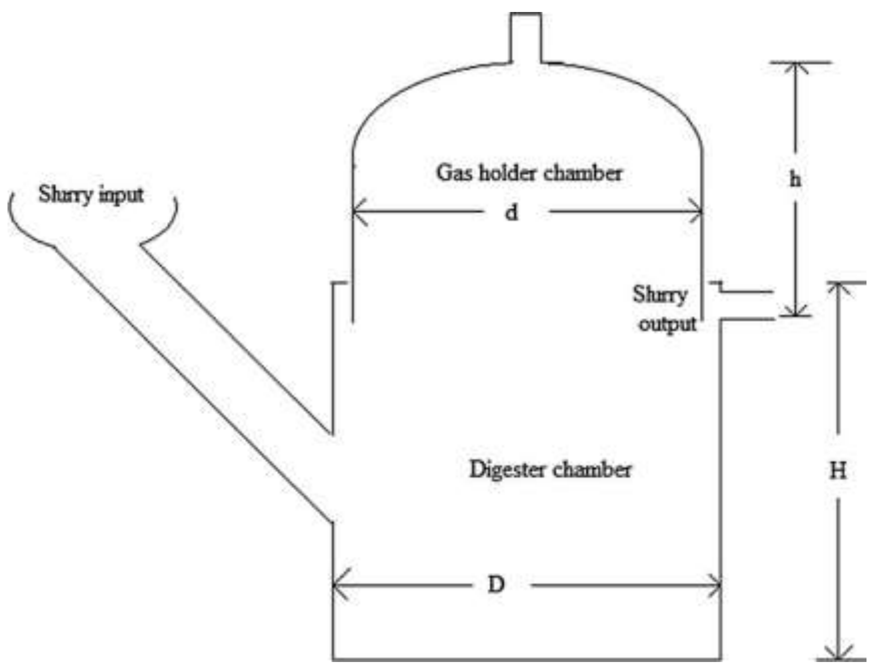

Fig.1. Block diagram of the Floating-drum type bio gas digester (http://www.kingdombio.com/ggcdraw.html)

Where;

D = the diameter of the digester.

H = the height of the digester/digester pit.

h = the height of the gas-holder.

d = the diameter of the gas-holder

Conclusions

From the project carried out on the improvement on the design and construction of the floating drum type bio digester (plastic) it was found out that the introduction of frames which prevent the gas holder from tilting and the black plastic drum and gas collector which has high heat absorption and retention have significant effect in the production of the biogas. It was found out that the initial PH value of the slurry is 8.5 and with the help of the heat adsorption and retention in 21days dropped the PH value to 6.5 which acidic and combustible. According to Chinnappan (2012), 1kg of cow dung will produced 0.264m^3 of gas, but with the improvement made, 0.305m^3 per 1kg of cow dung and rumen fluid was produced. This means that for a design capacity of 25kg cow dung and rumen fluid it is expected that 8.75m^3 of gas would be produced.

From the experiment Biogas digester plants provide a sustainable way to meet concerns related to hygiene and also to meet the energy requirements in rural areas. Raw materials for the operation of biogas digester plant are found in abundance in villages, mainly cattle waste. Many biogas digester plants have already been set up in some villages all across Nigeria, but the technology has not yet reached most parts because of the lack of initiatives and education. The installation cost of a biogas digester plant is also very high which is another deterrent for larger scale setup of plants. But there needs to be proper awareness among people. This presents a challenge for the government

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