Production of Biogas using Locally Fabricated Bioreactor

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ABSTRACT

Energy is one of the most basic things to modern life and provides the basis necessary for sustained economic development. This century is heading into the perfect energy storm. Increases in energy prices, diminishing energy availability and security, and growing environmental concerns are quickly affecting the global energy panorama. Energy demands can be taking care of by diversifying into renewable energy production of which biogas cannot be left out.

Biogas was produced from decomposition of cow dung and goat manure for over 37 days and above at different goat dung and cow dung (GD:CD) ratios. The production of biogas was carried out by varying the composition of biomaterials before mixing. The pre-treatment of the substrate was carried out using NaOH solution and the concentration was varied within a range of 7-9%. Total solids also varied within a range of 7-10% Initial properties were determined. Cow dung was found to be the highest with solids of 93.5% followed by Goat dung (72.5%). In terms of volatile solids, cow dung and goat dung almost have the same reaction close to each other, respectively. Biogas production from organic wastes are having prospects in contributing towards solving the national energy crisis of most countries.

(Keywords: biogas, bioreactor, cow dung, goat dung, renewable energy).

INTRODUCTION

The quest for environmentally friendly sources of energy, along with the increasing costs of fuel and recent regulations on disposal and emissions, has necessitated the search and need for renewable energy, such as biofuels, which comprise of bioethanol and biodiesel (Yamaji, et al., 2006). Bioethanol is a distilled liquid produced by fermenting sugars from sugar plants and cereal crops such as sugarcane, corn, beet, cassava, wheat, and sorghum. Several researchers have reported biofuel production from various agricultural materials including biogas from mixture of cassava peels and livestock waste (Adelekan, *et al.,*2009), fuel from indigenous biomass wastes (Saptoadi, *et al*., 2009), as well as ethanol from non-edible plant parts (Marina, *et al*., 2009) in (Adeleke, *et. al*., 2014).

Another recent development that necessitated the need for renewable energy is severe fluctuations in fossil fuel prices and global environmental problems have greatly accelerated efforts to develop renewable energy. The current dearth of fossil fuels focuses attention on a new approach to energy sources and solutions including distributed micro generation and the smart grids. The small facilities of production are installed as close as possible to the different new renewable energy sources: wind, sun, biomass, etc. (Liguori, 2016).

Investments in renewable energy, such as new wind farms and hydro schemes, are being promoted as a new means of diversifying rural employment in Scotland*. However, such investments are associated with a range of environmental impacts which might be detrimental to other economic activities, such as those based on nature tourism. When designing policy instruments for more sustainable energy futures, the main goal is to generate the lowest possible adverse socio-economic and environmental impacts ensuring a certain degree of economic efficiency (Bergman, *et al*., 2007).

In accordance with *REN21 Renewables 2010 Global Status Report* renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services: renewable energy provides 19% of electricity generation worldwide. Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas, for example, 14% in the U.S. state of Iowa, 40% in the northern German state of Schleswig-Holstein, and 49% in Denmark.

Some countries get most of their power from renewables, including Iceland (100%), Norway (98%), Brazil (86%), Austria (62%), New Zealand (65%), and Sweden (54%). Solar hot water makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWh). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households.

The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly. Renewable biofuels have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced the equivalent of an estimated 68 billion liters of gasoline, equal to about 5% of world gasoline production (Ewa Klugmann-Radziemska, 2014).

Biogas is a combustible gas derived from decomposing biological waste under anaerobic conditions which normally consists of 50-60% methane with relatively less CO_2, ammonia (NH_3), hydrogen sulphide (H_2S), nitrogen, and water vapor (Teodorita, *et al*., 2008).

Agricultural residues should be shredded into a small particle size prior to entering into the anaerobic digestion tank, because the decomposition and methane (CH_4) potential of biomass could be considerably enhanced by pretreating for reduction of particle size (Mshandete, *et. al*., 2006, Tsapekos, *et. al., 2015*). The length of cereal residues is usually cut into the range of 2-3 cm.

The major component in this system is anaerobic digestion technique. An anaerobic digester is a sophisticated process in which in soluble organic polymers are broken down and converted into CO_2 and CH_4 by anaerobic bacteria in the absence of oxygen. Several factors within the reactor such as temperature, pH, retention time, inoculum-to-feed ratio, C/N ratio and organic loading rate can impact the efficiency of anaerobic digester, degradation rates, biogas production, and biomethane content (Ward, *et.al., 2008*). In this model, the influence of different temperature is taken into account in detail: mesophilic anaerobic digestion and thermophilic anaerobic digestion.

Anaerobic digestion is a microbiological process of decomposition of organic matter, in the absence of oxygen, common to many natural environments and largely applied today to produce biogas in airproof reactor tanks, commonly named digesters. A World Bank (2000) report noted that biogas energy has an additional potential to ensure sustainable development, help reduce the dependence on non-renewable resources, and minimize social impacts and environmental degradation problems associated with fossil fuels. Biogas is a substitute replacement for firewood and cattle dung that can meet the energy needs of the rural population (Jingfei and Xiaohua, 2005).

Different raw materials produce different amounts of biogas and methane depending on their content of carbohydrates, fats, and proteins (Tsapekos, *et al.,* 2015). In principle, all biodegradable materials with reasonable lignin content (except wood) are suitable raw materials for biogas processes.

In rural areas, manure and most plant biomass can be directed to biogas plants, while from municipalities, food waste and sewage sludge are the most important material flows to biogas processes. Domestic biogas plants convert animal manure and human excreta at the household level into a combustible methane gas. This biogas can be used effectively in simple gas stoves for cooking and in lamps for lighting (Chae, *et al*., 2008).

AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to develop a reactor and evaluate the performance of biogas produced from cow dung and goat manure. The specific objectives are:

1. To develop a bioreactor using locally made material.

2. To produce biogas using the developed bioreactor.

3. To analyze the produced biogas.

DESIGN METHODOLOGY

The processes flow chart of biogas production using the constructed bioreactor is as shown in Figure 1.

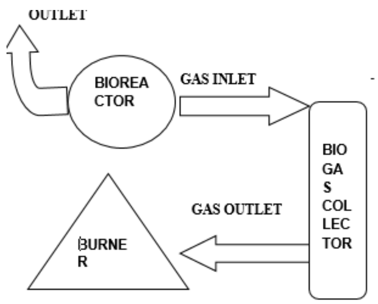

Figure 1: Block Diagram of Bioreactor.

COMPONENTS USED

The materials used in constructing the bioreactor are as listed below:

1. Plastic drum(120litre)
2. 2 Bulkhead fitting 40mm
3. Hose clamps
4. PVC ball valve
5. 15mm High pressure hose
6. Pressure
7. ¾ Hose barb
8. 1 Elbow
9. PVC pipe 15mm
10. 1’ PVC pipe
11. Adaptor plastic thread
12. Gas cylinder

Plastic Drum

In this drum, the biodegradation of segregated waste takes place under anaerobic conditions and in the presence of methanogenic bacteria, and as a result produces a methane-rich biogas. This generated biogas can be further used for cooking and for electricity generation, which can be processed through gas engines.

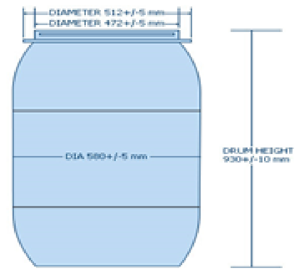

Figure 2: Plastic Drum.

Gas Cylinder

A gas cylinder is a pressure vessel for storage and containment of gases at above atmospheric pressure. High-pressure gas cylinders are also called bottles.

Figure 2: Gas Cylinder.

Bulkheads Fitting, 40mm

PVC bulkhead fittings, also known as tank adapters, are a common connector used to connect a tank to a pipeline or create a leak-proof seal between a line from inside an enclosure to outside.

Figure 3: Bulkhead Fittings.

Hose Clamps

A hose clamp's design allows to secure a hose over a fitting, thereby preventing any fluid flowing through the hose from leaking at the connection.

Figure 4: Hose Clamp

1' 3/4 Hose Barb

Hose barbs are cylindrical pieces or parts for attaching and securing of hoses (tubing). The barb-like rings on the cylindrical piece allow for an easy push-connection of flexible-plastic or rubber tubing that is not so easily disconnected.

Figure 5: Hose Barb.

PVC Ball Valves

Commonly used in landscaping, PVC ball valves allow the turning of flow of the liquids on and off, while creating a watertight seal.

Figure 6: PVC Ball Valves

15mm High Pressure Hose

The high-pressure hose is a component of the overall system that can receive significant abuse simply due to the nature of the application in which it is used.

Figure 7: Pressure Hose.

Pressure Regulator

Pressure regulators are valves that automatically cut off the flow of a gas or liquid when it is at a certain pressure. Regulators are also used to allow high-pressure fluid supply tanks or lines to be reduced to a usable and safe pressure for different applications.

Figure 8: pressure regulator

1' Adaptor Plastic Thread

The plastic thread adaptor is also called reducing couplings, and is a versatile fitting. These fittings are designed to change the end type of a pipe, allowing it to connect to fittings and pipes of many sizes.

Figure 9: Adaptor Plastic Thread.

PVC pipe 40mm

These are used in between the bulkhead fitting in the inlet of the plastic drum where the waste is being passed.

Figure 10: PVC pipe 40mm.

1' PVC pipe

The 1' PVC pipe is used in between the ball valve, adaptor plastic thread and elbow on the inlet of the plastic drum.

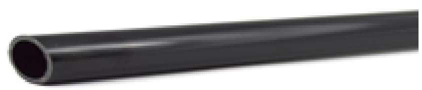

Figure 11: 1' PVC Pipe.

Experimental Setup to Produce Biogas

The anaerobic digestion experiment was conducted under ambient conditions in a laboratory at the Department of Mechanical Engineering, Federal University Oye Ekiti, Nigeria.

The ambient temperatures during digestion were mesophilic, at an average of 40°C. Fresh Cow Dung (CD) and Goat Dung (GD), were collected from Faculty of Agriculture Research Farm. Biogas production was monitored and measured until biogas production reduced significantly. Samples of the biogas produced were analyzed.

RESULTS AND DISCUSSION

An anaerobic digester (Plate 1) was developed. The constructed digester was used to produce biogas using three substrates both as single and co-digested substrates in this study. The observations and results obtained during the monitoring period in the study were presented below.

Plate 2: Setup of Bioreactor.

Measurement of Gas Production for the Three Substrates Digested Alone and with its Co-Digestion

The study of biogas production from Cow Dung, Goat Dung, and their mixtures was conducted in digesters. The daily biogas production from the various combinations of cow dung and goat dung at varying percentage ratios.

At the end of 37-days retention period the biogas production rate reduces, it was observed that digester produced the highest biogas production potential, followed by 100% CD, 100% GD, 50% CD-50%GD and 75% GD-25% CD produced the least biogas. This is due to adequate balance between the carbon to nitrogen ratio, which lies between the optimum of 20:1–30:1 (Yadvika, *et.al*., 2004) and the lignin content. Also, the time taken for the bacteria to acclimatize was the fastest in the digester 25%GD-75%CD, which may be attributed again to the optimum level of carbon to nitrogen ratio of substrate in this digester and possible presence of sufficient bacteria population in the cow manure used as the co-substrate which confirmed previous studies of (Rongpin, *et al*., 2009).

The higher biogas production from 25%GD-75%CD could also be attributed to the high content of carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorous, potassium, calcium, magnesium, and a number of trace elements. The reason for choosing these percentage ratios is to balance between the foods to bacteria. If food is less or more than the needed amount, the production may decrease. However, if the case is reversed, this makes the substrate insufficient to improve bacteria activity and thus reduces methane production. This result is in agreement with those obtained by Parawira, *et al.* (2004).

Inflammability Test

When the biogas and air mixtures reaches the burner ports and is burnt, it formed a pilot heat, which is blue cone shaped. The cone shaped blue flame produced is as a result of laminar flow in a cylindrical mixing tube which shows the quality of a gas, which agrees the previous studies of Ward, *et al*. 2008).

Plate 2: Testing of the Bioreactor Gas.

Plate 3: Testing of the Bioreactor Setup.

Plate 4: Setup of Biogas to the Cylinder.

Plate 5: Scale used to Measure the Initial and Final Measurement of the Gas Cylinder.

CONCLUSIONS

From the results of the study, the following conclusions are made:

1) The bioreactor constructed using locally available materials worked efficiently as significant biogas production was achieved.

2) The bioreactor constructed in this study was used for the anaerobic digestion of cow dung, goat dung, grass, as well as co-digestion. It was observed that digester with (25%CD-75%GD) produced the highest biogas production potential as observed in previous studies (Yusuf, et al., 2019) with a total of 0.451m3 of biogas during the retention period of 37 days.

3) The parameters determined in the proximate analysis both before (fresh) and after (digested) anaerobic digestion of the biomass resources in case of Carbon to Nitrogen ratio, Sulphates, Nitrates and Phosphates were within the optimum range which enhanced biogas production potential.

4) The pH values in the reactor were very stable and always in the optimal range between 6.5-8.0, and also the temperature inside the digesters were stable, fluctuating around 40±1°C which is within the mesophilic range.

RECOMMENDATIONS

1) Government and other relevant agencies should educate the people on the production and utilization of biogas.

2) Government and other responsible agencies should adopt and commercialize small scale reactor as a means of producing energy for the use of the rural dwellers.

3) The Local, State and Federal Government should encourage the use of Biogas as alternative source of energy to ease the current price depletion suffering in the world fuel market.

4) Relatively high temperatures should be used in producing of biogas for better yields.

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