Production and Quality Evaluation of Biogas from Animal Waste (Cow Dung)

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Abstract
The production of biogas from animal waste offers a sustainable and eco-friendly solution to global energy demands while addressing Agricultural waste management challenges, and turning waste to wealth. This research is aimed at producing and evaluating biogas from cow dung. The biogas produced was gotten from the anaerobic digestion of cow dung, in the absence of oxygen, using a locally made digester. The biogas generated from the anaerobic digestion process was analyzed in the laboratory using a portable gas meter, and the data generated through triple determination, were subjected to statistical analysis using a Statistical Software Packages for Social Sciences (SPSS version 23) to obtain the mean values and standard deviation. Results of the compositional analysis obtained were as follows: 65.86% methane (CH_4); 27.15% carbon dioxide (CO_2); 2.74% carbon monoxide (CO); 2.16% hydrogen sulfide (H_2S); and 2.09% oxygen (O_2). The result gotten from the analysis demonstrates the viability of cow dung as a feedstock for renewable energy production with methane content indicating a significant calorific value.

Keywords: *Biogas, Digestate, Cow dung, Anaerobic digestion, Renewable energy, Animal waste.*

INTRODUCTION

Biogas is a flammable gas produced by the biological fermentation of organic materials such as agricultural waste, manure and industrial effluents in an anaerobic (oxygen deficient) environment to produce methane, carbon-dioxide and traces of hydrogen sulphide (Ahmadu, 2009). During digestion, bacteria and *archaea* convert complex organic compounds into simpler molecules, releasing methane and carbon dioxide as byproducts. Methane is the primary component of biogas and is highly combustible, making it a valuable renewable energy source (Achinas *et al*., 2017).

The production of biogas from animal waste has emerged as a promising avenue towards sustainable energy solutions and efficient waste management practice. Pandey *et al*. (2020) studied the advancements in anaerobic digestion for efficient biogas production and proposed that through the use of anaerobic digestion process of converting organic matter, particularly animal waste, is an efficient means of obtaining a renewable biogas. By adopting anaerobic digester, methane emissions are captured from decomposing waste and converted into a valuable energy resource.

Several factors influence biogas production efficiency, including substrate composition, temperature, pH, and retention time (Yin *et al*., 2021). The type and proportion of organic matter in animal waste significantly impact biogas yield and composition, with higher organic content generally leading to increased methane production (Yadav *et al*., 2020).

The production of biogas from animal waste does not only offers an environmentally friendly alternative to fossil fuels but also addresses the pressing issue of organic waste management in agricultural settings. Additionally, Hossain *et al*. (2019) discussed the dual role of biogas in renewable energy production and waste management in agricultural systems which clearly placed emphasis on the development of innovative storage solutions to ensure the reliable supply and utilization of biogas produced, thereby enhancing its viability as a renewable energy source and also to contribute to the advancement of sustainable energy practices and to promote the adoption of biogas technology in agricultural communities. Using biogas for cooking and lighting reduces the strain on the environment by decreasing the use of biomass and the production of greenhouse gases (as methane that is produced normally from manure is now captured and used). The biogas system also provides a barrier, protecting ground water from contamination from untreated waste (Ocwieja, 2010).

According to Suyog (2010), the composition of biogas is typically methane (50-70%), carbon-dioxide (30-40%) and the rest is made up of traces of elements of hydrogen sulphide. Biogas is characterized based on its chemical composition and the physical characteristics which result from it. It is primarily a mixture of methane (CH_4) and inert carbonic gas (CO_2). The products of anaerobic digestion are biogas and slurry that is useful as fertilizer. Biogas contain about 55-60% methane, 25-45% carbon dioxide, 0.1% oxygen, 0.1% carbon monoxide, 1-10% hydrogen, 1-3% Nitrogen and traces of Hydrogen sulphide.

In Nigeria, majority of the population in the rural areas are without access to gas or electricity and therefore depend on firewood for cooking and lightening. Unfortunately, this has contributed immensely to the rapid rate of deforestation and desert encroachment (Adiotomre and Ukrakpor, 2015).

Nigeria is tremendously blessed with a variety of energy resources (both conventional and non-conventional). The reserves for animal waste alone which is a viable source for biogas production as at 2005, was estimated to be 61.00 million tons per year, and crop residue was put at 83.00 million tons per year (Agba *et al*. 2010). Estimates suggest that Nigeria could generate over 17 billion cubic meters of biogas annually, which could meet a substantial portion of its energy needs (Eze *et al*., 2020).

The current disposal system for agricultural waste has created a negative effect through disease and pollution problems. The search for alternative sources of energy such as biogas from waste materials when increased would help in the elimination and control of deforestation. The establishment of biogas plants would greatly mitigate these problems and help preserve the environment.

The importance of biogas as alternative source of energy cannot be over emphasized. It is a sustainable, more environmentally friendly and cheaper source of energy.

This study is therefore aimed at producing and evaluating biogas from animal waste (cow dung) through anaerobic digestion.

MATERIALS AND METHODS

Materials

Materials used were: Animal waste (cow dung), Water, Digester and gas collection tools, Hand-gloves and Hand trowel.

Sample collection

Fresh cow dung (Plate 1), was collected from a local cattle settlement in Ikot Abasi L.G.A, Akwa Ibom State, Nigeria. A hand trowel was used to collect the animal waste into a clean plastic container. The cow dung gotten at the cattle settlement was later measured to be 6.5kg (Plate 2).

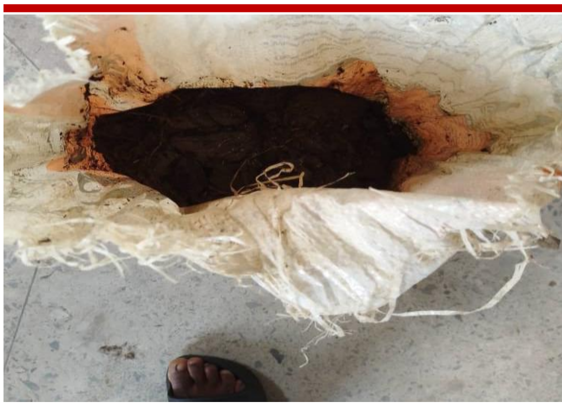

Plate 1: Sample of fresh cow dung

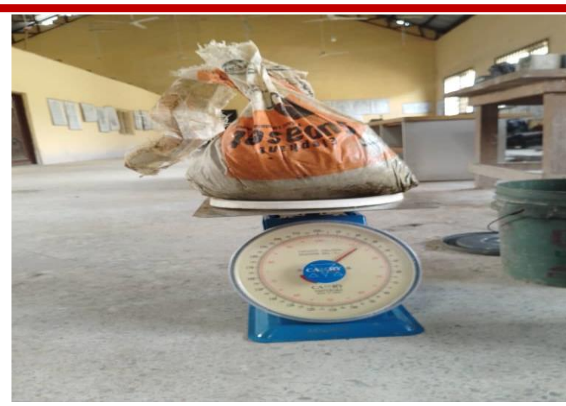

Plate 2: Weighing of the cow dung sample

Slurry formation

After the weight of the waste was measured, water was then added to the animal waste in required amount to maintain a moderate water content level and also to form perfect slurry for the production of the biogas. The mixture of water to the waste was done in the ratio of 1:1.5 in a plastic container where the slurry was formed (Plate 3), before it was transferred into the digester.

Plate 3: Mixing process to form slurry

Plate 4: Feeding the digester with the formed slurry

Digester used

An air tight drum was developed since anaerobic digestion does not require the presence of oxygen. Two openings were made at the top of the air tight drum and a gas hose was connected into one of the opening to serve as a medium for capturing the produced biogas into a primary storage unit and the second opening remained as an inlet for feeding the slurry into the digester. An opening was also made at the side of the drum and a pipe connected into the drum to face the base of the drum and serve as an outlet for the digestate after the biogas has been produced. A gas holder was attached to the gas capturing unit to be able to primarily store the produced gas.

Regardless of the storage method employed, proper maintenance and monitoring are essential to ensure the safety and efficiency of biogas storage systems. Regular inspections, leak detection, and pressure monitoring help identify and address potential issues before they escalate.

Feeding of the digester with the formed slurry

The slurry prepared was fed into the digester through the inlet (Plate 4), after it was measured to be about 9.75kg in weight. The slurry fed into the digester was left sealed without opening the link to the gas collection unit for 10 days to allow it generate pressure for the gas to be produced. The anaerobic fermentation in the digester led to the formation of biogas which passed through to the gas holder which was later detached for proper analysis on the composition the biogas. The digestate was disposed at an isolated area with minimum number of human footprint.

Gas capturing

The gas outlet valve in the digester was opened on the tenth day of retention; the biogas was then captured in the primary storage unit.

Determination of the composition of the biogas

The following compositions of the biogas produced from animal waste (Cow dung) were determined using a laboratory portable gas meter: Methane, Carbon dioxide, Carbon monoxide, Hydrogen sulphide and Oxygen.

Statistical Analysis

Statistical Package for Social Sciences (SPSS version 23) was used to analyze data by computing the mean and standard deviation.

RESULTS AND DISCUSSIONS

The total weight of biogas produced using cow dung was recorded as 26.29 g.
The results of the compositional analysis of the biogas produced from animal waste (cow dung) are presented in Table 1.

Table 1: Results of Analysis of the Biogas Composition.

S/N	Composition	Percentage (%)
1	Methane	65.86±0.006
2	Carbon (iv) oxide	27.15±0.011
3	Carbon monoxide	2.74±0.002
4	Hydrogen sulphide	2.16±0.021
5	Oxygen	2.09±0.004

Note: Values are mean ± standard deviation of triple determination.

Methane (CH_4)

The percentage composition of methane in the biogas produced from cow dung is 65.86% (Table 1). This value is within the range of 50-70%, earlier reported by Suyog (2010). One of the primary reasons for analyzing biogas composition is to assess its energy efficiency. Methane, the key energy component, determines the calorific value and energy yield of biogas.
A higher methane concentration means greater energy output, which is essential for designing efficient biogas-powered equipment like generators and burners (Ofoefule *et al.*, 2009).
The methane percentage of 65.86 makes the biogas valuable for energy generation in applications such as cooking, electricity generation, and heating.

Carbon Dioxide (CO_2)

Results of the compositional analysis of the biogas produced using cow dung indicate that carbon dioxide recorded 27.15% (Table 1), which is lower than 30-40% range of value earlier reported by

Suyog (2010). The presence of carbon dioxide at this percentage indicates that the biogas is a typical by-product of anaerobic digestion. It does not contribute to the energy value of the gas and must be removed or reduced to increase methane purity. To make this gas sample suitable for high-efficiency use (e.g., in compressed natural gas [CNG] engines), the carbon dioxide (CO_2) would need to be removed through processes such as water scrubbing, pressure swing adsorption, or chemical absorption.

Carbon Monoxide (CO)

Carbon monoxide content of the biogas recorded a value 2.74% (Table 1). This value is slightly higher than 0.1%, earlier reported by Suyog (2010). Carbon monoxide is a toxic gas that poses significant health risks even at low concentrations. Its presence in the gas sample indicates incomplete combustion or reduction reactions during the biogas formation process. It does not contribute to the energy value of the biogas.

Hydrogen Sulfide (H_2S)

The biogas produced composed of 2.16% hydrogen sulfide (Table 1). Hydrogen sulfide is highly toxic and corrosive. Even at low concentrations, it is harmful to human health and equipment. Its corrosive nature damages gas cylinders and any other infrastructure it is used on. Due to its toxicity and foul odor, H_2S must be eliminated through desulfurization processes (e.g., using iron oxide filters or activated carbon). Once H_2S is removed, the gas becomes safer and more suitable for energy production.

Oxygen (O_2)

Oxygen composition in the biogas produced was recorded to be 2.09% (Table 1). Oxygen is not a common component in biogas, as anaerobic processes occur in oxygen-free environments. Its presence suggests contamination during sampling or storage. A small amount of oxygen can support the combustion process, but its presence might also increase the risk of explosions in enclosed systems. The presence of oxygen might indicate leaks or mixing with ambient air during collection, storage, or transport.

CONCLUSION

The analysis of the biogas composition highlights the successful production of biogas from animal waste, with methane constituting the majority of the gas mixture; it confirms the potential of animal waste as a viable feedstock for biogas generation. The significant presence of carbon dioxide and smaller amounts of hydrogen sulfide, carbon monoxide and oxygen are typical of biogas generated through anaerobic digestion. While methane provides the primary energy value, the presence of impurities like CO_2 and H_2S indicates the need for further purification to enhance the quality and usability of the biogas.

This study also indicates that animal waste (cow dung) can be effectively converted into biogas, contributing to renewable energy production and waste management.

The study also demonstrates the environmental and economic benefits of biogas technology as it offers a sustainable waste management solution, thereby reducing greenhouse gas emissions and providing a renewable energy source.

Conflict of Interest

The Authors declare that no conflicts of interest exist.

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