Generation of High Quality Biogas from Cow Dung Using a Simple Anaerobic Digester

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Abstract: Waste management has become a major environmental concern due to the increasing accumulation of organic waste and its associated impacts on environmental quality and public health. Open dumping and uncontrolled burning of waste contribute significantly to greenhouse gas emissions and environmental degradation. This study investigated the production of biogas from cow dung using a laboratory-scale anaerobic digester. A 20 L capacity prototype biogas digester was designed, fabricated, and tested under batch operating conditions. Fresh cow dung was mixed with water in a ratio of 1:2 and supplemented with Moringa oleifera leaves as a biological starter to enhance microbial activity. The digestion process was monitored for 21 days, during which temperature, pH, gas production, and gas composition were evaluated. Results showed that biogas production commenced on the third day of digestion and increased steadily until peak production was attained. Gas analysis revealed methane concentration of 50.8%, carbon dioxide concentration of 25.5%, hydrogen sulphide concentration of 0.2%, and carbon monoxide concentration of 0.1%. The cumulative biogas yield obtained at the end of the retention period was 0.21 m³. The study demonstrates that cow dung is a suitable feedstock for renewable energy generation through anaerobic digestion. The developed digester offers a low-cost and environmentally sustainable solution for organic waste management and household energy production.

Keywords: *Biogas, Anaerobic Digestion, Cow Dung, Renewable Energy, Waste Management, Methane Production.*

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I. INTRODUCTION

Energy demand in Nigeria has continued to increase due to population growth, urban expansion, and industrial development. Most of this energy demand is still met through fossil fuels, which are costly and environmentally damaging. Rising fuel prices have made energy access more difficult for many households and small industries.

This situation highlights the need for alternative and renewable energy sources. Biogas presents a viable solution because it can be produced from locally available organic waste materials. Nigeria generates large quantities of organic waste daily from livestock farms, abattoirs, markets, and households. If properly managed, these wastes can be converted into useful energy.

Biogas is produced through anaerobic digestion, a biological process that occurs in the absence of oxygen. During this process, microorganisms break down organic matter and release a mixture of gases mainly methane and carbon dioxide[1]. However, the constant increase in fuel prices has made it difficult for many people to afford and access energy for their daily needs. This situation has created the need for cheaper, cleaner, and more sustainable alternative energy sources. One of the most promising alternatives in

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Nigeria is biogas [2]. Biogas is especially suitable for the country because large amounts of organic waste are generated daily from homes, farms, markets, and industries. Instead of allowing these wastes to pollute the environment, they can be converted into useful energy through the production of biogas. The energy produced from this process can serve as an environmentally friendly alternative fuel while also helping to improve waste management practices [3]. Biogas is widely used in many countries as a source of fuel for cooking, heating, electricity, and other domestic and industrial purposes. It can also be compressed in a similar way to natural gas, making it easier to store and transport for different energy applications. Biogas can be produced from a variety of organic materials, including agricultural waste, animal manure, sewage, green waste, poultry droppings, cow dung, human waste, expired food products, and organic liquid waste from industries [4]. The availability of these materials makes biogas production both practical and sustainable, especially in countries with high levels of organic waste generation. The production of biogas from cow dung has shown that flammable biogas can be produced from these waste through anaerobic digestion for biogas generation. [5]. Cow dung biogas can be a dependable source of cooking fuel. Although production starts slowly due to an initial lag phase, the gas output becomes steady and reliable over time. Overall, cow dung is a simple, affordable, and sustainable option for producing household energy, particularly in areas with limited access to cleaner fuel options [6]. The production of biogas occurs through a biological process known as anaerobic digestion, which takes place in four main stages: hydrolysis, acidification, acetogenesis, and methanogenesis. During the hydrolysis stage, complex organic materials are broken down into simpler compounds. These compounds are then converted into organic acids during acidification and acetogenesis. In the final stage, known as methanogenesis, methanogenic bacteria act on acetate, hydrogen, and carbon dioxide to produce methane gas, which is the main component of biogas [7]. The process of biogas production takes place in an oxygen free environment inside a container known as a digester. Digesters can be designed in different shapes and sizes depending on the materials available and the quantity of waste to be processed [8]. Small or mini biogas digesters are particularly advantageous because they are relatively cheap to construct and can serve as a practical solution to energy shortages, especially in developing communities [9]. Animal waste like cow dung can be effectively used in biodigesters to produce biogas, which can then be converted into electricity using a microturbine system. The study found that system performance depends on factors such as temperature, retention time, and feed rate [10]. Apart from producing energy, the slurry left after digestion is also highly beneficial. It can be used as an organic fertilizer and has been reported to significantly improve soil fertility and crop yield [11]. Biogas itself is considered a clean and renewable source of energy because it is produced from organic waste through the process of anaerobic digestion [12]. Typically, biogas is made up of methane (50–75%) and carbon dioxide (25–50%), along with small amounts of other gases such as nitrogen (0–10%), hydrogen (0–1%), hydrogen sulphide (0–3%), and oxygen (0–2%) [13]. A study on anaerobic digestion of municipal and industrial organic wastes showed that wastes containing higher amounts of cellulose, lipids, and starch produced more biomethane, while materials with high lignin and ash contents slowed down digestion and reduced methane yield. The study further explained that the type and composition of waste play an important role in determining the efficiency of biogas production [14]. Since biogas is a renewable and environmentally friendly biofuel, its use can help reduce dependence on fossil fuels and lower environmental pollution [15]. Therefore, anaerobic digestion remains an effective and sustainable technique for energy production and waste management. The aim of this study is to design a simple biogas digester and evaluate the production of biogas from cow dung with the addition of Moringa oleifera as a natural bio starter.

II. MATERIALS AND METHODS

➢ *Digester Design*

A 20 litre batch anaerobic digester was constructed using PVC materials. The system was designed to operate under airtight conditions to ensure anaerobic digestion.

The main components include:

- Feeding inlet for slurry introduction
- Gas outlet connected to collection system
- Slurry outlet for digested residue
- Control valve for gas regulation
- Sealed joints to prevent oxygen leakage
- The digester was placed under ambient environmental conditions during the experiment.

➢ *Materials Used*

The materials used in this study include:

- Cow dung of 25 kg
- Clean water of 50 kg
- Fresh Moringa oleifera leaves of 10 kg
- PVC pipes and fittings
- Gas hose and storage container
- pH meter
- Thermometer
- Biogas gas analyzer

➢ *Waste Collection and Preparation*

Fresh cow dung was collected from a slaughterhouse in Udu, Delta State. Fresh Moringa oleifera leaves were obtained from Lagos State.

The waste materials were mixed with water in a ratio of 1 to 2 to form a uniform slurry. The mixture was stirred thoroughly to ensure proper blending before loading into the digester.

➢ *Experimental Procedure*

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The prepared slurry was introduced into the digester through the inlet pipe. The system was immediately sealed to maintain anaerobic conditions.

The digester was operated in batch mode for 21 days. The ambient temperature was maintained at approximately 30 degrees Celsius. Slurry temperature and pH were monitored throughout the experiment.

Gas production was observed after a few days of fermentation. Daily gas volume was recorded using a gas collection system. The cumulative gas production was calculated at the end of the retention period.

➢ *Functioning*

The mini biogas digester was designed to perform the following task:

- Provide a means to discharge the spent slurry
- Keep the charge at operating temperature
- Accept new quantities of charge and
- Collects the gas for processing and storage.

Fig 1. Schematic Diagram of the Fabricated 20 L Biogas Digester

The figure illustrates the laboratory-scale anaerobic digester developed for this study. The system consists of a digestion chamber, feed inlet, slurry outlet, gas outlet, control valve, gas hose, and gas storage unit. The airtight configuration ensured anaerobic conditions necessary for methane-producing microorganisms.

Table 1 Daily Biogas Production from Cow Dung

Day	**Volume of Gas m^3**
1	0.000
2	0.005
3	0.010
4	0.015
5	0.018
6	0.020
7	0.023
8	0.025
9	0.028
10	0.030
11	0.032
12	0.033
13	0.034
14	0.035
15	0.036
16	0.037
17	0.038
18	0.039
19	0.040
20	0.041
21	0.042

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Table 1 shows the daily gas production pattern during the 21 day retention period.

The pattern shows gradual increase in gas production followed by stabilization toward the end of the digestion cycle.

Table 2. Feedstock Composition and Mixing Ratio

Feedstock	Mass (kg)	Water (kg)	Mixing Ratio
Cow Dung	25	50	1:2

Table 3. Composition of Produced Biogas

Gas Component	Composition (%)
Methane (CH_4)	50.8
Carbon Dioxide (CO_2)	25.5
Hydrogen Sulphide (H_2S)	0.2
Carbon Monoxide (CO)	0.1

Table 4. Summary of Digestion Parameters

Parameter	Value
Mass of Waste Used	25 kg
Mass of Water Used	50 kg
Total Slurry Mass	75 kg
Digestion Period	21 Days
Total Biogas Yield	0.21 m³
Maximum Ambient Temperature	32°C
Maximum Slurry Temperature	36°C

➢ *The Time Required for Biogas Information*

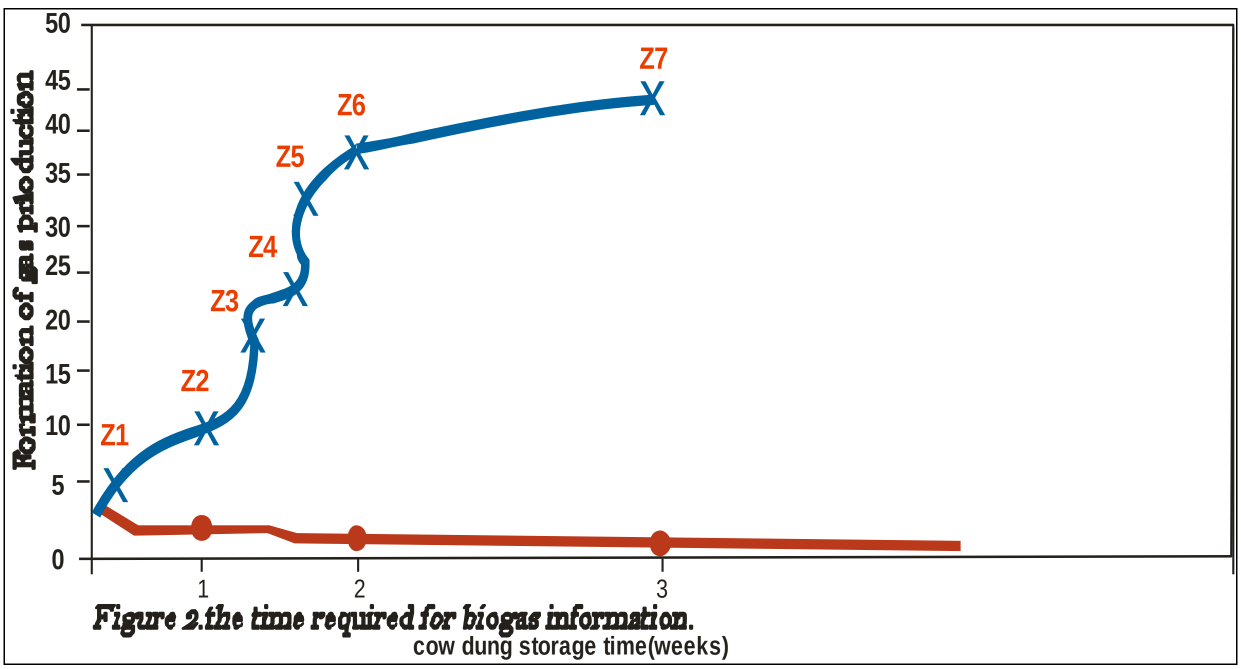

Fig 2. Daily Biogas Production During the 21-Day Retention Period

The figure presents the variation in daily biogas production throughout the digestion period. Gas production was initially low during the microbial adaptation phase and increased progressively as digestion proceeded. Peak production occurred around the tenth day, after which gas generation gradually declined due to substrate depletion.

From the graph, we observed that using a starter, the emission of gas started from the day three (3) when fermentation had taken place. This process continued for three (3) weeks. From the first bar z1, corresponding to three days, the total volume of gas produced was 30m³. This is the same with Z2, Z3, Z4, Z5, Z6 and Z7 which shows that the total volume of gas for the production of cooking gas for constant twenty one (21) days is 0.21m³.

III. RESULTS AND DISCUSSION

➢ *Biogas Composition*

Gas analysis showed that the biogas produced consisted of:

- Methane 50.8 percent
- Carbon dioxide 25.5 percent
- Hydrogen sulfide 0.2 percent
- Carbon monoxide 0.1 percent

The methane content indicates good energy potential since methane is the main combustible component of biogas. The presence of carbon dioxide reduces calorific value but is typical in anaerobic digestion systems.

Biogas production did not begin immediately after loading. There was a short lag phase of about two days. This period corresponds to microbial adaptation to the new environment.

From day three, gas production increased steadily as microbial activity intensified. The highest production occurred between day 9 and day 12, which represents the peak methanogenesis phase.

After the peak period, gas production gradually declined due to depletion of easily degradable organic matter.

IV. CONCLUSION

This study demonstrates that cow dung is an effective substrate for biogas production using a simple anaerobic digester. The system produced methane rich biogas under ambient conditions without complex equipment.

The addition of Moringa oleifera improved microbial activity and enhanced digestion performance. The results confirm that anaerobic digestion is a sustainable approach to waste management and renewable energy production.

This technology is suitable for small scale applications and can help reduce environmental pollution while providing alternative energy for cooking and other domestic uses.

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