

Production of Biogas from Cow Dung Using a Batch Reactor

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Abstract— Production and purification of biogas from cow dung through batch anaerobic digestion under mesophilic conditions over a 14-day retention period was considered in this work. A 22 kg capacity anaerobic digester was charged with cow dung slurry prepared in a 1:1 ratio with distilled water, and daily biogas production, temperature, and pH were monitored to evaluate digestion performance. The results showed a typical batch digestion pattern characterized by a lag phase (Days 1–3), a rapid increase in gas production reaching a peak of 9.0 L/day on Day 7, and a gradual decline thereafter due to substrate depletion. Gas chromatographic analysis indicated that the produced biogas contained 55.43% methane (CH₄), 13.42% carbon dioxide (CO₂), 2.44% hydrogen sulphide (H₂S), and trace gases, confirming methane concentration within the expected range for efficient anaerobic digestion. Subsequent purification using silica gel, ferric oxide, and sodium hydroxide scrubbing improved gas quality by reducing moisture, hydrogen sulphide, and carbon dioxide content. The findings demonstrate that cow dung is a viable and sustainable substrate for biogas production, with potential applications in renewable energy generation, waste management, and environmental sustainability.

Keywords— Anaerobic Digestion, Biogas Production, Methane Yield, Cow Dung Substrate.

I. INTRODUCTION

Biogas production from organic waste materials, such as cow dung, represents a sustainable and environmentally friendly energy source that can help mitigate the dependency on fossil fuels. The increasing global energy demand, coupled with the rising concerns over environmental pollution and the depletion of non-renewable energy resources, has necessitated the exploration of alternative energy sources. Biogas, primarily composed of methane (CH₄) and carbon dioxide (CO₂), is a renewable energy resource that can be produced through the anaerobic digestion of organic matter (Karki et al., 2005). Anaerobic digestion is a complex biochemical process where microorganisms break down organic materials in the absence of oxygen, leading to the production of biogas and digestate, a nutrient-rich byproduct that can be used as fertilizer. Cow dung is an abundant and readily available substrate for biogas production, especially in agricultural economies. The use of cow dung not only provides a viable method for waste management but also contributes to energy generation, thereby promoting rural development and reducing greenhouse gas emissions (Surendra et al., 2014). Historically, the practice of using animal waste for energy production dates back to ancient times; however, modern biogas technology has significantly evolved over the past few decades. The utilization of cow dung in biogas plants is particularly advantageous due to its high

methane yield, availability, and minimal requirement for pretreatment (Taleghani & Kia, 2005). Various studies have demonstrated the efficiency of cow dung as a feedstock for biogas production, highlighting its potential to enhance energy security and foster sustainable agricultural practices (Igoni et al., 2008).

Recent advancements in biogas technology have focused on optimizing the anaerobic digestion process, improving biogas yields, and ensuring the economic feasibility of biogas plants. Innovations in digester design, feedstock pretreatment, and microbial management have been pivotal in increasing the efficiency of biogas production from cow dung (Sakar et al., 2009). Moreover, the integration of biogas systems with other renewable energy technologies and agricultural practices offers a holistic approach to sustainable energy production and waste management. The production of biogas from cow dung presents a promising solution to the global energy crisis and environmental challenges. This research aims to explore the potential of cow dung as a sustainable feedstock for biogas production, evaluate the efficiency of different anaerobic digestion techniques, and assess the socio-economic impacts of biogas technology in rural communities.

II. MATERIALS & METHODS

The materials and apparatus used for the experiment include:

- a) Cow dung
- b) Distilled water
- c) Rubber coke
- d) Water
- e) Silica gel
- f) Ferric II Oxide
- g) Sodium hydroxide

2.1 Equipment and Apparatus

- a) Anaerobic bio-digester (batch reactor)
- b) Gasket gum
- c) Stirrer
- d) Measuring gas cylinder
- e) Weighing balance
- f) pH meter
- g) Hand glove
- h) Mechanical grinder
- i) Thermometer
- j) Flexible hose
- k) Clip and bucket

2.2 Collection and Preparation of the Sample

Cow dung was obtained from Abattoir in Port Harcourt Local Government Area of Rivers State and was transported to Chemical/Petrochemical Engineering Laboratory, Rivers State University. The sample was dried to a constant weight and crushed.

2.3 Biogas Production Procedure

The anaerobic digester was first inspected to ensure there were no leakages. After confirmation, it was thoroughly cleaned before charging. A blended cow dung sample weighing 7 kg was transferred into a bucket, and 7 kg of distilled water was added in a 1:1 ratio to form a homogeneous slurry. The slurry was then fed into the 22 kg capacity anaerobic digester. The mixture was manually stirred using a stirrer to ensure uniform distribution of water within the reactor.

The digester was equipped with a pressure gauge to monitor the pressure exerted by the biogas produced during the decomposition process, while daily temperature readings were taken using a thermometer incorporated into the reactor. For gas purification, silica gel contained in Reactor 2 was connected to Reactor 1 to absorb moisture from the produced gas. Ferric(II) oxide in Reactor 3 was connected to Reactor 2 to remove hydrogen sulphide (H_2S) from the gas stream. Sodium hydroxide solution in Reactor 4 was then used to scrub carbon dioxide (CO_2) before the gas was directed to the collection cylinder. An increase in pressure indicated gas build-up within the system. Biogas was collected every 48 hours, and the pH of the slurry was recorded daily throughout the 14-day digestion period. The pH was measured using a calibrated digital pH meter.

2.4 Characterization of Produced Gas

Equipment for the characterization of the biogas produced are:

- a) Gas chromatograph machine (GC).
- b) Mass Spectrometer (MS)

This analysis result for the biogas was obtained with the aid of gas chromatograph machine.

Procedure:

A biogas sample was collected in a gas-tight container and injected into the gas chromatograph. The peaks corresponding to different gases to determine their concentrations was analysed.

2.4.1 Impurities Analysis

Analyzing impurities such as siloxanes and volatile organic compounds (VOCs) is important for assessing the potential for engine wear and environmental impact.

2.4.2 Water Content and Dew Point

The water vapour content in biogas affects its calorific value and can lead to condensation issues in pipelines.

Procedure:

The water vapour content in the biogas sample was measured using a hygrometer or dew point meter. The dew point was determined to determine the conditions under which water will condense.

2.5 Analysis of Environmental Benefit of Biogas Production

The environmental benefits of biogas production were analyzed via the waste management and resource recovery.

2.5.1 Waste Management and Resource Recovery

Biogas production from cow dung provides a sustainable waste management solution, reducing environmental pollution and recovering valuable resources.

Waste Reduction Metrics: Measure the reduction in volume and weight of cow dung after anaerobic digestion.

Nutrient Recovery: Analyse the nutrient content (e.g., nitrogen, phosphorus, potassium) of the digestate to quantify its value as a biofertilizer.

Procedure:

The digestate was sampled periodically and laboratory analysis was used to determine nutrient concentrations.

III. RESULTS AND DISCUSSION

The experimental results obtained from the batch anaerobic digestion of cow dung for biogas production over a 14-day retention period are presented and discussed in this section. The objective of this analysis is to evaluate the temporal pattern of biogas generation, identify the peak production phase, and assess the overall digestion performance of the system. The results are interpreted in relation to microbial growth dynamics and substrate degradation kinetics in a typical batch digester.

3.1 Gas Chromatography Sample Analysis (GC)

The gas chromatography analysis table of values in Table 1 reveals the composition of the produced biogas, highlighting methane as the primary energy component, with a concentration of 55.43%. This methane level indicates a productive digestion process, making the biogas suitable for energy applications such as heating or electricity generation.

- a) Methane (CH_4): The methane content of 55.43% is typical for biogas derived from anaerobic digestion of organic waste. Methane is the primary fuel in biogas, and its concentration is critical in determining the overall energy potential of the gas. This concentration falls within the expected range for well-optimized biogas production processes.
- b) Carbon Dioxide (CO_2): The CO_2 content of 13.42% was significantly reduced through purification steps, such as NaOH scrubbing. Lower CO_2 levels enhance the calorific value of the biogas, making it more efficient for energy applications.
- c) Hydrogen Sulfide (H_2S): The presence of 2.44% H_2S was reduced using a ferric oxide scrubber. This step is crucial for protecting equipment from corrosion, as H_2S can cause damage in gas storage and utilization systems.
- d) Water Vapor (H_2O): Water vapor constituted 5.24% of the biogas, which is typical and was reduced using silica gel. Removing water vapor ensures that the gas can be stored without risk of condensation, which could lead to equipment damage or decreased gas quality.
- e) Carbon Monoxide (CO), Hydrogen (H_2), Nitrogen (N_2), and Oxygen (O_2): These gases were present in relatively small quantities. The presence of nitrogen

and oxygen could indicate minor air infiltration during the process, while carbon monoxide and hydrogen levels are typical byproducts of incomplete combustion or side reactions during the digestion process. Monitoring these gases is essential to ensure safety, as high concentrations of CO could pose a toxic hazard.

The combination of the biogas volume trends and GC analysis indicates that the anaerobic digestion process was successful in producing a significant amount of methane-rich biogas. The peak production on day 7 reflects an optimal stage of microbial activity, while the gradual decline afterward aligns with substrate depletion.

The GC analysis confirms that the biogas is composed mainly of methane, with relatively low levels of contaminants like CO₂ and H₂S, thanks to purification measures. The concentration of methane is sufficient for practical applications, though further reductions in CO₂ and H₂S could further enhance gas quality.

TABLE 1: Gas Chromatography Sample Analysis Result

Gas Component	Concentration (%)
Methane (CH ₄)	55.43
Carbon Dioxide (CO ₂)	13.42
Hydrogen Sulfide (H ₂ S)	2.44
Water Vapor (H ₂ O)	5.24
Carbon Monoxide (CO)	6.71
Hydrogen (H ₂)	3.87
Nitrogen (N ₂)	7.03
Oxygen (O ₂)	5.86

The daily biogas readings in Table 2 shows the biogas production for 14days during anaerobic digestion of the cattle

dung. The production starts low, with a volume of 0.5 L on day 1, gradually increasing as microbial activity intensifies, and peaks on day 7 with a maximum volume of 9.0 L. This increase corresponds to the exponential phase of microbial growth, particularly methanogenic bacteria responsible for methane production.

TABLE 2: Daily Biogas Volume Readings

Day	Biogas Volume (L/day)
1	0.5
2	1.0
3	1.8
4	3.2
5	5.0
6	7.1
7	9.0
8	8.2
9	6.7
10	5.1
11	3.8
12	2.6
13	1.4
14	0.9

After day 7, a noticeable decline in biogas production begins, reducing to 0.9 L on day 14. This gradual reduction suggests the depletion of easily digestible organic material, marking the deceleration phase of the digestion process. The decreasing trend indicates that most of the bioconversion had been completed, and the digesters were transitioning into the final phase of anaerobic digestion.

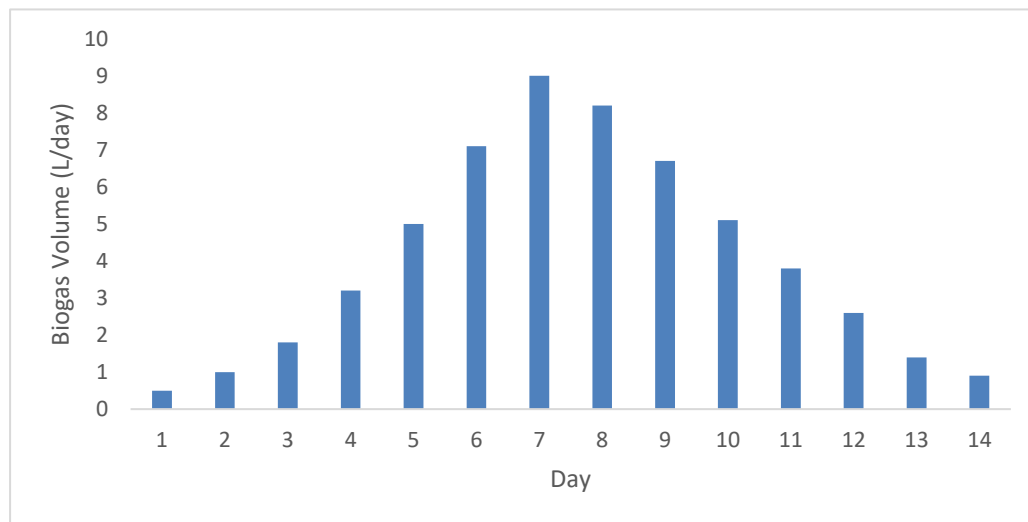


Figure 1: Daily Biogas Production

Figure 1 shows the biogas production from cow dung for a retention period of 14days which clearly depicts the typical phases of biogas production:

Lag Phase (Days 1-3): During this initial phase, microbial communities, especially hydrolytic bacteria, are acclimatizing to the substrate. The low gas yield in this phase reflects the slow breakdown of complex organic compounds in cow dung.

Exponential Production Phase (Days 4-8): The sharp rise in gas production from day 4, peaking at day 7, marks the methanogenic phase where most of the methane is produced. Methanogens actively convert intermediate products (like volatile fatty acids) into methane and carbon dioxide.

Decline Phase (Days 9-14): The decline in biogas production from day 9 onward signifies the depletion of readily

available organic matter, leaving more recalcitrant compounds that are harder to digest. As methanogen activity reduces, the biogas volume declines.

Figure 1 matches the expected behaviour for anaerobic digestion, highlighting an efficient gas production process during the mid-phase of the experiment.

3.2 Temperature

The experiment was conducted at a consistent temperature of 30°C, which falls within the mesophilic range (20–40°C) favorable for anaerobic digestion. Mesophilic conditions are optimal for microbial activity, particularly methanogens responsible for methane production. The temperature remained constant throughout the experiment, ensuring stable biogas production rates and preventing any temperature-related disruptions in microbial activity.

The stable pH and constant mesophilic temperature throughout the experiment contributed to maintaining optimal conditions for methane production. The steady decline in gas yield toward the end of the experiment indicates that most of the digestible organic matter had been converted into biogas, with minimal substrate remaining for further breakdown.

3.3 Comparative Analysis with Literature

The results obtained in this study are consistent with findings reported in previous investigations on anaerobic digestion of cow dung. The methane concentration of approximately 55% falls within the typical range of 50–70% reported for mesophilic anaerobic digestion of livestock manure (Appels et al., 2008; Angelidaki et al., 2011). This confirms that cow dung remains a suitable and reliable substrate for biogas production due to its balanced carbon-to-nitrogen ratio and established microbial consortia. Furthermore, the gas purification techniques employed, including moisture removal with silica gel, hydrogen sulfide scrubbing using ferric oxide, and carbon dioxide absorption with sodium hydroxide, are well-documented methods for improving biogas quality and upgrading methane concentration (Ryckeboosch et al., 2011). The observed production pattern, characterized by an initial lag phase, exponential increase, and subsequent decline, also agrees with the classical kinetic behavior of batch anaerobic digestion systems described in the literature (Batstone et al., 2002). However, several studies emphasize that tighter temperature control within the mesophilic range (30–40°C) or operation under thermophilic conditions (50–55°C) significantly enhances microbial activity, hydrolysis rates, and methane yield (Chen et al., 2008; Ward et al., 2008). Therefore, while the present system demonstrated stable digestion performance, further optimization through controlled temperature regulation and process monitoring could improve overall biogas yield and system efficiency.

3.4 Implications of Results for Practical Applications

The results of this study have practical implications for small- to medium-scale biogas production systems, particularly in rural or decentralized energy systems where organic waste like cow dung is readily available. The ability to produce and purify biogas with simple and cost-effective technologies has the potential to provide energy independence for small

communities or farms, while also contributing to waste management solutions. The purified biogas can be used for cooking, heating, or even electricity generation, making it a versatile renewable energy source. These results also demonstrate the potential for scaling up the process to industrial levels, where continuous biogas production and advanced purification techniques could make biogas a viable alternative to fossil fuels for large-scale energy generation or transportation fuel.

3.5 Gas Purification Efficiency

The biogas was purified using a NaOH scrubbing system to remove carbon dioxide (CO₂) and a ferric oxide scrubber to eliminate hydrogen sulfide (H₂S). Table 4.3 presents the results of the gas composition before and after purification.

IV. CONCLUSION

This research has investigated the production and purification of biogas from cow dung using anaerobic digestion. The study aimed to monitor biogas production trends over a 14-day period and perform gas composition analysis. The results have provided significant insights into the anaerobic digestion process, gas yield, and the efficacy of purification methods for improving the quality of biogas. The biogas production trend followed a typical pattern seen in batch anaerobic digestion, characterized by an initial lag phase (days 1-3), a rapid increase during the exponential phase (days 4-7), and a gradual decline (days 8-14). Peak production was observed on day 7, with a gas yield of 9.0 L. This trend is consistent with the metabolic activities of methanogenic bacteria, which break down the organic matter in the cow dung to produce methane (CH₄), carbon dioxide (CO₂), and other gases. Gas composition analysis using Gas Chromatography (GC) revealed that the biogas consisted primarily of methane (55.43%) and carbon dioxide (13.42%), with small amounts of hydrogen sulfide (H₂S), nitrogen (N₂), and oxygen (O₂). The NaOH scrubbing system effectively reduced CO₂ levels, while the ferric oxide scrubber significantly lowered the H₂S content. These purification techniques improved the overall quality of the biogas, making it more suitable for energy production. The findings indicate that cow dung is a viable substrate for biogas production, yielding high methane concentrations with appropriate purification methods. The study highlights the potential of biogas as a renewable energy source that can be harnessed from organic waste, contributing to both energy generation and waste management.

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