Global Journal of Engineering and Technology Advances
eISSN: 2582-5003
Cross Ref DOI: 10.30574/gjeta
Journal homepage: https://gjeta.com/

(RESEARCH ARTICLE)

Assessing the potential of cow dung and carpet grass as feedstock for biogas production to power a generator

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Global Journal of Engineering and Technology Advances, 2024, 20(03), 125–132

Publication history: Received on 22 July 2024; revised on 10 September 2024; accepted on 13 September 2024

Article DOI: https://doi.org/10.30574/gjeta.2024.20.3.0165

Abstract

This study investigates the potential of cow dung and carpet grass as feedstock for biogas production, aiming to provide a sustainable energy source for powering generators. A digester was fabricated to produce biogas from a mixture of cow dung and carpet grass under controlled anaerobic digestion conditions. The composition and energy content of the biogas were analyzed, and the biogas yield was measured over a 30-day period. Key parameters such as pH, system temperature, and total dissolved solids (TDS) were monitored to understand their influence on biogas production. Results showed that the pH values ranged from 4.1 to 5.2, which is lower than the optimal range for methanogenesis, yet biogas production was still feasible, peaking at pH 5.0. System temperature ranged from 28°C to 36.8°C, with the highest biogas yield observed at the upper end of this range. TDS levels fluctuated between 1,331 ppm and 3,060 ppm, indicating variations in the feedstock composition and microbial activity. The purified biogas successfully powered a 2.5 KVA generator for 30 minutes, demonstrating its practical application as an alternative energy source. This study highlights the potential of using cow dung and carpet grass for biogas production, contributing to sustainable energy solutions and waste management strategies.

Keywords: Biogas; Methanogenesis; Cow-dung; Carpet grass; Generators

1. Introduction

A sustainable global energy strategy currently plays a crucial aspect in the reduction of fossil fuel usage. Fossil fuel, such as coal, oil, and gas, have played a crucial role in powering the industrial revolution but, has in recent time been associated with several pressing challenges including, the depletion of conventional oil wells, a finite resource that has fueled global energy demands for decades [1].

In addition to this, it is important to acknowledge that the use of fossil fuels has also had negative consequences for the environment, including: the issue of climate change [2]; the rising levels of greenhouse gases; and, the detrimental impact of deforestation which is often driven by the demand for wood-fuel [3].

Amidst the various challenges and negative consequences affiliated with the use of fossil fuel, the urgency for alternative energy sources is of great essence amongst which is the development and utilization of renewable energy resources [4].

The recognition of the importance of renewable energy and other energy-related matters, such as energy efficiency, has been widespread on a global scale. These issues are considered crucial for sustainable development and play a significant role in achieving the Sustainable Development Goals (SDG) outlined in the United Nations Resolution, 2030 Agenda [5]. The shift towards a clean energy system and a carbon-neutral economy, along with the use of renewable gases, is anticipated to have a significant impact.

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Renewable technologies are technologies that generate power, heat, or mechanical energy through various sources such as biomass, wind, solar, hydro, and geothermal energy. Biomass as a source of renewable energy include an array of organic materials and diverse substrates such as: wood, food waste, energy crops, grass; which is nature's efficient means of solar energy storage [6], and animal waste like cow dung. In addition, renewable gas production stands out from other renewable energy sources due to its ease of transportation and storage as well as that their production aligns closely with the principles of the circular bio-economy, offering potential benefits in managing local biomass resources such as food industry and agricultural by-products, as well as municipal waste [7].

The utilization of biomass waste is a prevalent practice in biogas production. It is a well-established technology for converting bio-waste into bioenergy [8]. The efficiency and cost-effectiveness of biogas production from bio-waste makes it a competitive alternative to other forms of bioenergy (e.g. Fossil fuels) [9,10]. In addition, renewable gas production stands out from other renewable energy sources due to its ease of transportation and storage as well as that their production aligns closely with the principles of the circular bio-economy, offering potential benefits in managing local biomass resources such as food industry and agricultural by-products, as well as municipal waste [7].

Furthermore, global grasslands which constitute a significant expanse of the world's agricultural and land area, have garnered heightened interest and exploration for their potential applications in the field of bioenergy, notably in Europe and North America [11]. This surge in attention is underpinned by the multifaceted benefits these grasslands offer in sustainable energy production. Extensive research, including studies by [6,12], has consistently demonstrated the suitability of grassland biomass for bioenergy generation. The versatility of these ecosystems provides a diverse range of substrates, encompassing various grass species and organic matter, which can be harnessed to produce biofuels. This not only tackles the increasing energy needs but also supports the overarching goals of advocating for eco-friendly and sustainable energy sources.

Renewable gases can be classified into four categories namely: biogas, produced via anaerobic digestion; bio-methane, produced through thermal gasification or by purifying biogas; hydrogen, produced from natural gas using carbon capture storage or from the electrolysis of water using renewable electricity; and lastly, methane which is produced from hydrogen through the methanation of renewable electricity-sourced hydrogen [13].

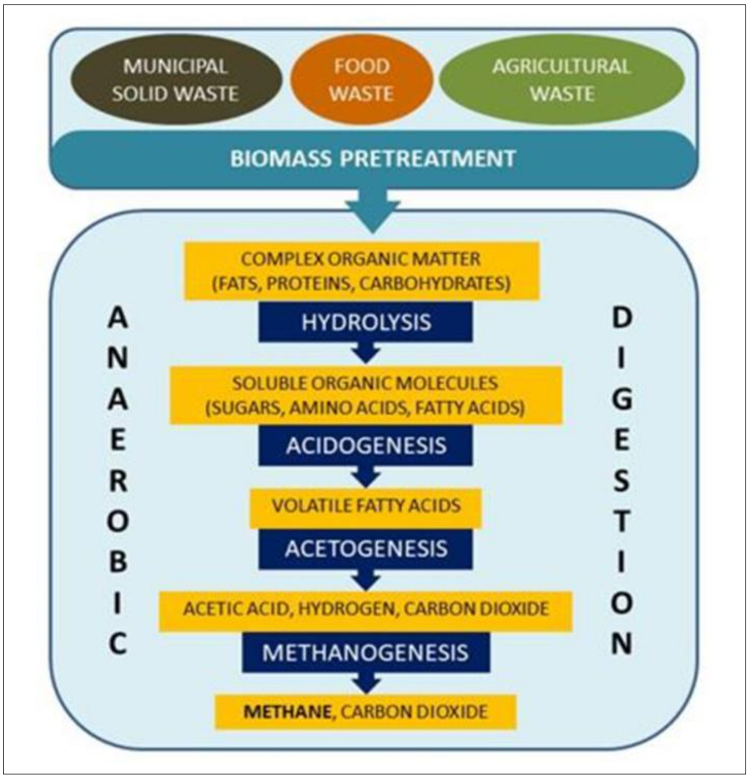

Figure 1 The AD process [15]

Biogas is an important component produced by the anaerobic digestion of organic materials using microbes. An anaerobic environment, such as a biogas digester, is the source of its production. In this environment, bacteria break down biomass, which results in the release of methane and carbon dioxide. In addition, there is a possibility that minuscule quantities of other gases, such as nitrogen and hydrogen sulfide, are present. Within the context of the anaerobic digestion process, the chemical composition changes in accordance with the feedstock that is used. In the context of this study, the generation of biogas, which emphasizes a sustainable and environmentally friendly approach to the harvesting of energy, entails the breakdown of organic materials produced from cow dung and carpet grass [14].

Anaerobic digester possesses a robust legacy and the capacity to fulfill present energy requirements, curtail greenhouse gas (GHG) emissions, and reclaim valuable nutrients. Nevertheless, even with the aforementioned factors in place, and with the necessary laws and funding mechanisms in place, the utilization of the AD potential remains below 2.5% [16].

2. Materials and methods

2.1. Materials

The materials used include: 250-litre drum, PVC pipes (2-inch and 1-inch), PVC gum, Thread tape, PVC elbows, adapters, and valves, Metallic nipple pipe (3/4 inch), Tools fometallicr cutting and drilling, Gas hose, pH reader, TDS meter, Thermometer, Carpet grass, Cow dung, Water and a 200-litre floating drum digester.

2.2. Study Area

The research was conducted in Rumuosi, Obio/Akpor LGA of Rivers State within one month.

2.3. Methods

2.3.1. Sample(s) and Sampling Techniques

The samples for this research consist of the biomass materials used in biogas production, specifically carpet grass and cow dung. The carpet grass was sourced from the lawn of the Chapel of Annunciation, University of Port-Harcout, and the cow dung was obtained from Boundary Slaughter, Aluu.

2.3.2. Research Design

The research design for this study involved investigating the production of biogas from a mixture of carpet grass and cow dung and assessing its potential for powering a generator. The design focussed on evaluating the effect of carpet grass and cow dung on biogas production, quality, and the possibility of energy generation. The study followed a single-factor experimental design, where the ratio of carpet grass to cow dung was the independent variable.

2.3.3. Experimental Setup

Independent Variables: Ratio of carpet grass to cow dung (70:30).

Dependent Variables: Biogas production rate, composition, and suitability for powering a generator.

2.3.4. Procedure

Fabricating the Digester

In this study, a 250-litre floating drum digester was fabricated to produce biogas from a mixture of carpet grass and cow dung. The fabrication process involved repurposing a 250-litre drum by cutting off its top and drilling holes for the feedstock inlet and digestate outlet. For the inlet assembly, a 2-inch backnut with an adapter and pipe was attached to the drum, while the digestate outlet assembly featured a 1-inch backnut with a valve and directing pipe. A separate drum was inverted over the digester to serve as a gas holder, equipped with a valve for gas collection. This cost-effective fabrication method allowed for efficient biogas production and gas storage suitable for small-scale energy applications. The digester was kept in a slightly shaded area while exposed to environmental conditions.

Pre-treatment of Biomass

The carpet grass was washed and dried to remove unwanted substances that may affect the result of the experiment. The size of the carpet was reduced by grinding manually, this was done to increase the surface area for substrate adsorption, allowing increased microbial activity and a subsequent increase in gas production.

Preparing the Feedstock

The biomass, carpet grass and cow dung were mixed in a ratio of 70:30. The mixing ratio was 3:1, water to biomass, stirred thoroughly to make a homogenous mixture. The process led to a combined 165 liters of water and biomass. The mixture was loaded into the 200-litre floating drum digester.

Biogas Purification

The methods used for purifying the biogas produced were water scrubbing and activated charcoal.

Biogas Collection

After purification, the gas was moved to a bio-bag for storage.

Powering a generator

The carburetor of a 2.5 KVA generator was changed to allow for biogas. The gas hose was connected from the biobag to the generator and the generator was used to power a building.

2.3.5. Data Collection

Data was collected directly from the experimental setup. Temperature was measured using thermometers, pH was assessed using pH meters, total dissolved solids were measured with a TDS meter and the volume of gas produced was measured. Daily measurements of temperature, pH, total dissolved solids, and volume of gas produced were recorded throughout the experimental period to track changes in biogas production over time.

2.3.6. Data Analysis

The method of analysis used for this research is the Pearson correlation, which is a statistical measure used to assess the strength and direction of a linear relationship between two continuous variables. Pearson correlation was selected because it allows for the examination of potential associations between the variables of interest in this study: pH, system temperature, total dissolved solids and volume of gas produced. This method helps to quantify the degree of relationship between these variables and provides insights into their interdependencies.

3. Results

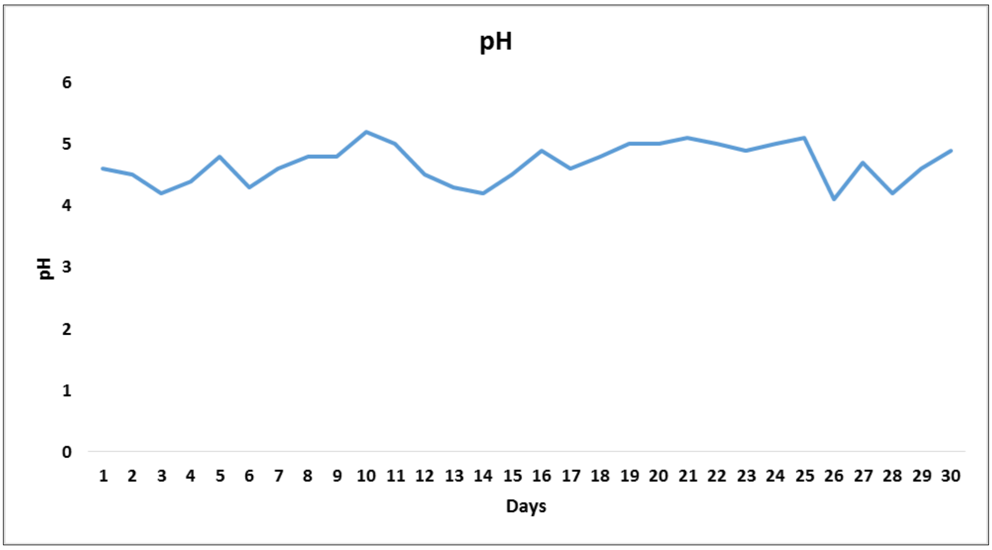

Figure 2 pH Variation over 30 Days of Biogas Production

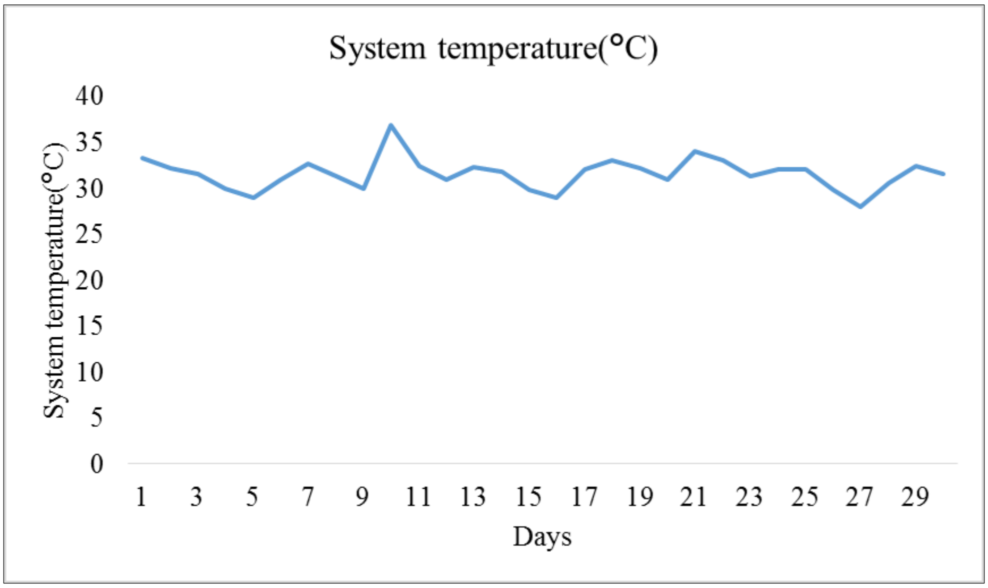

Figure 3 System Temperature Trends during Biogas Production

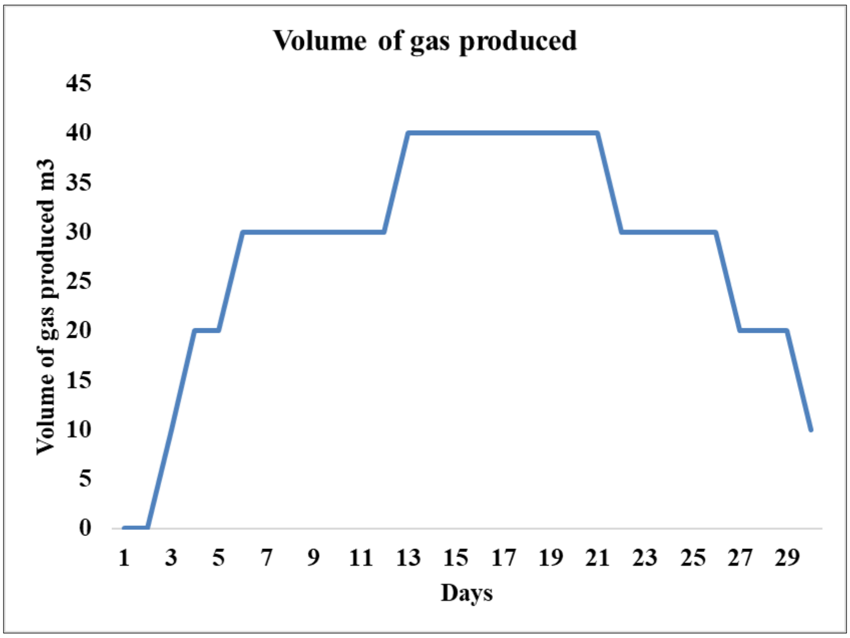

Figure 4 Volume of Gas Produced Over a 30-Day Period

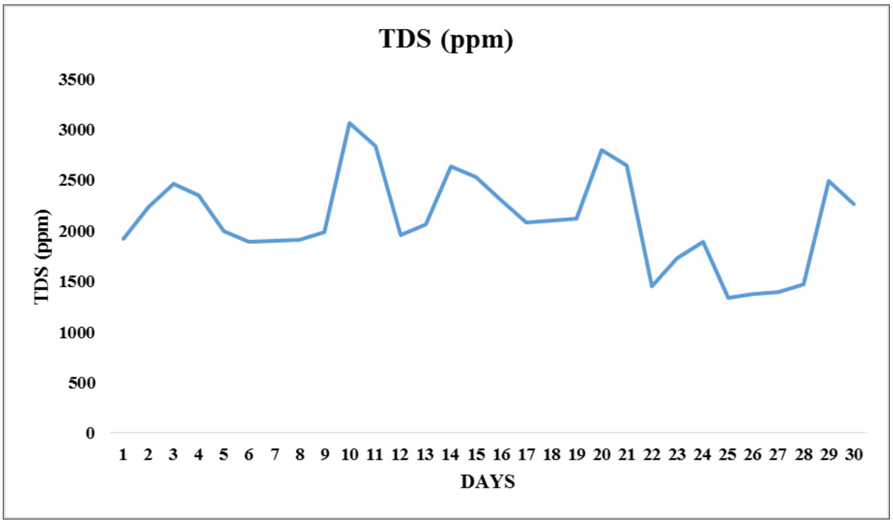

Figure 5 Total Dissolved Solids (TDS) Variation in Biogas Production Over 30 Days

4. Discussion

4.1. pH

The pH levels remained within a relatively stable range after the experimentation, showing slight fluctuations but no drastic changes. The pH values ranged from 4.1 to 5.2 over the 30-day period as depicted by figure 3.1 but, optimal pH for biogas production typically falls within a relatively stable range of 6.5 to 8.0 for methanogenic activity. In this case, the pH values observed (i.e. a value ranging from 4.1 to 5.2) are lower than ideal for methanogenesis, which might impact gas production efficiency. Notably, biogas production was observed to increase as pH values approached the range of 4.2 to 5.1, with a peak volume of 40 units at pH 5.0. This suggests that maintaining optimal pH levels is crucial for enhancing biogas yield from the specified feed stocks [17, 18].

4.2. System Temperature

The system temperature ranged from 28°C to 36.8°C during the experiment. This is seen in Figure 4.2. Temperature influences microbial activity in anaerobic digestion. Warmer temperatures generally promote faster microbial activity, leading to increased biogas production. The highest gas production (40 m3) was observed when the temperature peaked at 36.8°C, indicating a positive correlation between temperature and gas yield. Warmer temperatures generally promote faster microbial activity, enhancing biogas production efficiency [19,20].

4.3. Volume of Gas Produced

Gas production varied over the experimental period, ranging from 0 to 40 m3. Initial days showed no gas production (0 m3) but gradually increased as the experiment progressed. Gas production significantly increased when the pH was around 4.2 to 5.1 and the system temperature ranged from 29°C to 36.8°C, reaching a peak of 40 units (Figure 3.3).

Overall, gas production was influenced by both pH and system temperature, with optimal conditions resulting in higher gas yields.

4.4. Total Dissolved Solids

The TDS values range from a minimum of 1,331 ppm to a maximum of 3060 ppm over the 30-day period as shown in Figure 3.4. There appears to be variability in the TDS levels, suggesting fluctuations in the composition of the liquid phase of the biogas production system. Initially, the TDS values start relatively low, gradually increasing and peaking around day 10 with a value of 3060 ppm, before decreasing again towards the end of the experiment. The initial fluctuations in TDS could be attributed to changes in feedstock composition, microbial activity, or variations in the degradation of organic matter. The peak TDS observed around day 10 (3060 ppm) might indicate a shift in the degradation of organic material or accumulation of certain dissolved solids during this period. Towards the later stages of the experiment, the TDS values stabilize and then decline, possibly due to a reduction in organic matter availability or changes in the microbial community.

4.5. Generator Application

An essential aspect of this study was the practical application of the biogas produced from carpet grass and cow dung. After the experimental period, approximately 0.800 cm3 of raw biogas was generated, which was then purified to yield about 0.700 cm3 of usable biogas. This purified biogas was subsequently utilized to power a 2.5 KVA generator continuously for approximately 30 minutes demonstrating the feasibility of biogas as an alternative energy source.

5. Conclusion

Total dissolved solids (TDS) were shown to be a possible component that might affect the efficiency of biogas generation in this investigation. While the experiment was running, the measured TDS levels in the system were between 1,331 and 3,060 parts per million. Although further research is needed to determine a clear correlation between TDS and gas generation, these results do indicate that TDS might impact the actions of microbes and the digestive processes. Even though the pH values that were found were below the usual range for methanogenic activity, gas production was still possible, but at different rates. Warmer temperatures promoted quicker digestion processes and increased gas production, suggesting that system temperature is a key driver of microbial activity in anaerobic digestion. The research highlights the potential of carpet grass and cow dung as sustainable energy sources by contributing useful information about the relationship between pH, temperature, TDS, and gas output.

The fact that a generator can be powered by pure biogas shows how promising biogas is as an alternative energy source. This bodes well for distributed energy generation, particularly in remote places that have an abundance of organic waste materials like cow manure and carpet grass. Biogas production might be a viable component of sustainable energy plans, helping with waste management and cutting down on fossil fuel use, according to the results. Biogas technology has the potential to revolutionize energy generation and promote environmental sustainability if it undergoes further study and development.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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