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UNLOCKING THE POTENTIAL OF BIOENERGY: A SUSTAINABLE SOLUTION FOR ENERGY SECURITY, WASTE MANAGEMENT, AND ENVIRONMENTAL CONSERVATION

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ABSTRACT

The study was carried out to generate biogas from fresh cowdung. Proximate analysis on the cow-dung sample revealed moisture content to be 60.53%, Ash content 11.01%, total solids 39.47%, volatile matter 10.78%, protein content 12%, nitrogen content 1.6%, carbohydrate 5.68% and fixed carbon 17.68%. The pH and Temperature were measured daily at 2:00pm, the temperature ranged from 30^{O}C-38^{O}C and the pH range was 6.7 - 7.2. The gas produced was measured daily by calculating the volume with the height increased daily up to 36 days. The results showed a typical biogas production curve, consisting of lag, acceleration, maturation, and decline phases. The optimal retention time for biogas production is identified as 20-30 days, during which biogas yields are highest. The findings indicate that microorganisms require an initial adaptation period (Days 1-3) before biogas production commences, followed by a significant increase in production (Days 11-20) and a stable production rate (Days 21-30). A decline in production is observed after 30 days. This study highlights the importance of retention time in biogas production and demonstrates the need for monitoring production kinetics to optimize retention time for specific substrates and microbial communities. The results have implications for the design and operation of biogas production systems.

Keywords: Cow-dung, Waste management, Bioenergy, Environmental conservation

INTRODUCTION

The world is facing a triple challenge of energy insecurity, waste management, and environmental degradation (Rai and Da Silva, 2017). Bioenergy, derived from biomass, offers a promising solution to these pressing issues (Owusu and Asumadu-Sarkodie, 2016). Biomass, encompassing all organic matter, can be converted into electric power, heat, or motion, providing a renewable energy source (Lee & Shah, 2013). However, the large amounts of biomass waste generated pose significant environmental risks (Fulford, 2011). Anaerobic digestion (AD) of organic waste streams can produce biogas, a green energy resource, offering a versatile and clean fuel for various energy services (Mshandete & Parawira, 2009; Owusu and Asumadu-Sarkodie, 2016). Biogas technology not only provides energy but also contributes to sustainable development, socioeconomic benefits, and a green environment. This paper explores the benefits and challenges of bioenergy, highlighting biogas as a viable alternative to traditional energy sources, and discusses the potential of anaerobic digestion to combine waste management and energy production, leading to a more sustainable future (Monnet, 2003). Interestingly, bioenergy offers a promising solution to the world's energy insecurity, waste management, and environmental degradation challenges. Biogas technology plays a crucial role in this context, converting organic waste into energy and providing numerous benefits (Owusu and Asumadu-Sarkodie, 2016). The use of biogas technology can lead to socioeconomic benefits, a green environment, and contribute to sustainable development. Additionally, biogas technology produces nutrient-rich organic fertilizer and effluent slurry, useful for algae growth, fish production, and seed germination, making it a valuable tool for small-scale and large-scale applications, including electric power production.

Anaerobic digestion, the process behind biogas technology, can be used to treat biodegradable wastes and produce saleable products like heat, electricity, and soil amendments (Monnet, 2003). The most valuable use of anaerobic digestion is to combine waste management and the utilization of bi-products, making it an attractive solution for sustainable development. The anaerobic digestion process involves four stages: pre-treatment, digestion, gas upgrading, and digestate treatment, each with varying requirements depending on the feedstock and its contamination (Monnet, 2003). The final stage, biogas upgrading, is necessary to remove impurities and make the gas suitable for various applications, including boilers, combined heat and power units, natural gas, or vehicle fuel (Monnet, 2003).

MATERIALS AND METHODS

Chemicals/Reagents

American Chemical Society grade ≥ 95 hydrochloric acid (British drug house), Analytical Reagent grade ≥ 85 Sodium hydroxide (British drug house) and Analytical Reagent grade ≥ 95 Boric acid (British drug house).

Sample and Sampling

Fresh cow dung sample was collected from Gidan Yunfa Village, located close to the Department of Energy and Applied Chemistry at Usman Danfodiyo University Sokoto. The collected samples were carefully stored in a large sack until they were ready to be used for experimentation.

Sample pre-treatment for proximate analysis

The sample was measured and then mixed with water at a 1:1 ratio to form a uniform slurry. Proximate laboratory analysis was conducted on the substrate to determine its physicochemical properties, including moisture content, total solids, ash content, volatile matter, fixed carbon and carbon-to-nitrogen (C:N) ratio. These analyses were performed using standard procedures outlined in the Kjeldahl method. This comprehensive analysis provided essential information on the substrate's composition and characteristics.

Biogas Plant Description and Operation

The biogas plant features a fabricated floating dome digester, comprising two PVC tanks: a 1000 m³ tank and a 750 m³ tank. The 750 m³ tank is inverted and inserted into the 1000 m³ tank, creating a floating dome design. The digester has an inlet channel for slurry injection and an outlet channel for overflow. The top tank has a separate outlet that serves as a gas collector. The gasholder stores the biogas produced in the digester, causing it to float as it fills with gas. Biogas is extracted from the gasholder through a 3 mm diameter gas pipe, with flow control provided by a valve fitted to the pipe. This setup enables efficient collection and utilization of the produced biogas.Figure 1 shows the typical bio-digester used

Figure 1: Floating Dome digester

Generation of Biogas

A modified procedure is employed and described in this article. Fresh substrate (200kg) was divided into five sacks, each weighing 40kg. Slurry preparation involved measuring 20L of water, which was then mixed with the substrate in each sack to create a uniform slurry. A total of 400 L of slurry was poured into a 1000m^3 digester, filling approximately two-thirds of the container, and leaving one-third for biogas production. Daily temperature readings were taken using a digital thermometer to monitor both ambient temperature and slurry temperature and the results are reported in Figure 2. The pH of the digesting system was also recorded daily as reported in Figure 3, as microorganisms are sensitive to pH variations, which can impact biogas production.

Measurement of Volume of Gas Produced

The daily biogas production was measured by calculating the volume of the digester, as described elsewhere (Alfa, 2010). To ensure accurate readings, the gas holder was calibrated using tape measurements. The volume of biogas produced was recorded at 7:00pm daily and presented in Figure 4. This was done by calculating the volume of the gas holder that floated above the water level in the water jacket. The volume of the gas holder was calculated using the formula:

$$V=\pi r^2 h \quad (1)$$

π=3.142

r=radius of the digester

h=height(x) which may varies

RESULTS AND DISCUSSION

Proximate Analysis

The results of the proximate analysis are presented in Table 1 below.

Table 1: Proximate analysis of Cow Dung

S/No	Parameter	Cow dung
1	Moisture content (%)	**60.53**
2	Ash content (%)	**11.01**
3	Total solid (%)	**39.47**
4	Volatile matter (%)	**10.78**
5	Protein content (%)	**12.00**
6	Nitrogen content	**1.60**
7	Carbohydrate (%)	**5.68**
8	Fixed Carbon (%)	**17.68**

Table 1 presents the proximate analysis results of the substrates. The moisture content was determined to be 60.53%. The moisture content is suitable for biogas generation, as excessive moisture can dilute the substrate and reduce the concentration of organic matter (Rajinikanth and Natarajan, 2017). The ash content was found to be 11.01%, which is within the optimal range for biogas substrates. Extremely high ash content can reduce biogas yield by displacing organic matter that would otherwise be converted into methane (Brown, 2016). The volatile matter content was 10.78%, indicating a normal digestible organic matter content for biogas production. The carbohydrate content was 5.68%, likely due to the high carbohydrate composition of the cow dung feed. These carbohydrates can be broken down into simple sugars during anaerobic digestion, providing a source of organic matter for methane production (Chandel et al., 2019). The protein content was 12%, resulting from the excretion of nitrogenous waste products by the cow. High total solids substrates tend to have more concentrated nutrients, influencing microbial activity and biogas production rates (Yi et al., 2014). The nitrogen content was 1.6%, consistent with the findings of Walker et al. (2009).

Temperature and pH Results

Figures 2 and 3 below show the results of pH and temperature as recorded during the production of biogas. The temperature of the digester was taken at 2:00 PM daily for 36 days. From the range of the temperatures, it can be observed that the temperature is favorable for biogas production. The slurry temperature varies from 30– 38^{O}C, these temperature ranges signify that biogas production is achieved within the mesophilic temperature range (25 – 45^{O}C) Ukapai and Nnabuchi, (2012).

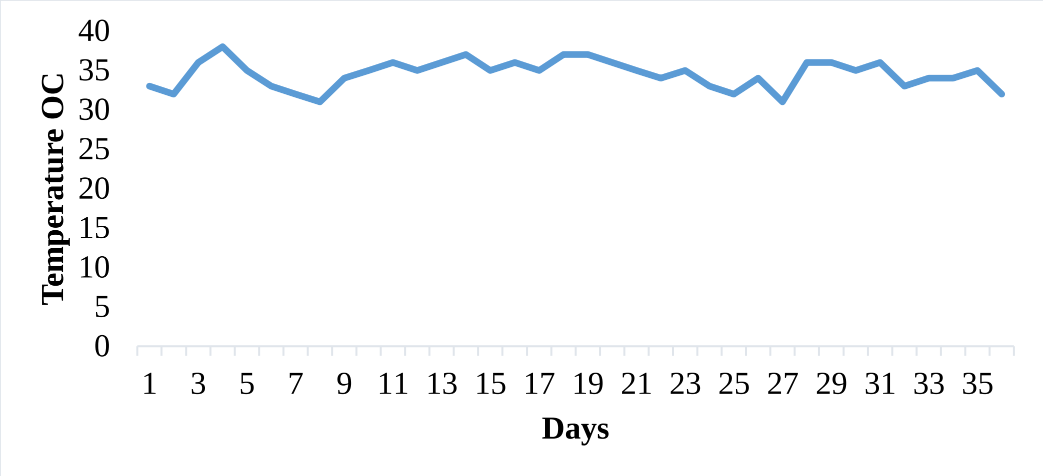

Figure 2: Daily temperature of the feedstock

The pH of the substrate was found to be within 6.7 - 7.2 and it's in agreement with the studies carried out by Kheireddine et al (2014) and Hassan et al,(2022).

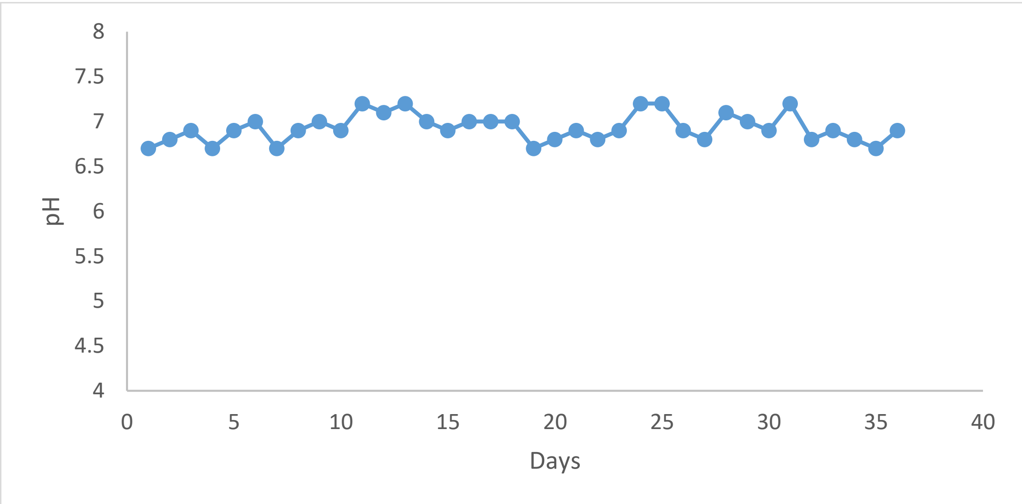

Figure 3: Daily pH of the feedstock

The results shown in Figure 4 revealed the volume of biogas produced against retention time over 36 days. The Initial phase (Days 1-3) indicates no biogas production was observed during the first three days, indicating a lag phase where microorganisms are adapting to the substrate. Early production phase (Days 4-10) in which biogas production starts on Day 4 and increases gradually, reaching 27.9952 m^3 on Day 10. This phase is characterized by a steady increase in biogas production as microorganisms start breaking down the substrate. The acceleration Phase (Days 11-20) the biogas production accelerates from Day 11 to Day 20, reaching 82.8545m^3. This phase is marked by a significant increase in biogas production, indicating optimal microbial activity.

More so, the maturation Phase (Days 21-30) of the biogas production continues to increase, but at a slower rate, reaching 139.6933m^3 on Day 30. This phase is characterized by a stable biogas production rate, indicating a mature microbial community. However, in the decline phase (Days 31-36) the biogas production starts to decline from Day 31, reaching 192.2904m^3 on Day 36. This phase is marked by a decrease in biogas production, indicating a reduction in microbial activity. Overall, the results showed a typical biogas production curve, with an initial lag phase, followed by an acceleration phase, a maturation phase, and finally a decline phase. The optimal retention time for biogas production appears to be between 20-30 days, where biogas production is highest.

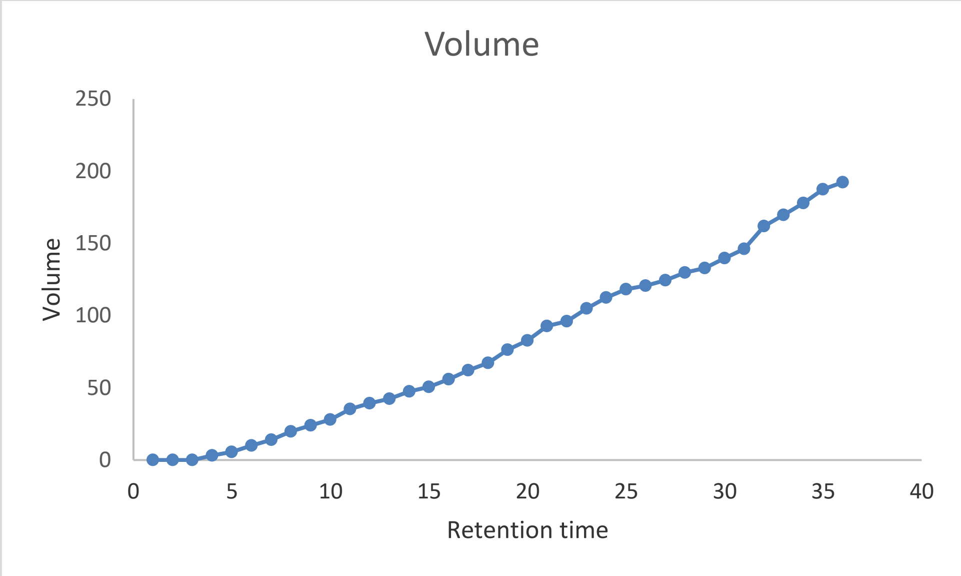

Figure 4: Volume of biogas produced

CONCLUSION

The biogas production curve follows a typical pattern, consisting of an initial lag phase, an acceleration phase, a maturation phase, and a decline phase. The optimal retention time for biogas production is between 20-30 days, where biogas production is highest. The lag phase (Days 1-3) indicates that microorganisms need time to adapt to the substrate before biogas production begins. The acceleration phase (Days 11-20) shows a significant increase in biogas production, indicating optimal microbial activity. The maturation phase (Days 21-30) is characterized by a stable biogas production rate, indicating a mature microbial community. The decline phase (Days 31-36) shows a decrease in biogas production, indicating a reduction in microbial activity. The results suggest that retention time has a significant impact on biogas production, and optimizing retention time can lead to increased biogas yields. The study demonstrates the importance of monitoring biogas production over time to determine the optimal retention time for specific substrates and microbial communities.

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