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The processing and preservation of biogas by utilizing cow manure

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Abstract

This study focused on the generation of biogas from cow dung, specifically examining the anaerobic production process using 10kg of cow dung as input. The results indicated that the amount of biogas produced was directly proportional to the quantity of dung used. A cumulative volume of 35.63m² was obtained, with an average daily production of 7.5m², suggesting the process was in its final stage. Additionally, the findings revealed that biogas production is influenced by the quantity of dung employed, meaning that a larger amount of dung can potentially yield a greater quantity of biogas. It is recommended that governments in developing countries encourage private organizations to engage in large-scale biogas production and incorporate its development into rural energy policies, considering the abundant availability of cow dung, the primary raw material for biogas production.

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Introduction

The global need for alternative sources of cooking gas has become a matter of great concern. Developing countries particularly welcome any material that can serve as an alternative fuel source Cromwell (1999). Waste is generated by communities on a daily basis, whether in liquid, solid, or gaseous form, and the proper management of this waste has always been a significant issue. There is a growing emphasis on promoting a sustainable environment, and it has become evident that a substantial portion of the materials discarded as waste can actually be utilized for beneficial purposes (WEC, 2001). The production of biogas from organic waste is an efficient method of waste management and a cost-effective means of obtaining an alternative fuel source. Biogas technology offers a two-fold approach to addressing the issue of organic waste management. The first phase involves effective waste disposal, accomplished by utilizing microorganisms in an odor-free process, thus avoiding the negative aspects associated with landfill sites. The second phase involves the conversion of organic waste into useful end products, such as organic fertilizer and biogas, with the latter serving as a fuel source.

The affordability and accessibility of biogas make it particularly valuable for meeting the energy needs of low-income individuals. While a significant proportion of the world's population resides in rural areas, primarily in developing countries, traditional fuels like wood, dung, and crop residues are still the predominant sources of energy for cooking (UNEP, 1981). Despite their drawbacks in terms of sustainability, collection efforts, and pollution, traditional fuel sources are likely to remain the primary cooking fuel for rural communities in developing countries for the foreseeable future. Biogas, utilizing resources such as cow dung and other organic waste materials, is often cited as an excellent example of appropriate technology that effectively addresses the basic need for a cooking fuel. Moreover, biogas production from organic waste not only generates energy but also conserves valuable nutrients, allowing them to be recycled back into the soil as slurry. In many developing countries, where fossil fuel prices are rising steadily (Gunnerson and Stukey, 1986), biogas can serve as an attractive alternative to increasingly scarce conventional fuels. Biomass-derived fuels, including biogas, represent an important energy product obtained through the combustion or conversion of organic material into gaseous or liquid fuel. Biomass, derived from photosynthesis, is the organic material that converts solar energy into stored chemical energy.

The anaerobic process for biogas production relies on two groups of bacteria: acid producers and methane producers, which operate at different levels. The complete anaerobic decomposition of organic material involves the degradation of proteins, lipids, and carbohydrates into various volatile fatty acids, ultimately resulting in the production of acetic acid and hydrogen. Biogas is then generated from acetic acid or hydrogen. The initial step in anaerobic decomposition is the breakdown of complex organic molecules into simpler ones, such as sugars, which are then fermented into even simpler molecules like acetate and H_2 Gunnerson and Stukey, (1986). Numerous studies have been conducted on biogas production, with methane (CH_4) being the primary component of biogas produced during the decomposition of plant matter under conditions of limited air supply. Successful methane production units from cow dung have been reported in various parts of the world (Moses Jeremiah *et al*, 2022). It has been noted that trapped methane due to poor ventilation in coal mines can cause explosions in the mining industry (Yadava and Hesse,1981).Proper management of such gas can enhance the economic value of coal mines. Cow dung, as a rich source of nitrogen and suitable for high biogas yields due to pre-fermentation in the stomachs of ruminants, holds great potential for biogas generation Allmam *et al.*, (2013), Megonigal *et al.*, (2004). The wastes generated from domestic and agricultural activities can also be converted into valuable products, such as methane and manure, through anaerobic digestion technology Ukpai and Nnabuchi (2013).

Alternative energy sources, in this context, refer to energy sources that do not rely on the burning of fossil fuels or the splitting of atoms. These sources are often referred to as renewable energy sources and have gained interest due to the adverse effects of burning fossil fuels and the continually increasing costs of conventional fuels. It is estimated that by the turn of the century, renewable energy could replace 5-15% of the fossil fuel consumption in developing countries Melemey and Bryant (1981), Rohjy *et al.*, (2013) thereby reducing dependence on non-renewable resources.

Problem Statement: Despite the availability of raw materials for biogas production, the challenge lies in harnessing and storing this energy efficiently. While biogas technology is well-established in some developed countries, its implementation in developing countries has been limited. The interest in biogas technology stems from its potential to provide an economically viable solution to the energy demands of non-renewable fossil fuels and waste management. This article seeks to address how biogas can be harnessed as an alternative cooking fuel. Several factors influence biogas production, including the composition of methane in the biogas, which is primarily determined by the nature of the biomass substrate and prevailing physiochemical conditions Rohjy *et al.* (2013). Factors such as temperature, pH, carbon-to-nitrogen ratio, nutrient addition, and the nature of the raw material affect the biodegradability of biomass for biogas production. Methane bacteria, being strict anaerobes, thrive best at approximately 35°C and have a pH range of 6.8-7.4. According to Sagagi *et al.* (2009) and Bouallagui *et al.* (2004) the volume of slurry content in the material also plays a crucial role in the transformation into biogas. The carbon content contributes to high methane yield, while nitrogen is essential for bacterial growth. A deficiency in nitrogen hampers bacterial growth and activity, while an excess can lead to toxic ammonia levels Samchucks (2004).

Materials and methods

A plastic container was utilized to hold 10kg of cow dung, which was mixed with 20kg of water, maintaining a ratio of 1:2 dung to water. The mixture was fed into the digester through the inlet (Fig. 1). Stirring of the mixture was performed daily to ensure homogenous bacterial activity and prevent scum accumulation on the digester. Stirring is necessary to facilitate direct contact between microorganisms and organic material, reducing scum formation on the sludge's surface.

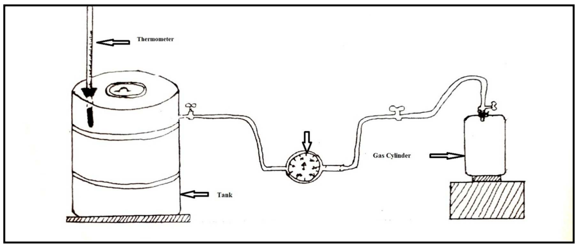

Fig. 1. Schematic Diagram of the Biogas Setup.

In the biogas production setup, a storage tank was connected to a balloon using a hose. The balloon, in turn, was connected to the outlet of the digester, which allowed for the collection of the produced gas. A pressure gauge was installed on the storage tank to measure the pressure of the gas inside. This arrangement is illustrated in Fig. 1. Additionally, a thermometer was used to measure the ambient temperature as well as the temperature inside the digester. Fig. 1 represents the schematic diagram outlining the process of preparing for biogas production.

Results

The daily temperature measurements taken after feeding the digester with the mixture of dung are presented in Table 2. These measurements provide an insight into the temperature changes over the course of 12 days. Table 3 presents the recorded pressure, volume, and temperature during the 12-day production period. These values provide an understanding of the changes in pressure, volume, and temperature of the produced biogas. There is marked difference in biogas yield between the lag phase, the optimum phase and the death phase.

Detailed analysis and interpretation of the results will be discussed to determine the relationship between temperature, pressure, and volume during the biogas production process. These findings will shed light on the efficiency and effectiveness of the biogas production from cow dung and its potential as an alternative cooking gas.

Table 1. The material and Quantity used.

<table>
<tr><th>S/N | Material Quantity /unit</th><th>S/N | Material Quantity/unit</th><th>S/N | Material Quantity/unit</th></tr>
<tr><td>1</td><td>Cow dung</td><td>10kg</td></tr>
<tr><td>2</td><td>Deionized water</td><td>20kg by mass</td></tr>
<tr><td>3</td><td>Thermometer for monitoring temperature(0°C — 100°C range)</td><td>1</td></tr>
<tr><td>4</td><td>Stainless storage tank with stirrer, inlet and valve suitable for storage of the gas</td><td>1 unit with appropriate volume</td></tr>
<tr><td>5</td><td>Pressure gauge for measuring the pressure of gas</td><td>1 unit capable of reading the pressure of the gas</td></tr>
<tr><td>6</td><td>12.5kg gas cylinder</td><td>1 unit</td></tr>
<tr><td>7</td><td>Digester (Fermentation tank) consisting of inlet chamber, inlet and outlet pipe, the gas delivering tube and a stirrer</td><td>1 unit</td></tr>
<tr><td>8</td><td>Scaled weighing balance</td><td>1 unit</td></tr>
<tr><td>9</td><td>Plastic container used for mixing</td><td>1 unit</td></tr>
</table>

Table 2. Temperature of digester and ambient temperature.

Days	Temperature of digester(0^{c})	Ambient temperature (0^{c})
Day 1	37	32
Day 2	36	32
Day 3	40	35
Day 4	45	35
Day 5	43	36
Day 6	42	32
Day 7	44	35
Day 8	43	35
Day 9	40	27
Day 10	45	34
Day 11	42	33
Day 12	32	32

Table 3. Measurement of volume, Pressure and Temperature of Biogas in the last six days of the experiment.

Days	Time	Temperature (°C)	Pressure (mmhg)	Volume (m^3)	Average temperature (°c)	Average Pressure (mmhg)
Day 1	11am-1pm	44	0.20	3.75	42	0.40
	3pm-4pm	40	0.60	7.50		
Day 2	11am-12pm	44	1.00	3.75	42	1.10
	3pm-4pm	40	1.20	3.75		
Day 3	12pm-1pm	45	1.50	3.75	42	1.60
	4pm-5pm	39	1.60	3.75		
Day 4	11am-1pm	45	2.50	3.75	42	5.40
	3pm-5pm	42	2.90	3.75		
Day 5	11am-12pm	43	3.50	1.88	42	3.70
	3pm-5pm	44	3.80	Nil		
Day 6	11am-1pm	44	3.80	Nil	43	3.80
	3pm-5pm	42	3.80	Nil		

Discussion

The temperature measurements presented in Table 2 indicate that the digester consistently maintained a higher temperature than the ambient temperature. This can be attributed to the direct absorption of sunlight by the digester. The measurement of both ambient and digester temperatures is important to assess the rate of decomposition during the biogas production process. Table 3 shows that peak yield of biogas was recorded on day one between 3.00-4.00 p.m. On this day and time, the concentration of methane and carbon dioxide were possibly higher in the organic substrate. Thereafter, there was a sharp decline in biogas yield from day 2 to 4, with a uniform volume of output for 3 day, despite a slight variation in temperature between morning and afternoon, although the average temperature was uniform throughout the experiment. Biogas production further reduced in the morning of day 5 and was non-existent in the afternoon and throughout day 6, suggesting that the concentration of methane and carbon dioxide in the organic substrate could have been exhausted, leaving only the residual fibers from the undigested gut contents (Table 3). Similarly, the study further revealed that biogas yield was optimum at high pressure potential with abundant concentration methane and carbondioxide. For instance, biogas yield was highest at 0.60mmhg but dropped to a moderately uniform yield threshold with fluctuations in pressure between 1.00, to 2.90mmhg respectively, further reduced at 3.50mmhg and finally ebbed out at 3.80mmhg on the afternoon of the 5^{th} day to the 6^{th} day which indicates the death phase of the production process. This shows that biogas production was inversely correlated with the pressure potential of the setup.

In the measurement of gases, three key quantities are involved: volume, temperature, and pressure. The data from Table 3 confirms the relationship between volume, temperature, and pressure. It shows that a uniform average temperature was needed for sustainable biogas production within a range of pressure above which the production may begin to decline. The results suggest that the quantity of dung used and the biodegradability of the organic material play crucial roles in biogas production. Using a larger quantity of dung increases the likelihood of producing a greater volume of gas. Additionally, the ambient temperature during the production period ranged from above 36 °C to less than 45 °C, with an average of 42 °C as shown in Table 3.

Conclusion and recommendation

In conclusion, the anaerobic digestion of biomass, such as cow dung, offers significant benefits in terms of energy generation and environmentally safe waste management. Biogas technology can serve as a local and refined solution for turning waste into wealth, improving the livelihoods of rural populations, and reducing dependence on fossil fuels. Anaerobic digestion can also help mitigate environmental pollution caused by the improper disposal of livestock manure in developing countries. Based on these findings, it is recommended that governments of developing countries incorporate the development of renewable energy, specifically biogas production, into their energy policies, particularly in rural areas where cow dung is readily available. By doing so, governments can promote employment generation and contribute to sustainable development.

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