**Effect of EM4 Addition on Biogas Pressure in a Small-Scale Household Digester**

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**Abstract.** Biogas is a renewable energy source derived from the anaerobic decomposition of organic waste by microorganisms. In this study, cow manure was selected as the primary substrate due to its high content of methane-producing bacteria. The research aimed to evaluate the effect of EM4 (Effective Microorganisms) addition on the gas pressure produced in a household-scale biogas digester. Three different substrate compositions were tested: 1:1 (manure : water), 1:1:1 (manure : water : EM4 at 1 ml), and 1:1:2 (manure : water : EM4 at 2 ml). The fermentation process lasted for 20 days under anaerobic conditions. The results showed that the addition of 2 ml EM4 resulted in the highest biogas pressure of 3.5 kPa and a gas mass of 0.00607 kg. In comparison, the other compositions produced lower pressures ranging from 2 to 2.6 kPa and gas masses between 0.00354 kg and 0.00455 kg. These findings indicate that increasing EM4 concentration can enhance biogas production performance in small-scale applications.

# INTRODUCTION

The increasing population in Indonesia has led to a growing demand for energy, particularly for oil and gas fuels. The continuous use of fossil-based fuels has caused energy shortages, as fossil energy sources are non-renewable. Therefore, the development of alternative energy sources is urgently needed [1].

To meet household energy needs, a systematic effort is required to utilize renewable energy. In daily life, people heavily rely on natural gas such as LPG (Liquefied Petroleum Gas) for activities like cooking and water heating. This condition highlights the need for alternative energy sources such as biogas [2].

Biogas is considered a promising alternative to fossil fuels because of its renewable nature and lower emissions, making it more environmentally friendly. Biogas is produced with the help of microorganisms that convert biomass (e.g., animal waste), which is abundant and underutilized by the community [3].

Cow manure is widely used as a substrate for biogas production due to its ideal carbon-to-nitrogen (C/N) ratio of 26.6, compared to chicken manure, which has a lower C/N ratio of 9.1 [4]. Several studies have shown that biogas can be produced through the anaerobic fermentation of organic waste, such as cow manure, under oxygen-free conditions [5].

Previous research has investigated the use of high-density polyethylene (HDPE) plastic digesters with a mixture of organic waste, cow manure, and water at a ratio of 4 kg:2 kg:60 kg. These materials were fermented for 30 days to evaluate digester efficiency [6].

Other studies examined biogas production using livestock waste mixed with rumen fluid and water to determine the effect of different compositions on biogas yield [7]. Another experiment utilized a batch digester with a 2-liter capacity to analyze biogas production from a mixture of cow manure, chicken manure, and dwarf elephant grass [8].

Further experiments evaluated biogas production using cow manure and elephant grass diluted at three different water ratios, with the mixture processed in a plastic drum batch digester to observe temperature and gas quantity [9].

In another study, fresh organic waste was combined with cow manure in a batch reactor at five different composition ratios. The optimal ratio of 1:1 with a total solids (TS) content of 9% and a C/N ratio of 9.7 produced the highest gas yield of 1.03 liters [10].

The present research aims to determine the gas pressure and gas mass produced in the digester [12, 13]. Additionally, it includes an analysis of the digester installation cost. The main objectives are to evaluate digester performance, measure biogas pressure and mass, and assess the feasibility of biogas as a simple and sustainable alternative energy source for small-scale use.

This study is limited to monitoring digester temperature, reading the U-manometer, and analyzing the digester setup.

# Methodology

This experimental study was conducted from June 10 to July 5, 2024, in a rural area of East Java, Indonesia. The research approach involved several stages, beginning with a literature review to identify relevant previous studies [14]. This was followed by the preparation of materials and equipment, assembly and testing of the digester system, and concluding with data observation, collection, and analysis.

The biogas digester was constructed using commonly available workshop tools and materials. The digester consisted of a 150-liter plastic drum as the main reactor chamber, connected with 3-inch PVC pipes. Additional components included a ¼-inch stop valve, one T-joint, two elbow (L) joints, three end caps, a U-tube manometer for pressure measurement, and a digital thermometer for temperature monitoring [15]. EM4 (Effective Microorganisms) liquid was used as the biological additive.

The raw material used for biogas production was fresh cow manure obtained from local livestock sources. The manure was mixed with water and EM4 in three different ratios:

* Without EM4: 1 kg manure : 1 L water
* With 1 ml EM4: 1 kg manure : 1 L water : 1 ml EM4
* With 2 ml EM4: 1 kg manure : 1 L water : 2 ml EM4

The first step of the experiment involved assembling the digester and performing a leak test [16]. Once confirmed airtight, each mixture was prepared according to the designated ratio and placed into the digester to begin the fermentation process under anaerobic conditions [17, 18].

Throughout the experiment, several parameters were recorded at regular intervals, including temperature, biogas pressure, and biogas mass. The biogas pressure (Pg) was calculated using the following equation:

(1)

represents the biogas pressure, measured in Newton per square meter (N/m²). refers to the atmospheric air pressure, expressed in atmospheres (atm). The symbol *ρ* denotes the density of the fluid in kilograms per cubic meter (kg/m³), while *g* is the gravitational acceleration. The term *h* indicates the difference in water height, measured in meters (m). The mass of the biogas can be calculated using the ideal gas law, which is expressed as:

(2)

thus

(3)

The variables used in the equation are defined as follows: *P* represents the gas pressure, measured in newtons per square meter (N/m²). *V* denotes the temporary storage volume, expressed in cubic meters (m³). *m* refers to the mass of the gas in kilograms (kg), while *T* indicates the temperature in Kelvin (°K). The term *R* represents the gas constant, which has a value of 518 N·m/(kg·°K).

## RESULTS AND DISCUSSION

After the biogas production process was carried out for 20 days, the following data were obtained.

## EM4 Ratio Data Results

**TABLE 1** presents the results of biogas production without the addition of EM4, while **TABLE 2** and **TABLE 3** show the results for EM4 additions of 1 ml and 2 ml, respectively.

**Table 1.** Ratio without EM4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Day | ∆Temp | ∆T(m) | P(Kpa) | m(kg) |
| 1 | 2 | 27 | 0 | 0 | 0 |
| 2 | 4 | 30 | 0.13 | 1.2753 | 0.00220 |
| 3 | 6 | 31 | 0.15 | 1.4715 | 0.00253 |
| 4 | 8 | 29 | 0.14 | 1.3734 | 0.00237 |
| 5 | 10 | 29 | 0.17 | 1.6677 | 0.00288 |
| 6 | 12 | 30 | 0.18 | 1.7658 | 0.00304 |
| 7 | 14 | 30 | 0.19 | 1.8639 | 0.00321 |
| 8 | 16 | 31 | 0.21 | 2.0601 | 0.00354 |
| 9 | 18 | 31 | 0.20 | 1.9620 | 0.00337 |
| 10 | 20 | 31 | 0.21 | 2.0601 | 0.00354 |

**Table 2.** Ratio With EM4 1 ML

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Day | ∆Temp | ∆T(m) | P(Kpa) | m(kg) |
| 1 | 2 | 27 | 0.08 | 0.07848 | 0.00013 |
| 2 | 4 | 30 | 0.14 | 1.3734 | 0.00236 |
| 3 | 6 | 31 | 0.16 | 1.5696 | 0.00269 |
| 4 | 8 | 29 | 0.18 | 1.7658 | 0.00305 |
| 5 | 10 | 29 | 0.21 | 2.0601 | 0.00356 |
| 6 | 12 | 30 | 0.24 | 2.3544 | 0.00406 |
| 7 | 14 | 30 | 0.27 | 2.6487 | 0.00457 |
| 8 | 16 | 31 | 0.28 | 2.7468 | 0.00472 |
| 9 | 18 | 31 | 0.26 | 2.5506 | 0.00438 |
| 10 | 20 | 31 | 0.27 | 2.6487 | 0.00455 |

**Table 3.** Ratio With EM4 2 ML

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Day | ∆Temp | ∆T(m) | P(Kpa) | m(kg) |
| 1 | 2 | 27 | 0.12 | 1.1772 | 0.00205 |
| 2 | 4 | 30 | 0.18 | 1.7658 | 0.00303 |
| 3 | 6 | 31 | 0.26 | 2.5506 | 0.00438 |
| 4 | 8 | 29 | 0.24 | 2.3544 | 0.00407 |
| 5 | 10 | 29 | 0.25 | 2.4524 | 0.00424 |
| 6 | 12 | 30 | 0.28 | 2.7468 | 0.00474 |
| 7 | 14 | 30 | 0.31 | 3.0411 | 0.00524 |
| 8 | 16 | 31 | 0.35 | 3.4335 | 0.00590 |
| 9 | 18 | 31 | 0.32 | 3.1392 | 0.00539 |
| 10 | 20 | 31 | 0.36 | 3.5316 | 0.00607 |

## Biogas Pressure Data Results

The comparison of biogas pressure from all three variations is illustrated in **FIGURE 1**. Based on the calculated pressure values presented in **TABLE 1**, **TABLE 2**, and **TABLE 3**, it can be observed that biogas pressure generally increased over time, although some fluctuations occurred due to variations in ambient temperature, which affected bacterial fermentation activity.

From **FIGURE 1**, the addition of 2 ml of EM4 resulted in a significantly higher-pressure increase compared to other ratios. Two notable peaks occurred on Day 6 (2.7 kPa) and Day 16 (3.4 kPa).

EM4 2 mL

EM4 1 mL

Without EM4

**Figure 1.** Biogas Pressure Graph

In contrast, the addition of 1 ml of EM4 produced a more stable pressure increase, with the highest value reaching 2.7 kPa on Day 16. For the condition without EM4, the trend was similar to that of 1 ml EM4, but the overall pressure remained lower. On the first and second days, no gas production was recorded (0 kPa).

Therefore, based on the pressure data across the three ratios, the addition of 2 ml EM4 showed the most significant improvement in biogas pressure and began gas production earlier compared to the other variations.

## Biogas Mass Data Results

The mass of biogas produced for each variation is shown in **FIGURE 2**.

Without EM4

EM4 1 mL

EM4 2 mL

**Figure 2.** Biogas Mass Graph

As shown in **FIGURE 2**, all variations demonstrated an increasing trend in biogas mass, following a similar pattern to the pressure data. When biogas pressure increased, the corresponding mass also increased, and vice versa. This correlation indicates that higher gas pressure reflects a greater volume of gas produced.

However, fluctuations occurred due to environmental factors such as ambient temperature changes and inconsistencies in raw material quality during the initial mixing process for each tested variable.

# CONCLUSION

Based on the experimental results, the addition of EM4 significantly influenced the production of biogas in terms of both pressure and mass. Among the three variations tested, the addition of 2 ml of EM4 produced the highest biogas pressure and mass, with a maximum pressure of 3.53 kPa and a mass of 0.00607 kg on Day 20. This indicates that increasing the amount of EM4 accelerates and enhances the fermentation process, resulting in greater biogas production.

Conversely, the condition without EM4 showed the lowest performance, with no gas production observed during the initial days and a maximum pressure of only 2.06 kPa by the end of the observation period. The addition of 1 ml EM4 resulted in moderate improvement, achieving a maximum pressure of 2.65 kPa.

Overall, the study demonstrates that EM4 acts as an effective microbial activator to improve the efficiency of biogas production. However, fluctuations observed during the process were influenced by environmental factors such as ambient temperature and raw material quality. Future research should consider optimizing EM4 dosage and maintaining controlled conditions to achieve more stable and higher biogas yields.

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