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Effect of Fermentation Time on Biogas Composition from Palm Oil Mill Effluent (POME)

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ABSTRACT

Palm Oil Mill Effluent (POME) is a liquid waste from palm oil processing that holds great potential as a raw material for biogas production through fermentation in an anaerobic digester. Biogas is a form of renewable energy produced through fermentation in anaerobic conditions. This study aims to analyze the effect of fermentation time on the composition of biogas produced from POME. The research was conducted over a period of 30 days using anaerobic fermentation, with 200 liters of POME mixed with 2 probiotic capsules and 8 liters of water in the digester. Biogas composition including CH_4, CO_2, H_2S, and O_2 was analyzed every 5 days during the fermentation period.The results showed that fermentation time had a significant effect on both the production and composition of biogas. The volume and gas content increased over time, with optimal results achieved on the 25th day. On that day, the biogas composition consisted of 53.02% methane (CH_4), 26.32% carbon dioxide (CO_2), 0.054% hydrogen sulfide (H_2S), and 1.74% oxygen (O_2), with a total biogas volume of 62 liters. Based on these results, the 25th day was identified as the most optimal fermentation time for producing biogas from POME.

Keywords: *POME, Biogas, Fermentation, Renewable Energy, Anaerob*

1. INTRODUCTION

The increasing global demand for energy, coupled with the depletion of fossil fuel reserves and rising environmental concerns, has driven the search for renewable and sustainable energy sources. Among the various alternatives, biogas has gained significant attention as it not only provides a renewable energy supply but also contributes to waste management and greenhouse gas reduction [1].

Indonesia, as one of the largest palm oil producers in the world, generates substantial amounts of liquid waste during the milling process. This waste, known as Palm Oil Mill Effluent (POME), is characterized by high concentrations of organic matter, suspended solids, and nutrients [2]. If discharged untreated, POME can lead to severe environmental issues, including water pollution, eutrophication, and greenhouse gas emissions, particularly methane (CH_4) and carbon dioxide (CO_2) [3]. Thus, the conversion of POME into biogas through anaerobic fermentation represents a promising solution that integrates environmental protection with renewable energy production.

Biogas is produced via anaerobic digestion, in which microorganisms decompose organic material in the absence of oxygen, generating a mixture of gases primarily composed of methane (CH_4) and carbon dioxide (CO_2), along with small amounts of hydrogen sulfide (H_2S), oxygen (O_2), and other trace gases. Previous studies have reported that POME has a high potential as a substrate for biogas production due to its rich organic content [4]. However, the efficiency of methane production is strongly influenced by several operational factors, among which fermentation time plays a critical role.

Several researchers have investigated the effect of fermentation duration on methane yield, reporting varying results. For instance, [5] found that the optimum methane concentration (59.12%) was achieved on the 25th day of fermentation, whereas [6] reported a higher methane content (68.18%) at the same duration. In contrast, [7] demonstrated that the maximum methane yield (58.38%) occurred on the 35th day. These variations highlight that fermentation time is a key parameter that directly affects the quality and stability of biogas production.

Most of the existing studies have focused on co-digestion strategies, in which POME is mixed with other organic wastes such as cow manure to enhance methane yield [8]. While effective, this approach introduces challenges, including variability of raw material composition, additional pre-treatment requirements, and increased complexity in process control. Consequently, there remains a gap in understanding the biogas production potential of POME when used as the sole substrate, particularly with respect to optimizing fermentation time.

Therefore, this study aims to investigate the effect of fermentation duration on the composition and quality of biogas produced solely from Palm Oil Mill Effluent (POME). The findings are expected to provide scientific insights into optimizing methane yield while offering practical implications for sustainable waste-to-energy management in palm oil industries.

2. MATERIAL AND METHODS

1.1 Materials

The materials used in this study were 200 L of Palm Oil Mill Effluent (POME) liquid waste, 2 capsules of biofix probiotics, and 8 L of water. In addition, a simple laboratory-scale biogas digester was specifically designed and constructed for this experiment to facilitate the anaerobic fermentation process.

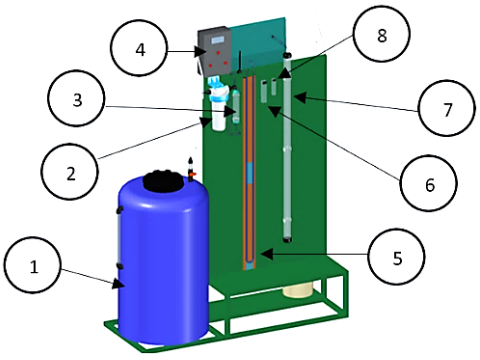


Figure 1. Realistic Design of the Biogas System

The experimental setup consisted of a laboratory-scale biogas digester system specifically designed for this study (Figure 1). The system had a total digester capacity of 250 L, made of high-density polyethylene (HDPE), with an effective working volume of approximately 200 L. The digester was operated in batch mode under anaerobic conditions to process Palm Oil Mill Effluent (POME).

The main components of the system are as follows:

1. **Digester** – cylindrical anaerobic reactor (250 L total volume, 200 L working volume) constructed from HDPE, used for fermenting POME.
2. **Water Treatment Unit** – installed at the gas outlet to remove moisture and water vapor from raw biogas.
3. **Filter** – served to trap impurities and solid residues before purification.
4. **Control Panel** – used to regulate gas flow and monitor operational parameters.
5. **U-tube Manometer** – measured the internal gas pressure of the digester with an accuracy of ±0.1 cm H_2O.
6. **Absorbent Flow Meter** – regulated and monitored the flow rate of the absorbent solution.
7. **Absorption Column** – packed with potassium hydroxide (KOH) solution to capture carbon dioxide (CO_2) and enhance methane (CH_4) concentration.
8. **Biogas Flow Meter** – positioned at the end of the system to measure the flow rate of purified biogas.

This system allowed effective monitoring of pressure, flow rate, and gas composition during the fermentation process. However, in this study, only the raw biogas composition before purification was analyzed, while the upgrading unit was not included in the data evaluation. The 250 L digester design was intended to provide a simple yet replicable system for laboratory-scale biogas production studies.

1.2 Method

A total of 200 liters of Palm Oil Mill Effluent (POME) was used as the raw material for the biogas production process. The probiotic used was a commercial product, Biofix, in capsule form. The probiotic solution was prepared by dissolving two Biofix capsules in 8 liters of water, followed by aeration using an aerator pump in an open container. The solution was then left to activate for three days prior to its application.

After the activation process, the probiotic solution was mixed with the POME waste and stirred for 10 minutes until homogeneous. The mixture was then introduced into a tightly sealed anaerobic digester to initiate the fermentation process, which lasted for 30 days. Observations are conducted every 5 days during the fermentation process (from day 5 to day 30). The parameters

observed include biogas volume, pressure, temperature, pH, and biogas composition. The produced biogas is temporarily stored in 20 liter plastic bags.

Gas samples for analysis were taken using urine bags connected to the biogas storage bags. Gas content analysis included methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and oxygen (O_2), which were measured using standard gas measuring instruments. All analyses were conducted at the gas and coal laboratory of Sriwijaya State Polytechnic, which is equipped with valid and calibrated testing equipment and procedures to ensure data accuracy.

3. RESULTS AND DISCUSSIONS

The results of the analysis show that fermentation time plays a pivotal role in determining both the biogas content and the total volume produced. As the duration of fermentation increases, microbial consortia involved in the anaerobic digestion process are provided with sufficient time to decompose organic substrates more effectively, thereby enhancing methane formation and overall biogas yield. Conversely, inadequate fermentation periods may lead to incomplete substrate degradation, resulting in lower gas production and suboptimal methane concentrations. These findings highlight the critical importance of optimizing retention time as a key operational parameter to maximize the efficiency and productivity of biogas generation systems

3.1 Effect of Fermentation Time on Biogas Volume

The volume of biogas in this study was carefully measured by utilizing a gas storage bag with a total capacity of 20 liters, which was specifically designed, manufactured, and tested to serve as a reliable medium for accurate gas collection during the experimental process. This storage bag was directly connected to the digester unit through a closed and airtight piping system that had been arranged in such a way as to minimize external interference, thereby ensuring that no gas leakage or pressure loss occurred during the transfer process. In this setup, the storage bag functioned not only as the main reservoir for accommodating and storing the biogas, but also as an essential component to monitor and regulate the total amount of gas produced continuously throughout the entire fermentation period until the end of observation.

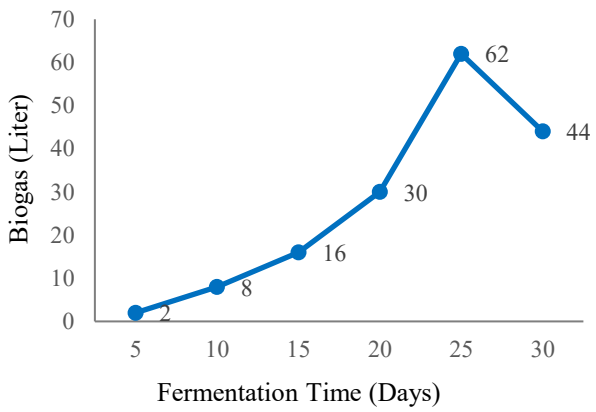


Figure 2. Effect of Fermentation Time on Biogas Volume

The volume of biogas produced in this study showed a gradual and consistent increase during the course of the fermentation period, particularly from day 5 to day 25, with the maximum recorded volume reaching 62 liters on day 25. The initial stage of production began relatively low, at only 2 liters on day 5, but then continued to increase in a steady manner, reflecting the progressive development of microbial activity and the ongoing breakdown of organic matter into simpler compounds that were subsequently converted into biogas. This upward trend persisted until the 25th day, when the process reached its peak production capacity, after which the volume of biogas experienced a noticeable decline, decreasing to 44 liters by day 30. The observed increase in production up to day 25 clearly demonstrates that the anaerobic fermentation process was proceeding under relatively optimal conditions within this time frame, as indicated by the effective performance of the microbial community in decomposing the organic substrate.

Meanwhile, the decline in gas production after day 25 is strongly suspected to be associated with several limiting factors, such as the accumulation of inhibitory by-products that interfere with microbial metabolism or the progressive depletion of essential nutrients within the fermentation medium, both of which can reduce the efficiency of microbial activity in sustaining biogas generation [9].

3.2 Effect of Fermentation Time on Biogas Composition

The results of biogas fermentation from liquid pome waste with probiotics took place over 30 days with sampling on days 5, 10, 15, 20, 25, and 30. The gas formed during this process was collected in a 2 liter urine bag before further analysis. After the gas

was collected, testing was conducted to determine the composition of the biogas, including the content of CH_4, CO_2, H_2S, and O_2, using a Gas Analyzer at the Gas and Coal Analysis Laboratory, Sriwijaya State Polytechnic. The results of biogas composition are presented in Table 1 and Figure 3

Table 1. Biogas Composition Data

Fermentation Time (Days)	Composition (%Vol)			
	CH_4	CO_2	H_2S	O_2
5	6,55	4,28	0,058	10,67
10	15,04	8,73	0,079	7,34
15	29,67	13,59	0,061	4,35
20	38,49	26,32	0,054	2,59
25	53,02	23,44	0,042	1,74
30	32,78	21,61	0,022	1,13

Source: Gas and Coal Laboratory, Chemical Engineering Department, Politeknik Negeri Sriwijaya, 2025

Based on the data results in Figure 3, During the fermentation process of biogas from palm oil mill effluent (POME), significant changes occur in the composition of the gas produced. Each gas component exhibits dynamic patterns over the course of fermentation.

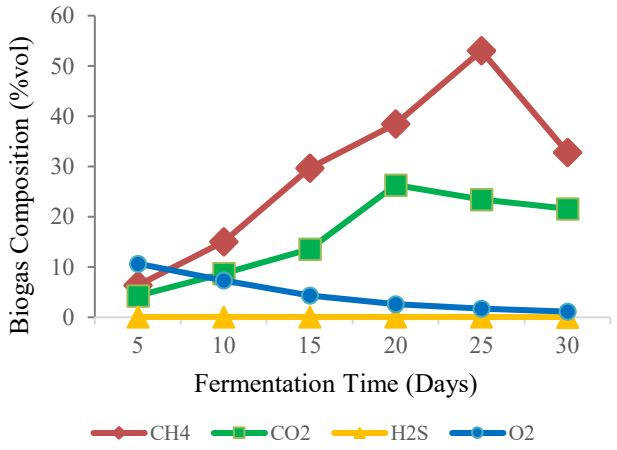


Figure 3. The Effect of Fermentation Time on Biogas Composition

Methane (CH_4) content increased from day 5, peaking at 53.02% on day 25, then decreasing to 32.78% on day 30. This increase indicates that the methanogenesis phase was proceeding optimally until day 25, while the subsequent decrease was caused by the depletion of substrate and the accumulation of volatile fatty acids that inhibited methanogen activity. These results are consistent with [10], who noted that the ideal Hydraulic Retention Time (HRT) for this process ranges between 20–30 days.

Carbon dioxide (CO_2) levels began to rise on day 5 (4.28%) and peaked on day 20, then gradually declined to 19.61% on day 30. The initial increase reflects the dominance of the acidogenesis and acetogenesis phases, while the decrease after day 20 indicates a shift in the system toward the methanogenesis phase, where CO_2 is converted into CH_4 [11] notes that this decrease indicates that the fermentation process has begun to enter the methanogenesis phase, where CO_2 and hydrogen gases begin to be converted into methane gas. In this phase, methanogenic bacteria begin to utilize CO_2 and H_2 to form CH_4.

The corrosive hydrogen sulfide (H_2S) content was recorded starting at 0.058% (day 5), peaking at 0.078% on day 10, then decreasing consistently to 0.021% on day 30. The decrease in H_2S indicates a decline in sulfate-reducing bacteria (SRB) activity, with the environment increasingly dominated by methanogenic bacteria, thereby improving biogas quality [12].

The oxygen (O_2) content in the digester decreased dramatically from 10.67% (day 5) to 1.13% (day 30). This decrease in O_2 indicates that the system is transitioning from a semi-aerobic condition to a fully anaerobic state. [13] note that an O_2 level below 1.5% is the ideal condition for efficient methane production.

4. CONCLUSIONS

This study demonstrates that fermentation time significantly influences the volume and composition of biogas derived from POME liquid waste. The maximum biogas volume of 62 L was observed on day 25, corresponding with the peak methane (CH_4) concentration of 53.02%. The CO_2 content increased until day 20 before declining, while both H_2S and O_2 concentrations consistently decreased throughout the fermentation period. These findings indicate that day 25 represents the optimal fermentation time for producing high-quality biogas.

REFERENCES

[1] S. Hayet, K. M. Sujan, A. Mustari, and M. A. Miah, "Hemato-biochemical profile of turkey birds selected from Sherpur district of Bangladesh," *Int. J. Adv. Res. Biol. Sci*, vol. 8, no. 6, pp. 1–5, 2021, doi: 10.22192/ijarbs.

[2] M. K. Jameel *et al.*, "Biogas: Production, properties, applications, economic and challenges: A review," *Results Chem.*, vol. 7, no. May, p. 101549, 2024, doi: 10.1016/j.rechem.2024.101549.

[3] K. W. Kan, Y. J. Chan, T. J. Tiong, and J. W.

Lim, “Maximizing biogas yield from palm oil mill effluent (POME) through advanced simulation and optimisation techniques on an industrial scale,” *Chem. Eng. Sci.*, vol. 285, Mar. 2024, doi: 10.1016/j.ces.2023.119644.

[4] B. Trisakti *et al.*, “Effect of hydraulic retention time and effluent recycle ratio on biogas production from POME using UASB-HCPB fermentor assisted with ultrafiltration membrane at mesophilic condition,” *South African J. Chem. Eng.*, vol. 50, no. May, pp. 209–222, 2024, doi: 10.1016/j.sajce.2024.08.012.

[5] Sajaruddin, L. Kalsum, and Z. Muchtar, “The Analysis of Biogas Fermentation Time from Cow Manure on Fixed Dome Biodigester Batch Systems,” in *Journal of Physics: Conference Series*, Institute of Physics Publishing, May 2020. doi: 10.1088/1742-6596/1500/1/012043.

[6] Y. Bow, L. Kalsum, A. Hasan, A. Husaini, and Rusdianasari, “The Purification of Biogas with Monoethanolamine (MEA) Solution Based on Biogas Flow Rate,” *Proc. 4th Forum Res. Sci. Technol.*, vol. 7, pp. 1–5, 2021, doi: 10.2991/ahe.k.210205.003.

[7] P. Studi Teknik Kimia *et al.*, “Analisis Kinerja Digester Terhadap Waktu Fermentasi Serta Pemurnian Biogas Dengan Metode Absorpsi Diethanolamine (Dea),” *J. Chem. Eng.*, vol. 5, no. 1, pp. 1–10, 2024.

[8] W. H. Saputera, A. F. Amri, R. Daiyan, and D. Sasongko, “Photocatalytic Technology for Palm Oil Mill Effluent (POME),” *Material*, vol. 14, pp. 1–35, 2021.

[9] H. El Bari and S. Habchi, “Enhancing biogas production from vinasse through optimizing hydraulic retention time and added load using the response surface methodology,” *Heliyon*, vol. 10, no. 19, p. e38967, 2024, doi: 10.1016/j.heliyon.2024.e38967.

[10] P. Aragüés-Aldea *et al.*, “Catalytic CO2 methanation for biogas upgrading using a polytropic fixed bed reactor,” *Catal. Today*, vol. 457, no. January, 2025, doi: 10.1016/j.cattod.2025.115351.

[11] D. Eka P, “No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title,” vol. 2, no. 4, pp. 1147–1152, 2021.

[12] B. P. Morais, C. P. Magalhães, G. Martins, M. A. Pereira, and A. J. Cavaleiro, “Effect of micro-aeration on syntrophic and methanogenic activity in anaerobic sludge,” *Appl. Microbiol. Biotechnol.*, vol. 108, no. 1, 2024, doi: 10.1007/s00253-023-12969-4.