# Analysis of Sesame Dehulling Wastewater Utilization for Biogas Manufacturing

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**Abstract.** At present, some sesame dehulling businesses cannot handle overloaded liquid waste and choose to dispose sesame dehulling liquid waste directly into sewers or rivers. The organic matter in sesame dehulling wastewater disposed directly into the environment causes many environmental problems. One alternative for handling liquid waste with organic content is to use it as biogas through an anaerobic process. In this study, data collection was carried out through direct experiments with laboratory-scale reactors. The experimental design used consisted of four combinations of wastewater treatment from sesame dehulling and cow dung starter (1:0; 9:1; 7:3; 1:1) with a total volume of 3 L and two types of digesters (focusing on gas production and focus on the substrate) with two repetitions for a total of 16 trials. The study was conducted for 40 days. The factors that were observed and tested were the ratio of carbon/nitrogen, the value of Chemical Oxygen Demand and pH every 10 days, the temperature of the substrate every day, the amount of biogas produced every day, the total biogas produced, and the content of the biogas produced. The data obtained were then analyzed using descriptive statistical analysis. The results showed that for 40 days retention time, the higher the content of cow dung starter, the higher the volume of biogas and methane content produced. Experiments with a 1:1 substrate produced a maximum biogas of 498 mL per day, a total biogas of 8.461 mL, and a methane content of 49.61%. Meanwhile, the highest decrease in Chemical Oxygen Demand for 40 days occurred at 1:0 substrate, which was 13.342,20 mg/L. The decrease occurred from the original 16,.711,20 mg/L to 3.369,0 mg/L. 40 days is not enough to lower the COD to environment safe limit.

**Keywords:** Biogas · Chemical Oxygen Demand · Sesame Dehulling · Wastewater

## 1 Introduction

The sesame dehulling business consists of various processes, namely milling, weighing, washing, bleaching, squeezing, drying, blowing, and packaging. The sesame dehulling business produces white dehulled sesame as the main product, sesame seed hulls as a by-product, and wastewater. The sesame dehulling wastewater is in the form of a


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cloudy brown suspension solution. The sesame dehulling wastewater consists of water, crushed sesame seeds and hull that passes the filter, and a small amount of chlorine. One sesame dehulling business with a sesame dehulling machine can produce about 3.861 L of wastewater per day.

Most of the sesame dehulling businesses already have a waste handling installation in the form of a sedimentation tank that functions as a temporary reservoir for sesame dehulling wastewater. However, the sedimentation tank cannot treat the wastewater that is generated in large quantities. The excess load of wastewater makes some sesame dehulling business choose to dispose of sesame dehulling wastewater directly into sewers or rivers. The content of organic matter in sesame dehulling wastewater that is discharged directly into waterways or rivers causes unpleasant odors, water turns black, and disrupts freshwater ecosystems.

The presence of organic matter in water containing toxic or antimicrobial chemicals can be determined by measuring its chemical oxygen demand (COD) value. The sesame stripping wastewater has a high COD value. In a study conducted by Isik, et al., 2021 [1], sesame stripping wastewater has a COD value of 10.010 mg/L which means that sesame stripping wastewater has a high organic matter content. One alternative for handling wastewater with organic content is to use it as biogas through an anaerobic process. The anaerobic wastewater process is a multi-step biochemical process in which the complex organic components of wastewater are hydrolyzed, broken down, and fermented into diabetes [mostly volatile fatty acids (VFA)] which are then reduced to methane and carbon dioxide [2]. Anaerobic reprocessing is a cost-effective solution for managing wastewater and producing methane that can be utilized as an energy source.

## 2 Material and Method

### 2.1 Sesame Dehulling Wastewater and Cow Dung Starter

Sesame dehulling wastewater and cow dung were collected in the morning from the industry in Bogor, Cawas, Klaten, Jawa Tengah. The sesame dehulling wastewater used is the result of mixture with a ratio of 1:1 between the wastewater coming out of the milling machine and the wastewater from weighing and washing process. The starter is made from fresh cow dung which is diluted by adding sesame dehulling wastewater in a ratio of 1:1 (W/V).

### 2.2 Experimental Design and Measurement

The reactor model used in this study is a laboratory-scale batch feeding digester. Batch feeding was chosen in order to know the changes in the characteristics of the substrate from the beginning to the end so that the best retention period can be determined which is marked by the end of the COD value of the substrate. The reactor is made according to Fig. 1 and Fig. 2.

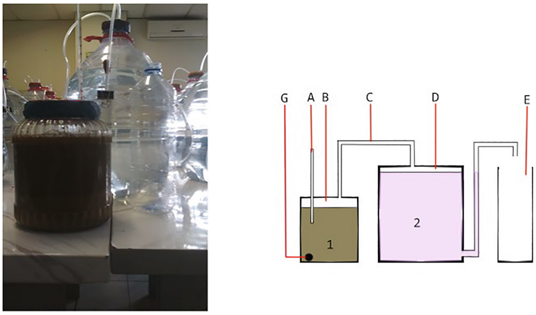


**Fig. 1.** Reactor model a

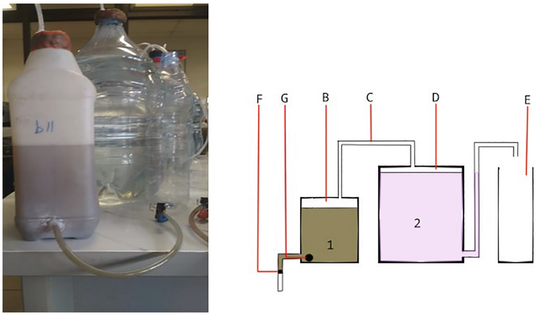


**Fig. 2.** Reactor model b

A = Thermometer
B = Digester
C = Hose
D = Gallon gas reservoir
E = Outgoing water reservoir
F = Channel stopper
G = Marbles
1 = Substrate
2 = Water

Two reactor models are made because it takes one reactor that focuses on biogas production from a certain volume of substrate, namely reactor code a and one reactor whose substrate will be taken periodically to measure its characteristics, namely reactor code b. The way the two reactors work is that the gas produced from the substrate fermentation process in the digester will be flowed through a hose and will be accommodated into a gallon of gas reservoir. The gas produced will enter the gallon and push the water contained in the gallon out. The water that comes out of the gallon will be accommodated in the bottle and the volume of water accommodated is measured. With this principle it is assumed that the volume of gas produced is equal to the volume of water that comes out. Reactor model b is given a substrate exit path for substrate extraction when the pH and COD values will be measured.

In this study, experimental design was made in the form of making substrates with various treatments based on variations in the composition factors of sesame dehulling wastewater and cow dung starter with a total volume of 3 L of each substrate. Substrates are added with a certain amount of $Na_2CO_3$ (Sodium Carbonate) so that the initial pH of all substrates is 7. Each digester is fermented under anaerobic conditions for 40 days. Each treatment was applied in two iterations due to space limitations and cost considerations. Variations in substrate composition are carried out to determine the minimum starter requirement to be able to produce biogas optimally. Sesame liquid waste is the main object in this study so that the minimum limit for the utilization of sesame liquid waste is 50% of the total substrate. The experimental design of this study is presented in Table 1.

The factors that were observed and tested were the ratio of carbon/nitrogen, the value of Chemical Oxygen Demand and pH every 10 days, the temperature of the substrate every day, the amount of biogas produced every day, the total biogas produced, and the content of the biogas produced. Observations and measurements were carried out every day at 09.00–10.00 WIB. During the retention period, before the substrate is taken for testing, stirring is carried out in each experiment. Stirring is carried out so that a small amount of substrate taken for testing can be representative of all substrates in a reactor. These observations and measurements are carried out at the same time to determine changes that occur within 24 h or multiples thereof.

## 3 Results and Discussion

### 3.1 Initial Characteristics of Sesame Dehulling Wastewater and Cow Dung Starter

Sesame dehulling wastewater is one of the products produced from various processes carried out to grind sesame. The Sesame dehulling wastewater produced is in the form of a cloudy brown suspension solution. The Sesame dehulling wastewater consists of water, extracts of crushed sesame components, seeds and sesame hull that pass the filter, and a small amount of chlorine. Cow dung is livestock manure which is solid waste from cattle farming and in the process of disposal it is often mixed with urine and gases such as methane and ammonia. The starter used was a mixture of fresh cow dung and sesame milling wastewater with a ratio of 1:1 (W/V). The initial characteristics of sesame dehulling wastewater and cow dung starter is presented in Table 2, while organic carbon, N-total, and C/N ratio are shown in Table 3, also Figs. 3, 4, and 5.

Measurement of the C/N ratio was carried out on the substrate with the best biogas production. From Table 2 it can be seen that organic C before the retention period was smaller than after the retention period except a11. This is not in accordance with the theory that carbon will continue to decrease during the biogas production process because it is used as an energy source for bacteria [3]. There is a possibility that an error was made by the researcher when taking the sample being tested. From Table 2 it can be seen that the total N before the retention period was greater than after the retention period on all substrates. This happens because nitrogen is used in the formation of microbial cells involved in all anaerobic digestion processes [4].

**Table 1.** Experimental design

| Code | Treatments | Initial pH | Retention Time (Days) | Volume (L) |
|---|---|---|---|---|
| a11 | (100% LCW + 0% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a12 | (100% LCW + 0% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a21 | (90% LCW + 10% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a22 | (90% LCW + 10% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a31 | (70% LCW + 30% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a32 | (70% LCW + 30% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a41 | (50% LCW + 50% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| a42 | (50% LCW + 50% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b11 | (100% LCW + 0% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b12 | (100% LCW + 0% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b21 | (90% LCW + 10% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b22 | (90% LCW + 10% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b31 | (70% LCW + 30% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b32 | (70% LCW + 30% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b41 | (50% LCW + 50% KS + $Na_2CO_3$) | 7 | 40 | 3 |
| b42 | (50% LCW + 50% KS + $Na_2CO_3$) | 7 | 40 | 3 |

LCW = sesame dehulling wastewater
KS = cow dung starter

The ideal C/N ratio is around 20–35 [4]. From Table 3 it is known that before the retention period, only a11 substrate has an ideal C/N ratio. Substrates a21, a32, and a42 have C/N ratios below ideal. After the retention period, as the organic C content increased and the total N decreased, the C/N ratio in all substrates increased. After

**Table 2.** Initial characteristics of sesame dehulling wastewater and cow dung starter

| No | Parameter | Sesame Dehulling Wastewater | Cow Dung Starter | Unit |
|---|---|---|---|---|
| 1 | pH | 5 | 6 | |
| 2 | COD | 16.711,20 | 59.493,50 | mg/L |
| 3 | Organic C | 0,40 | 0,42 | % |
| 4 | N Total | 0,02 | 0,59 | % |
| 5 | C/N | 20 | 0,71 | |

**Table 3.** Organic carbon, N-total, and C/N ratio before and after 40 days retention period

| **Substrate** | **C Organic (%)** | | **N Total (%)** | | **C/N Ration** | |
|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| a11 | 0,400 | 0,260 | 0,020 | 0,012 | 20,00 | 21,67 |
| a21 | 0,402 | 0,470 | 0,077 | 0,013 | 5,22 | 36,15 |
| a32 | 0,406 | 0,730 | 0,191 | 0,041 | 2,13 | 17,80 |
| a42 | 0,410 | 0,630 | 0,305 | 0,067 | 1,34 | 9,40 |

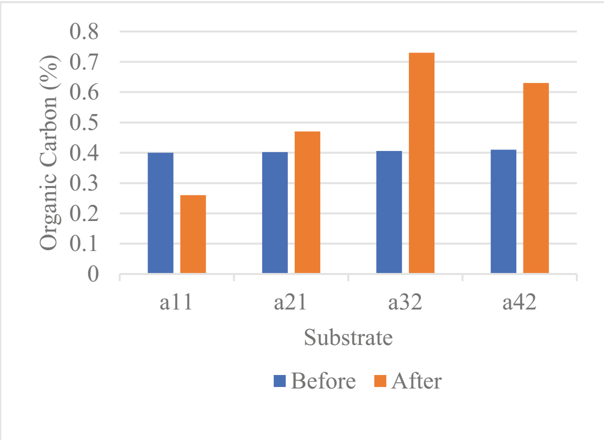


**Fig. 3.** Organic carbon conversion

40 days of retention, the C/N ratio in a11 and a21 became ideal, while the C/N ratio in a32 and a42 was still below ideal.

From the Fig. 6, it is known that the COD value of all substrates decreased until the 20$^{th}$ day. This indicates that methanogenic bacteria have consumed simple compounds that were initially present in the substrate to produce biogas. The COD value then increased on day 30. The COD value can increase during the anaerobic process due

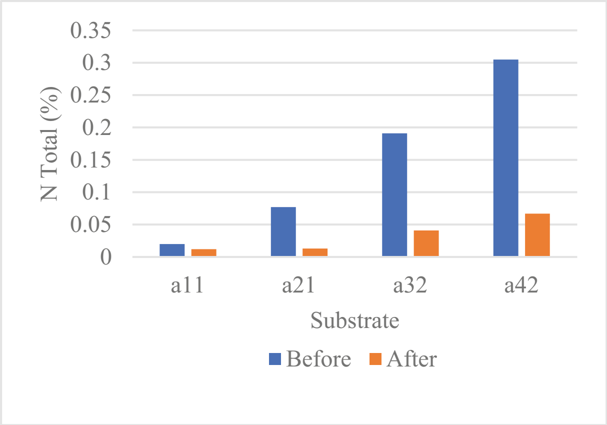


**Fig. 4.** N-Total conversion

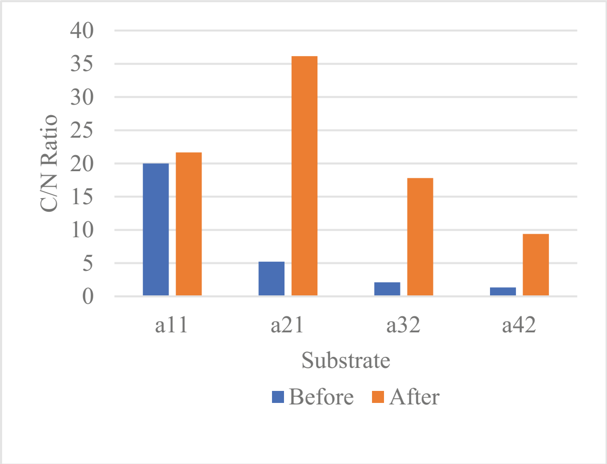


**Fig. 5.** C/N conversion

to the hydrolysis of suspended organic particles [5]. Substrates b11, b12, b21, and b22 decreased on the 40th day, while the b31, b32, b41, and b42 substrates experienced an increase on the 40$^{th}$ day. This indicates that the hydrolysis and acidification processes have decreased at b11, b12, b21, and b22, while at b31, b32, b41, and b42 the hydrolysis and acidification processes are still ongoing. After 40 days of retention, the best COD reduction occurred in the treatment with a ratio of 1:0 (a11 and a12) with an average of 13.298,20 mg/mL.

From Fig. 6, it is known that with a retention time of 40 days, the best variation to reduce the COD of the substrate is treatment without using a starter. The more starter added, the higher the COD on the substrate. Besides cow dung starter has a COD value that is greater than sesame milling liquid waste, the starter also has more bacteria so

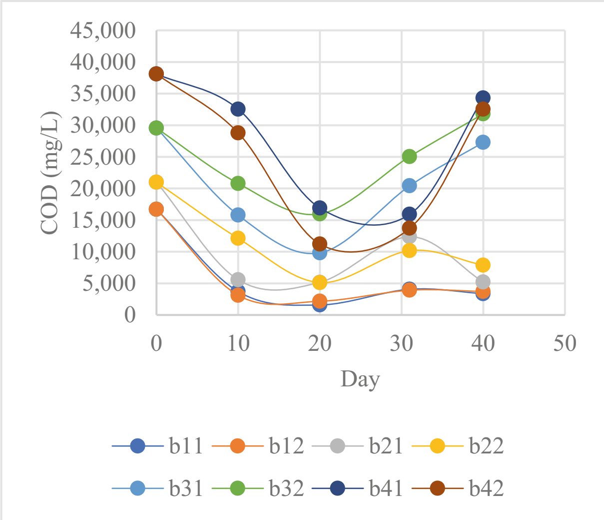


**Fig. 6.** Chemical oxygen demand (COD)

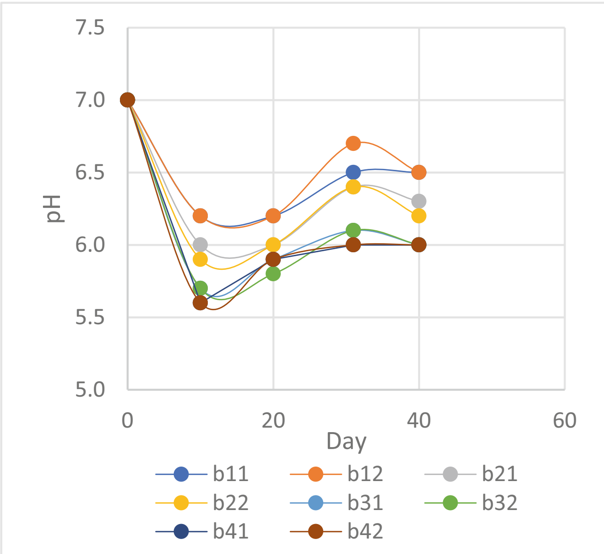


**Fig. 7.** pH value fluctuation

that it can produce more weak acids which causes a high COD value. Giving a retention period of 40 days on the substrate is not enough for bacteria to reduce COD on the substrate mixture of sesame milling wastewater and cow dung starter. From the tables and graphs it is also not possible to know a constant decrease in substrate COD, so it is not possible to predict when the substrate COD will be depleted.

All substrates had an initial pH of 7 because they were given pretreatment in the form of adding $Na_2CO_3$. As shown in Fig. 7, all substrates had a lower pH value than the initial pH with a pH value ranging from 5.6 to 6.2 on the 10$^{th}$ day of measurement. The decrease in pH occurs because the substrate undergoes an acidification process where acid-forming bacteria produce large amounts of organic acids [6]. Substrates with more starter content have a higher number of bacteria. This causes the amount of acid produced to be more so that the pH of the substrate becomes lower. After that, all substrates continued to increase in pH values on the 20th and 30th day measurements. This happens because the nitrogen digestion process is in progress, the NH4 concentration increases so that the pH value can increase [7]. On the 40th day, the pH of some substrates remained constant and some of them decreased slightly. This indicates that the acidification process is still running until the 40th day.

Several sources explain that biogas can be produced optimally at a pH of 6–7 [7], 6.0–8.0 [4]. Substrates b11, b12, b21 and b22 reached optimal pH values on the 10th day of measurement, while b31, b32, b41, and b42 only reached optimal pH on the 30$^{th}$ day of measurement. This shows that the more starter, the longer it takes for the substrate to reach the optimal pH. Several other sources state that biogas production will be optimal at a higher pH value on the 6, 5–7.2 [8]. The substrate has a fairly low pH which is around 6.0–6.5 on the 40$^{th}$ day. This is because there are still many organic acid compounds on the substrate due to the large amount of organic matter that is processed and has not had time to experience the methanogenesis process. So, it can be estimated that the pH can still increase in the future when organic matter and organic acids in the substrate have started to be consumed a lot.

From Fig. 8, it is known that the room temperature ranges from 25–29 °C, while the substrate temperature ranges from 24.5–28 °C. Substrate temperature tends to follow room temperature. There are five points where the substrate temperature drops quite low compared to other days, namely 18, 24, 25, 28, and 38. Indonesia's Meteorology Climatology and Geophysics Council (BMKG) explained that July 2022 is included in the dry season and there is a movement of air masses from Australia to Indonesia or known as Australian Cold Monsoon. This causes temperatures in some parts of Indonesia, especially the southern part of the equator, such as the islands of Java, Bali, and Nusa Tenggara to feel cooler. Until the 40$^{th}$ day, the substrate temperature is still below the optimal temperature for biogas production, which is 30–35 °C [9]. However, there are other sources that explain that the living temperature of mesophilic bacteria is 15–55 °C and optimal at 25–40 °C [10].

From Figs. 9 and 10, it is known that biogas begins to be produced the fastest by a41 on the 6$^{th}$ day followed by a42 on the 9$^{th}$ day, a12 on the 10$^{th}$ day, a31 and a32 on the 10$^{th}$ day, a12 on the 10$^{th}$ day. 10. -18, and a11 on the 21$^{st}$ day. The best biogas yield was produced on a42 substrate on day 29 with a biogas yield of 498 mL. The best total biogas production for each treatment was a11 for a ratio of 1:0 with a biogas yield of 1,569 mL, a21 for a ratio of 9:1 with a biogas yield of 2,092 mL, a32 for a ratio of 7:3 for a biogas yield of 4,390 mL, a42 for a ratio of 1:1 with a biogas yield of 8,461 mL.

Substrates with more cow dung starter tend to produce larger volumes of biogas as well. This is due to the higher number of methanogenic bacteria and the larger COD substrate. Fluctuations in biogas production are seen in almost all substrates. There were

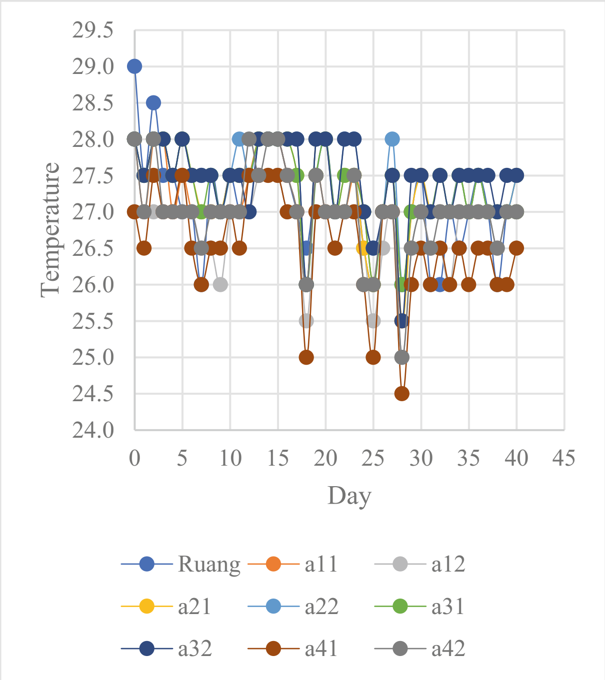


**Fig. 8.** Temperature fluctuation

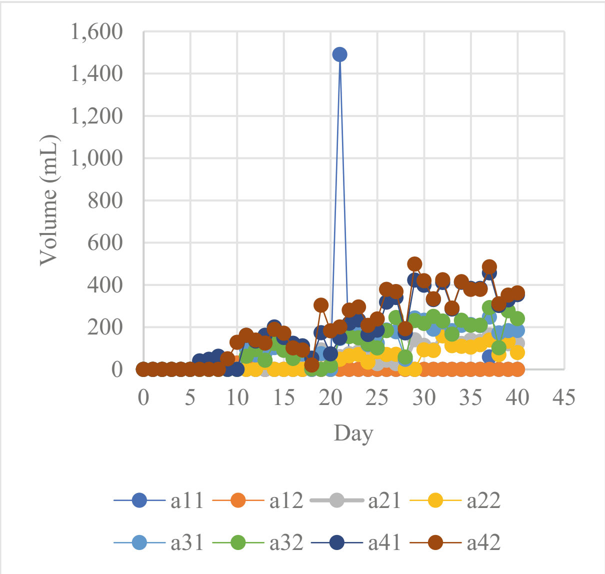


**Fig. 9.** Daily biogas production

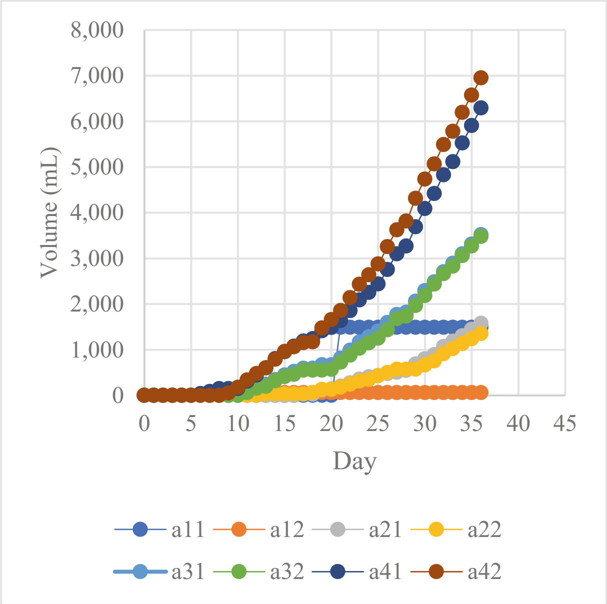


**Fig. 10.** Cumulative biogas production

five points of decline in biogas production compared to the previous day which occurred in almost all substrates. These days are the 18th, 24th, 25th, 28th, and 38th days. It has been explained that on the 18th, 24th, 25th, 28th, and 38th days there is a decrease in the temperature of the room and substrate. So that the cause of the decrease in daily biogas production is due to room temperature and low substrate factors on those four days. On the 20th day, it is suspected that a low room temperature occurred at night or the use of air conditioning in the laboratory on the previous day, so that the temperature of the room and substrate becomes low but returns to normal when the temperature is measured.

## 4 Conclusion

The results of the research on the utilization of sesame skin reducing wastewater as a biogas-producing material showed that with a retention time of 40 days, the higher the content of starter cow dung, the higher the volume of biogas and the content of methane produced. Experiments with a 1:1 substrate produced a maximum biogas of 498 mL per day, a total biogas of 8,461 mL, and a methane content of 49.61%. Meanwhile, the highest decrease in Chemical Oxygen Demand for 40 days occurred at 1:0 substrate, which was 13,342.20 mg/L. The decrease occurred from the original 16,711.20 mg/L to 3,369.0 mg/L. 40 days is not enough to lower the COD to a safe level for the environment.

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**Authors Contribution.** GR and MI developed the concept and designed the manuscript; AND and HY provided key information and key intellectual support also helped revise the manuscript.

## References

1. Isik, Z., Bouchareb, R., Saleh M., dan Dizge, N. 2021. Investigation of sesame processing wastewater treatment with combined electrochemical and membrane processes. *Journal Water Science & Technologies*.
2. Woong Kim, Seung Gu Shin, Kyungjin Cho, Changsoo Lee, dan Seokhwan Hwang. 2012. *Performance of* methanogenic *reactors in temperature phased two-stage anaerobic digestion of swine wastewater*. Dalam *Journal of Bioscience and Bioengineering*. Vol. 114: 635–639.
3. Silitonga, A. S., dan Ibrahim H. 2020. *Buku Ajar Energi Baru Dan Terbarukan*. Deepublish. Sleman
4. Syaichurrozi, Iqbal. 2022. *Teknologi Biogas*. Indramayu: Penerbit Adab.
5. Zheng, Xiarong, dkk. 2020. The influence of variables on the bioavailability of heavy metals during the *anaerobic* digestion of swine manure. *Journal Ecotoxicology and Environmental Safety*, Vol, 195.
6. Wahyuni, Sri. 2013. *Panduan Praktis Biogas*. Penerbit Swadaya. Jakarta Timur.
7. Wahyuni, Sri. 2013. *Energi Alternatif Pengganti BBM, Gas dan Listrik*. Agromedia Pustaka.Jakarta Selatan.
8. Toshitomi Yoshida. 2017. *Applied Bioengineering, Innovation and Future*. DirectionWiley-VCH Verlag GmbH & Co. Weinheim.
9. Wahyuni, Sri. 2017. *Biogas: Hemat Energi Pengganti Listrik, BBM, dan Gas Rumah Tangga*. AgroMedia Pustaka. Jakarta.
10. Setiarto, R. Haryo Bimo. 2022. *Teknologi Produksi Biogas Berbasis Mikrobiologi*. Guepedia.