Biogas Purification with Adsorption Method on Variation of Purification Time and Gas Flow Rate

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Abstract. Biogas purification is an effort to increase the calorific value of biogas. The CO_2 content in biogas causes the calorific value of the biogas to decrease, so Purification must increase the gas levels of CH_4. The research objectives were: To determine the effect of refining time on quality biogas, know the impact of gas flow rate on the quality of the biogas produced, and determine the duration of Purification and the best gas flow rate for purification biogas. The research method used a completely randomized design (CRD) with two factors, namely the purification time (15, 20 and 25 min) and the gas flow rate (2, 4 and 6 L/min), respectively, repeated three times, then analyzed using the ANOVA test and followed by the DMRT test. The results showed a significant effect on methane content, while carbon dioxide content has no natural impact. The result of purification with the highest methane content is at a duration of 25 min and a biogas flow rate of 6 L/min with values of 178,018.01 ppm and 474,744.3 ppm. The Purification that produces the lowest carbon dioxide content is at a purification time of 20 and a flow rate of 4 L/min with a value of 1201.62 ppm and 52,012.4 ppm.

Keywords: biogas · carbon dioxide · flow rate · methane · purification time

1 Introduction

Based on the Central Java Provincial Regulation Number 12 of 2018 (RUED), the target for New and Renewable Energy (EBT) of Central Java in 2025 is 21.32%, with the realization of NRE in 2018 of 10.82%, which is still far from the target. In line with the development of EBT, many energy sources have begun to be developed due to the depletion of petroleum reserves. One of the energy sources generated is biogas as an alternative energy that is environmentally friendly and easy to apply.

Biogas is a flammable gas from organic materials fermented anaerobically by bacteria [1]. Biogas is based on a chemical process involving microorganisms [2]. The chemical process is the anaerobic decomposition of organic matter, mainly producing carbon dioxide and methane [3]. The amount of carbon dioxide (CO_2) and methane (CH_4) in

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biogas will affect the calorific value of the biogas produced. If the amount of carbon dioxide is more than methane, the calorific value of combustion will decrease. On the other hand, if the amount of methane produced is more significant, the calorific value of the combustion will increase, and the resulting flame will be blue [4].

One of the efforts to increase the methane content in biogas is by purifying biogas. Biogas purification aims to remove impurity gases such as carbon dioxide, hydrogen sulfide, water, and other impurities that are less in number. Biogas purification is needed to increase the usefulness of the biogas. Biogas with high methane is used for cooking activities and other energy sources such as lighting (biogas lamps) and generators. Hydrogen sulfide in biogas can harm the environment because it is toxic, smells, and causes corrosion. Water compounds in biogas can cause the flash point to decrease and corrode combustion equipment [5]. One of the widely used purification methods is the adsorption method. Adsorption is a process that occurs when a fluid (gas or liquid) is bound to a solid and forms a thin layer on the surface of the solid [6]. In this adsorption method, purification duration and flow rate are thought to influence the results of biogas purification. The term purification is the length of time the biogas interacts with the adsorbent. At the same time, the flow rate of biogas is the flow rate given to purify the biogas.

Activated charcoal is an adsorption material in the form of granules or powders with a broad surface layer and has a stronger pull in absorbing water contaminants. Activated charcoal can purify water and eliminate foul odors by absorbing various substances in liquids and gases [6]. The purification method using activated charcoal has been widely used because, in addition to the low price, the way used is simple, so it is easy to use [7].

Another adsorbent that can be used for biogas purification is silica gel. Silica gel is one of the chemicals that has a solid form and can be made from silicate solutions, and is widely used as an adsorbent [8]. Apart from being an adsorbent, silica gel is also often used in food because it can absorb moisture to prevent damage to food. Due to active sites on the surface, silica gel is commonly used as an adsorbent or is adsorptive [9]. This research aims to determine the effect of purification time on biogas quality and the impact of gas flow rate on purification to determine the best duration and flow rate in biogas purification.

2 Methods

2.1 Tools and Materials

The tools used are digester units (plastic drums, water hoses, water faucets, pipes, *nipples,* plastic biogas containers), scales, *gas chromatography,* syringe*, vacuum tubes, flow meters,* and tubular biogas purifiers with 15 cm in diameter and 100 cm of height. The materials used are cow dung from *Exfarm*, Faculty of Animal Husbandry, Jenderal Sudirman University, water, solid adsorbents (activated charcoal and silica gel), and pipe glue.

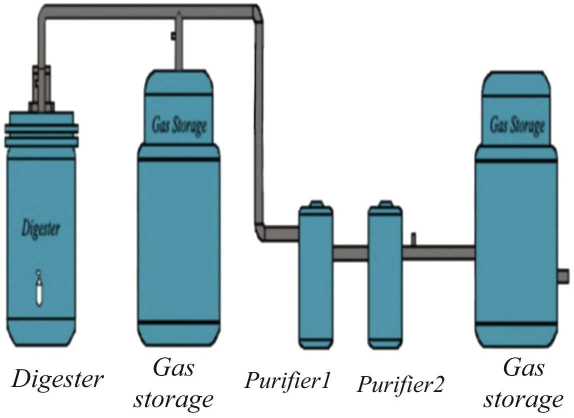

Fig. 1. Biogas purification plant

2.2 Research Stages

2.2.1 Preparation Stage

At this stage, the provision of tools and materials for research is carried out. Preparation starts with raw materials by preparing cow dung and assembling biogas installations and *methane purifiers.* A leak test is also carried out on the digester used at this stage.

2.2.2 Initial Measurement Stage

At this stage, the initial variables that affect the fermentation process and biogas formation are measured. The initial variables measured included the C/N *ratio, total slide,* and *volatile solid.*

2.2.3 Anaerobic Fermentation Stage

At this stage, the substrate in the form of water and cow dung is put into the digester (Fig. 1), and the substrate is mixed and stirred until it is homogeneous/unified into the assembled digester. At the fermentation stage, measure temperature and pH every 24 h.

2.2.4 Advanced Research Stage

At this stage, methane and carbon dioxide measurements are made through a layered biogas purification process using a methane purifier with different gas flow rates and fermentation times. The measurement results will be presented in graphical form.

2.3 Experimental Design

This study used a 2-factor utterly randomized design (CRD) method using various factors of purification time (15, 20, and 25 min) and biogas flow rate (2, 4, and 6 l/min) with three replications. Data analysis used *analysis of variance* (ANOVA) with a level of 5%, followed by *Duncan's multiple range test* (DMRT).

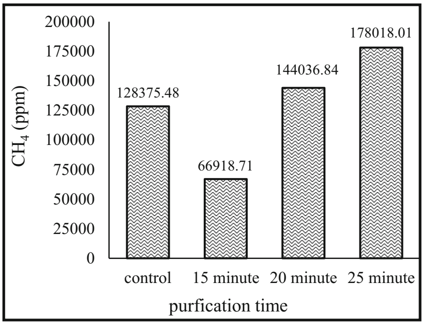

Fig. 2. Methane gas content based on variations in purification time

3 Results and discussion

3.1 Value of C/N Ratio, pH, Total Solid, and Volatile Solid Before Biogas Purification

The C/N ratio of the water and cow dung substrate mixture with a balance of 1:1 was 19.46%, carried out before the cow dung fermentation process. During the fermentation process, pH and substrate temperature measurements obtained an average pH of 7.3 and a substrate temperature of 30.23 °C. The biogas fermentation process lasts for 55 days. Measurement of total solids and volatile solids was carried out before and after fermentation. The total solids before fermentation were 6.68, the volatile solids were 85.99, and the total solids after fermentation were 7.217. The increase occurred due to the rise in the number of microbial cells carried by the sample. The volatile solids after fermentation were 79.459, decreased, which caused the load on the reforming process during hydrolysis to fall.

3.2 Methane Content (CH4) of Biogas After Purification

3.2.1 Methane Content (CH4) Based on Biogas Purification Time

Testing methane from the purification process using activated charcoal and silica gel as adsorbents with variations in purification time (15, 20, and 25 min). The methane content of the control (biogas before purification) was 128,375.48 ppm. The methane content in the purification period of 25 min produced the highest methane of 178.018.01 ppm (Fig. 2). The increase in methane content after purification was due to the excellent ability of the adsorbent to absorb CO2. The activated charcoal adsorbent used is hydrophobic and nonpolar, which can bind carbon [10]. Based on the research of [11], which carried out biogas purification using activated charcoal and silica gel adsorbents using variations of purification time (30, 60, and 90 min) obtained the best purification time of 30 min with a methane content of 200,227.95 ppm.

The results of the ANOVA test analysis on the duration of purification treatment for methane levels show that the purification time significantly affects the levels of methane produced. Table 1 shows that the longer the purification time has a significant difference ($\alpha = 5\%$) in the methane gas content. It is presumably because the interaction of the

Table 1. Methane content based on duration of biogas purification

Treatment	Methane content (ppm)
I (15 min)	66,918.71[a]
II (20 min)	144,036.84[b]
III (25 min)	178.018.01[b]

*) Note: different notations indicate a significant difference at = 5%

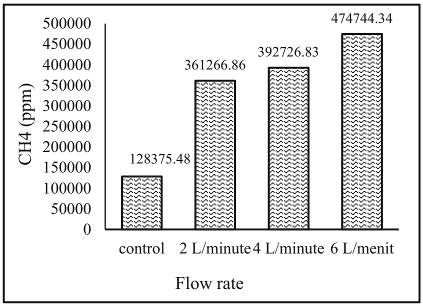

Fig. 3. Methane gas content of the average flow rate treatment.

adsorbent with the biogas for a long time causes the impurity gas bound to the adsorbent to increase so that the methane produced increases.

3.2.2 Methane Content (CH4) Based on the Flow Rate of Biogas

The control variable for methane content before purification can be seen in Fig. 3, where the highest methane content after purification is 474,744.34 ppm at a flow rate of 6 L/min. The increase in methane content is caused by the gaseous impurities that have been reduced or absorbed by activated carbon, while water vapor has condensed [5]. Based on research conducted by [12], who carried out biogas purification using activated charcoal as an adsorbent with variations in flow rates of 0.015 L/min, 0.02 L/min, 0.025 L/min, the highest methane content was obtained at 96.03% at a rate of 96.03%. The flow rate is 0.025 L/min, so it can be seen that the higher the flow rate, the higher the methane content produced.

Table 2 shows that the biogas purification rate variation produces a significant difference ($\alpha = 5\%$) in the methane gas content. Gases *impurities* have been reduced or absorbed by the activated carbon, while the water vapor has condensed. In biogas purification, there will be an increase in the concentration of methane (CH_4) at the output of the purifying column and an increase in the amount of carbon dioxide (CO_2) adsorbed on the purifying column [12]. Both the gas content will be directly proportional to the flow rate.

Table 2. Methane content of purified methane at flow rate

Treatment	Methane Content (ppm)
I (2 l/min)	361,266.9[a]
II (4 l/min)	392,726.8[b]
III (6 l/min)	474,744.3[c]

*) Note: different notations indicate a significant difference at = 5%

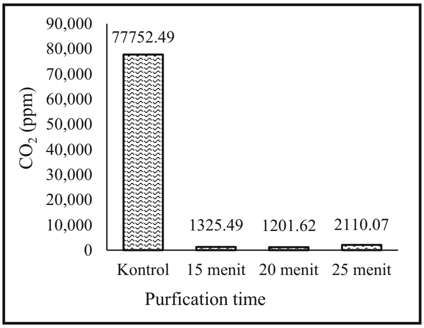

Fig. 4. Carbon dioxide gas content of the average treatment duration of purification

3.3 Carbon Dioxide (CO_2) Content of Biogas After Purification

3.3.1 CO_2 Content Based on Biogas Purification Time

The control variable for carbon dioxide content before purification was 77,752.49 ppm. The lowest carbon dioxide content was found in the 20-min purification period of 1201.62 ppm, while the 15-min and 25-min purification times were 1325.49 ppm and 2110.07 ppm, respectively (Fig. 4). The carbon dioxide content decreased due to carbon dioxide gas being reduced by activated charcoal and silica gel adsorbents. Silica gel adsorbent has an active side on its surface so that it has the absorption capacity to bind impurity gases in biogas.

Table 3 shows, the ANOVA test on the treatment duration of purification of the carbon dioxide content ($\alpha = 5\%$) did not significantly affect the carbon dioxide content produced. The content of carbon dioxide gas (CO_2) decreased by 80.90% from before purification.

3.3.2 CO_2 Content Based on Biogas Flow Rate

The control variable for carbon dioxide content before purification was 77,752.49 ppm. It is known that in Fig. 5 above, there was a decrease in carbon dioxide content after purification, where the lowest carbon dioxide content was 5202.41 ppm from a flow rate of 4 Lmin. The reduction was due to the excellent ability of the adsorbent to absorb CO2. The amount of carbon dioxide absorbed is because activated charcoal has an alkaline

Table 3. Average content of carbon dioxide from purification time of purification

Treatment	CO_2 (ppm)
I (15 min)	1324,49^{a}
II (20 min)	1201,62^{a}
III (25 min)	2110,07^{a}

*) Description: different indicates a significant difference at = 5%

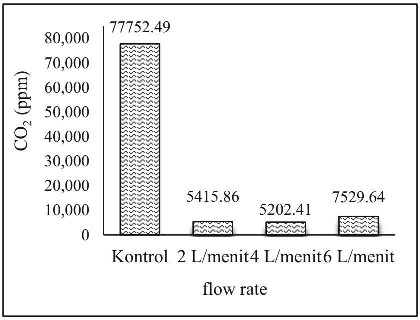

Fig. 5. Carbon dioxide gas content of the average biogas flow rate treatment

pH; at the same time, CO2 is acidic so that it can be well absorbed by the pores of the activated charcoal [13].

Table 4 shows, the ANOVA test on the treatment of biogas flow rate on the methane content (α = 5%) significantly affected the carbon dioxide content produced. Variation of the biogas flow rate of 2 L/min is the best treatment because it has the lowest CO2.

3.4 Color of Fire

The flame test aims to determine the quality of the biogas produced, namely, knowing the methane content in the biogas [14]. The flame test in this study was carried out by burning the gas coming out of the gas discharge hose. The color of the flame of the purified biogas is shown in Fig. 6 and 7.

The color of fire generated in the flow rate treatment looks regular. States that the blue color of the flame produced in biogas combustion indicates that the gas contains much oxygen so that the calorific value will be higher. [15].

During the time of purification treatment, the flame is slightly reddish yellow. The resulting fire still contains much carbon dioxide (CO2). The yellowish flame color still indicates the calorific value below the blue flame before the red flame color.

Table 4. Average content of carbon dioxide from purification at flow rate

Treatment	CO_2 (ppm)
I (2 L/min)	5202.41[a]
II (4 L/min)	5415.86[ab]
III (6 L/min)	7529.64[ab]

*) Note: different notations indicate a significant difference at = 5%

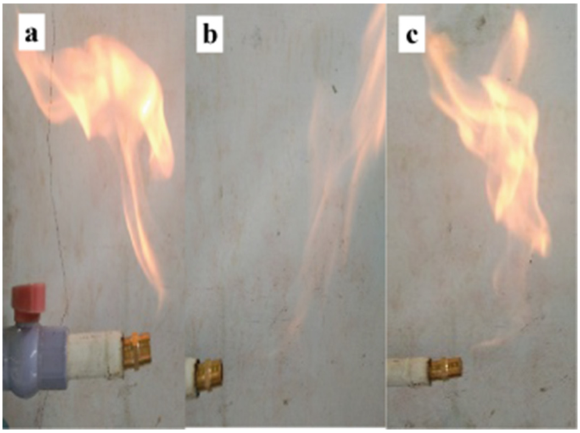

Fig. 6. The color of the old flame of biogas is based on the duration of purification, namely a). 10 min, b). 20 min, and c). 30 min

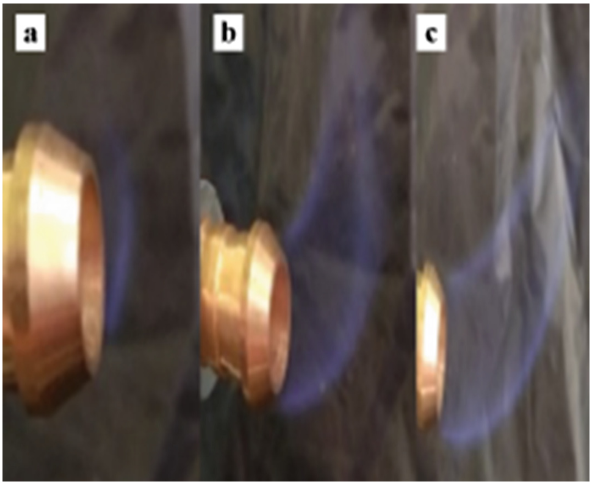

Fig. 7. Flame color based on rate variation, ie flow a). 0.1 L/min; b). 0.5 L/min; and c). 1.0 L/min

4 Conclusion

The highest concentration of methane gas (CH4) was produced by a variation of 25 min purification time of 178,018.01 ppm. The lowest concentration of CO2 gas produced at a purification time of 20 min was 1201.62 ppm. A flow rate of 6 L/min produced the highest methane of 474,744.3 ppm, and a flow rate of 4 L/min had the lowest carbon dioxide gas content of 5,202.41 ppm. The best purification time and biogas flow rate were 25 min and 6 L/min because they produced the highest methane content. The best way to reduce carbon dioxide content is at a purification time of 20 min and a flow rate of 4 L/min.

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Authors' Contributions. All authors conceived and designed the research. Abdul Mukhlis Ritonga and Dewi Novita conducted the experiments, analyzed the data, and wrote the paper. All authors contributed to manuscript revisions.

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