2021_Paper_Biogas_Purification_-_Sinta_4

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The Effect of Biogas Purification Process Using Calcium Oxide-Based Sorbents on the Diffusion Flame Combustion Characteristics

(Pengaruh Proses Pemurnian Biogas Menggunakan Kalsium Oksida Terhadap Karakteristik Pembakaran Api Difusi)

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Abstract

Biogas is an alternative energy source that could solve two problems at once, the problem of environmentally friendly energy needs and the problem of waste treatment. One of the sources of biogas is obtained from anaerobic bacterial fermentation of cow dung waste. The biogas fermentation process produces impurities such as carbon dioxide (CO_2) as a combustion inhibitor. Carbon dioxide will inhibit the combustion reaction, resulting in incomplete combustion. The biogas purification process is needed to reduce the amount of carbon dioxide in the biogas. The purification process is carried out using an absorbent compound of calcium oxide (CaO) to bind carbon dioxide contained in the biogas. Thus, the purpose of this study was to analyze the effect of the biogas purification process using calcium oxide on the characteristics of the diffusion flame produced by combustion. The research was conducted experimentally using the physicochemical-absorption method of purification by flowing biogas through a purificator device that contained a purification solution. After passing through the purification solution, the biogas was regulated at a fuel flow rate of 3 liters/min and then proceed to the bunsen burner. The results showed that purification affected increasing the characteristics of the diffusion flame combustion due to the reduced amount of carbon dioxide in the biogas. This is indicated by increasing the purification molarity, it also increases the flame speed of combustion and the flame angle, as well as a decrease in the flame height.

Keywords: Biogas; Calcium Oxide; Gas Purification; and Combustion

Sari

Biogas adalah sumber energi alternatif yang mampu menyelesaikan dua masalah sekaligus, yaitu masalah kebutuhan energi dan pengolahan limbah yang ramah lingkungan. Biogas dapat diperoleh salah satunya dari limbah kotoran sapi. Biogas dihasilkan dari proses fermentasi dari bakteri anaerob. Pada biogas terdapat unsur pengotor yang dihasilkan yaitu karbondioksida (CO_2) sebagai inhibitor pembakaran. Karbondioksida akan menghambat reaksi pembakaran sehingga terjadi reaksi pembakaran yang tidak sempurna. Proses purifikasi biogas dibutuhkan untuk mengurangi kadar Karbondioksida pada biogas. Proses purifikasi dapat dilakukan dengan menggunakan senyawa katalis absorben kalsium oksida (CaO) yang mampu mengikat karbondioksida pada biogas. Sehingga, penelitian ini bertujuan untuk menganalisis pengaruh proses purifikasi biogas menggunakan kalsium oksida terhadap karakteristik api hasil pembakaran. Penelitian dilakukan secara eksperimental menggunakan metode purifikasi absorsi fisikokimia dengan mengalirkan biogas pada alat purifikasi yang berisi larutan purifikasi. Setelah melewati larutan purifikasi, debit biogas diatur dengan debit bahan bakar 3 liter/min kemudian dialirkan menuju bunsen burner. Hasil penelitian menunjukkan purifikasi mempengaruhi karakteristik api pembakaran difusi yang disebabkan berkurangnya kadar karbondioksida pada biogas. Hal ini ditunjukkan dengan meningkatnya laju pembakaran dan sudut api kemudian menurunnya tinggi api seiring meningkatnya kadar molaritas purifikasi.

Kata-kata kunci: Biogas; Kalsium Oksid; Purifikasi Gas; Pembakaran

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I. INTRODUCTION

New technology to improve the quality and quantity of energy supply continuously will always be needed. Despite the COVID-19 pandemic, it doesn't mean that energy technology improvements could be ignored. Precisely this moment is a big challenge for researchers to find environmentally friendly energy, not just fossil energy. Currently, the largest energy consumption still relies on fossil energy. The decreasing availability of fossil energy requires alternative steps to overcome this. An alternative step that can be taken at this time is to utilize renewable energy. One of the renewable energy that is simple enough to produce but still has many and great benefits is biogas [1-3].

Biogas is a gaseous fuel produced from the anaerobic decomposition of organic matter [4]. The anaerobic decomposition process is assisted by microorganisms, especially anaerobic bacteria. The formation is done by fermenting livestock feces (dung), one of which is cow dung waste. Biogas is formed in a chamber called a digester. In the digester, the manure is fermented by bacteria which produces methane and other gases. The elements

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contained in biogas are dominated by methane gas consisting of methane (CH_4 50-70%), carbon dioxide (CO_2 30-40%), hydrogen sulfide (H_2S 0% - 3%), water (H_2O 0.3%), oxygen (O_2 0.1%) - 0.5%), hydrogen (H_2 1% -5%) and other gases [5]. Methane gas has flammable properties. However, biogas combustion is not optimal if the composition of the biogas contains impurities (inhibitors). This is because the calorific value of biogas is highly dependent on the methane content [6]. The impurity of the combustion reaction is carbon dioxide (CO_2) [7].

Carbon dioxide is a molecule that inhibits the rate of combustion reactions. Carbon dioxide could disrupt the chain of chemical combustion reactions so that the rate of chemical reactions during the combustion process is hampered. Excess carbon dioxide will reduce the calorific value [8]. Therefore, steps are needed to reduce CO_2 by purification. Purification aims to reduce CO_2 gas levels. Purification is done by absorbing CO_2 contained in biogas using CaO dissolved in water with varying molarity levels. Then the CaO solution is used to bind the CO_2 in the biogas so that the CO_2 level can be reduced [9-11]. Purification is one of the techniques used by circulating fuel into the solution so that optimal fuel is obtained [12]. Optimal combustion is one of the important things in the combustion reaction [13].

The previous research on biogas purification has been carried out by burning premixed biogas in external combustion with a mixture of stoichiometric fuels [6]. The results showed that CO_2 affects the formation of the flame angle and flame height. Increasing the CO_2 content in the fuel mixture will reduce the flame angle and more CO_2 content causes the flame height to increase. The condition of low CO_2 biogas fuel affects the characteristics of the flame [14]. In addition, purified biogas can improve engine performance on combustion engines [15].

In previous studies, various kinds of improvements in the quality of biogas combustion have been developed. However, research on the effect of purification without contact time to determine the laminar flame speed by diffusion is still rarely done. Therefore, further research is needed to determine the effect of purification without contact time on the characteristics of the flame in biogas.

II. METHOD

This research was carried out experimentally with the physicochemical-absorption method of purification on biogas followed by combustion reactions. The purification used is a CaO solution with a molarity variation of 1M, 2M, 3M, and 4 M. The purification apparatus is made of PVC pipe with a diameter of 89 mm and a length of 500 mm. The schematic of the absorbent as a purification tool can be seen in Figure 1.

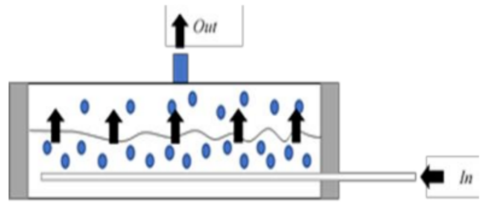

Figure 1. Biogas purification equipment

The biogas purification process is carried out by an absorption system for carbon dioxide (CO_2) gas content using CaO with a molarity variation of 1M, 2M, 3M, and 4M. Biogas is flowed to the purifier to absorb CO_2. The purified biogas is used as fuel for testing the characteristics of flame diffusion combustion. The test of this stage is to determine the effect of biogas purification on the flame speed of diffusion combustion, flame angle, and height of the flame. The dimensions of the bunsen burner are 14 mm in diameter, 140 mm in length. The purified biogas flows to the flow meter and then continues to the bunsen burner. The discharge of fuel used is 3 liters/min. After being fit by the predetermined discharge, the flame is ignited using a lighter. After that, the combustion occurs in the Bunsen burner then jointly recorded using a camera. The data collection scheme can be seen in Figure 2.

The flame image recorded from the camera is transferred to a computer in the form of video. Then the video is converted into an image form after it was saved. The next step is to analyze the flame speed and height of the flame from the experimental results that have been carried out. To analyze the flame speed of combustion, it begins by measuring the flame angle, then proceeds to calculate using equations 1 and 2.

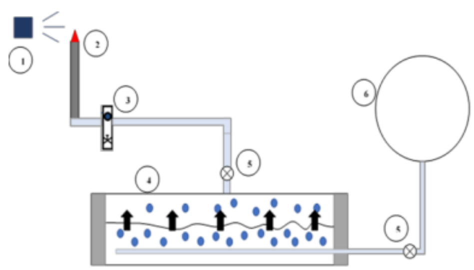

Figure 2. Schematic of biogas purification and combustion

Information: 1. Camera; 2. Bunsen burner; 3. Flowmeter; 4. Absorbent; 5. Valve; 6. Biogas

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$$V = \frac{Q}{A} \quad (1)$$

$$V = V' \sin\alpha \quad (2)$$

where:
V = Velocity of reactants (cm/s)
Q = Fuel discharge (L/Min)
A = Cross-sectional area (cm2)
V = Diffusion burning rate (cm/s)
V' = Velocity of reactants (cm/s)
α = Flame angle (°)

An example of measuring the flame angle can be seen in Figure 3 (a) while the measurement of flame height could be seen in Figure 3 (b). After the testing and data collection process is complete, the next step is to recap and save the data for analysis.

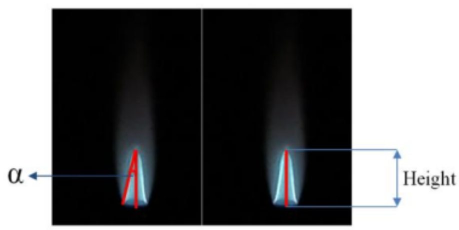

Figure 3. (a) Measuring the flame angle; (b) Measuring the flame height

IV. RESULT AND DISCUSSION

The results of biogas purification research using CaO obtained two types of data, namely the flame speed of combustion of the diffusion flame and the flame height. The experimental data can be compared with the effect of variations in the molarity of CaO on the characteristics of the flame to produce the flame speed of diffusion combustion, the flame angle, and the height of the flame shown in Table 1.

In Figure 4, the flame speed of combustion of biogas before and after purification with 1M, 2M, 3M, and 4M CaO solutions is different. We can observe that the combustion flame speed increases with each increase in molarity shown in Figure 4. The initial value of the test results is the experimental data for biogas without purification and it can be seen that the flame speed of diffusion combustion is very low compared to the data from the test with the purification process.

The molarity of CaO affects the flame speed of diffusion combustion when compared to before purification. The highest diffusion combustion flame speed is found in the 4M molarity composition with a value of 0.775 m/s when compared to 1M CaO purification with a value of 0.593 m/s. This is because the purification of 4M inhibitor (CO_2) in biogas is reduced so that the combustion reaction becomes more complete when compared to before purification [16, 17]. Therefore, the flame speed of diffusion combustion increases as the molarity increases. The higher the molarity, the lower the CO_2 content, so that the flame speed of diffusion combustion in biogas increases.

Table 1. The characteristics of diffusion flame combustion in various molarities

Sample Variant	Sample Code	Laminar Flame Speed (m/s)	Flame Height (mm)	Flame Angle (°)
Without Purification	0P	0.585	12.710	11.29
Purification With 1 Molar of CaO	P1M	0.593	12.479	11.415
Purification With 2 Molar of CaO	P2M	0.683	12.153	13.169
Purification With 2 Molar of CaO	P3M	0.705	11.922	13.62
Purification With 2 Molar of CaO	P4M	0.775	11.780	14.935

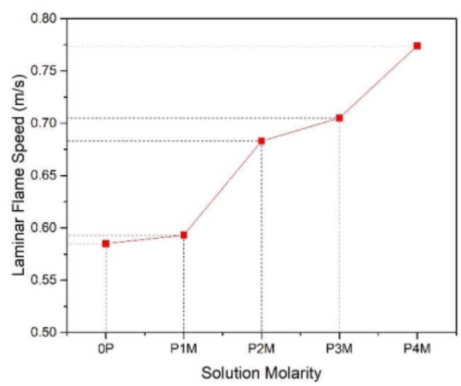

Figure 4. Graph of diffusion combustion flame speed before and after purification with 1M, 2M, 3M, and 4M CaO molarities.

In Figure 5, the height of the biogas flame after purification with CaO shows a decreasing trend. Biogas before purification has the highest flame height when compared to biogas that has been purified with 1M, 2M, 3M, and 4M solutions. The flame height with purified 4M CaO solution had the lowest flame height with a value of 11.780 mm. The highest flame in biogas without purification with a height of 12.710 mm. This shows that purification affects the flame height during the combustion process.

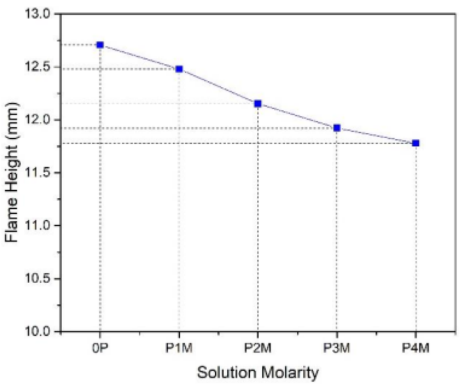

Figure 5. Biogas flame height in diffusion combustion before and after purification with 1M, 2M, 3M, and 4M CaO molarities.

In the flame test, the flame angle formed increased after purification. The flame angle increases as the molarity of the CaO solution increases. It can be observed in Figure 6 the value of the flame angle formed due to purification. This is due to a decrease in CO_2 content so that combustion is more optimal. Carbon dioxide affects the physical properties of the flame, namely the flame angle. The decrease in carbon dioxide levels causes the width of the flame to increase. This also causes methane to be more dominant during the combustion reaction process.

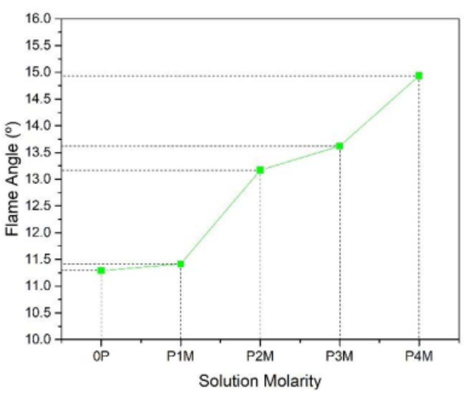

Figure 6. Flame Angle diffusion on combustion before and after purification with 1M, 2M, 3M, and 4M CaO molarities.

VI. CONCLUSIONS

In this study, the greater the molarity of CaO, the lower the CO_2 content in the biogas. This is indicated by the value of the diffusion combustion flame speed, which increases with increasing molarity. In testing the characteristics of flame with biogas fuel, the results of the flame test can be observed. The higher the value of the combustion flame speed and the flame angle, the lower the percentage of carbon dioxide content. The increase in the percentage of carbon dioxide is indicated by the increasing value of the flame height.

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