

The Purification of Biogas with Monoethanolamine (MEA) Solution Based on Biogas Flow Rate

Yohandri Bow^{1,*} Leila Kalsum² Abu Hasan² A. Husaini³ Rusdianasari²

¹Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, 30139 Indonesia

²Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.

³Chemical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya, Negara, Palembang, 30139 Indonesia.

*Corresponding author. Email: yohandrimk.2020@gmail.com

ABSTRACT

Biomass is a plant material which is quite abundant in Indonesia. Utilization is also currently undergoing development. One of the uses for biomass is conversion to biogas. Biogas is a renewable energy source that can be used as a substitute for fossil energy. Biogas can be produced by utilizing organic materials that are no longer used through anaerobic digestion processes. In the process of producing biogas as an environmentally friendly fuel, it is necessary to first wash the biogas. The CO₂ and H₂S content in biogas reduces the efficiency of the combustion process and causes corrosion of machining components. Biogas purification by absorption is a way to reduce levels of CO₂ and H₂S contained, so that the biogas produced can be used as fuel. In this study, absorption using a packed bed scrubber and monoethanolamine solution and varying the biogas flow rate. The results of biogas purification using 7M monoethanolamine solution decreased CO₂ and H₂S levels and increased methane gas production up to 87.6% with a biogas flow rate of 5 L/minute.

Keyword: *biogas, packed bed scrubber, purification, renewable energy*

1. INTRODUCTION

Fossil fuels such as oil and coal is the main energy source in Indonesia, will be but these energy sources have devastating effects on the environment, including air pollution, greenhouse gas emissions and global warming. Another problem is the high price of fossil fuels, the increase in the number of imports of petroleum due to national fuel consumption. Petroleum energy ranks first in the composition of the national energy mix, which is around 48% of the total national energy mix and the expounded petroleum resources are predicted to run out in about 12.26 years [1].

To overcome this, the Indonesian government seeks to increase the use of non-fossil energy in the form of new and renewable energy (RE) through Government Regulation (PP) No. 79/2014 concerning the National Energy Policy (KEN), where the target of RE utilization in 2025 increases to 23% while energy utilization from petroleum decreases to 25% [1].

Biomass is biological material derived from plants and animals and consists of large amounts of carbon and other elements in smaller amounts such as nitrogen,

oxygen, hydrogen, alkaline earth, and heavy metals. This type of energy is included in a renewable energy source because trees and other living things can reproduce and grow back. The raw material for making biomass which is always available is an inexhaustible and renewable source of energy. Many products can be generated from biomass, for example biomass can be used as a power source, a source of biofuel and others.

Renewable energy sources are environmentally friendly energy sources that do not pollute the environment and do not contribute to climate change and global warming. Biogas is an alternative energy which is currently being developed. Besides being cheap, biogas is also environmentally friendly. Making biogas is simple, namely by inserting a substrate in the form of cow dung or organic waste into a tightly closed digester container, in some time it will produce gas as an energy source [2].

The biogas produced from the organic waste fermentation process does not contain 100% flammable gas. Products biogas consists of methane (CH₄) 55-65%, carbon dioxide (CO₂) 35-45%, nitrogen (N₂) 0-0.3%, hydrogen (H₂) 1-5%, hydrogen sulfide (H₂S) 0-3%, oxygen (O₂) 0.1-0.5%, and water vapor.

All the elements that play a role in determining the quality of biogas, namely methane gas (CH_4) and carbon dioxide (CO_2). [3-5].

In order to produce optimal biogas, there are several factors that must be maintained in the process of biogas formation, namely the pH factor, the optimal pH value is at 6.8 - 7.4 [6]. The optimum temperature biogas formation at 35°C [7] and C/N ratio, is the relationship between the amount of carbon and nitrogen. For anaerobic digesters, the C/N value is between 20-30. If the C/N is too high, the biogas production will be low, if the C/N is too low, nitrogen will accumulate to form ammonia [8].

The purity of the CO_2 and H_2S content in biogas is important because it affects the resulting calorific value and the lifespan of the biogas-using equipment. The CH_4 content in biogas can be increased 75-98% by removing the CO_2 and H_2S content [9]. In this case the impurity which affects the heating value is carbon dioxide (CO_2). The presence of CO_2 in CH_4 gas is very undesirable, this is because carbon dioxide is an inhibitor of the rate of chemical combustion reactions in machinery [10]. The lower the level of CO_2 in CH_4 the higher the heating value of CH_4 , indicated by the yellowish red color in the resulting flame [11]. CO_2 reduces the rate of propagation of the combustion flame because the CO_2 molecule inhibits the collision reaction between the hydrocarbon refrigerant molecules and the air molecules [12]. The CO_2 content can also reduce the thermal efficiency of diesel engines. The optimal methane content of biogas for engine fuel is more than 90% [13].

In the production process of making biogas, the resulting biogas product must contain H_2S ranging from 100-10000 ppm, the H_2S content depends on the type of biomass and organics contained [14]. H_2S has been identified as a compound that causes problems in its use in machining because H_2S causes mechanical components to corrode [15]. The use of biogas which contains H_2S produces sulfur and sulfuric acid which are corrosive to various types of metals. H_2S content of 200 ppm if inhaled by humans for 30 minutes can cause death. The maximum permit for H_2S for safety and health standards is 20 ppm [16]. When the H_2S contained in this biogas burns, the H_2S will turn into sulfur oxide which will cause corrosion to metal components and make engine lubricant oil acidic. To reduce the damage caused by H_2S the compounds H_2S should be eliminated or reduced abortion up to the limit of tolerance [17, 18].

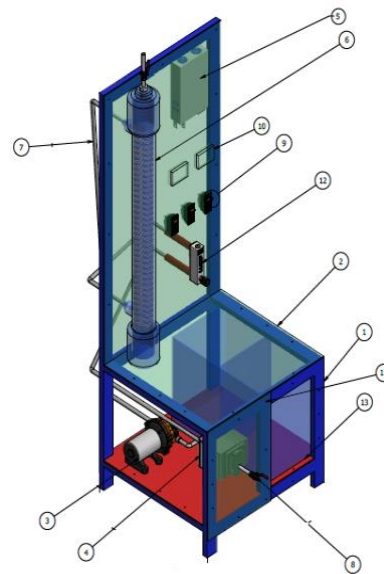
To increase the benefits of biogas as *renewable energy*, it is necessary to carry out the methane refining stage. Biogas purification techniques can be performed using a b sorption, namely the separation of a specific gas from a mixture of gases by way of transfer of mass into a liquid solvent that has a different selectivity of

gas which would remove. Various kinds of biogas purification methods include physical absorption, chemical absorption, membrane separation absorption, cyrogenic and chemical conversion into other compounds [19, 20]. It is also available to capture CO_2 with various solvents such as monoethanolamine, ammonia, tetrahydrofuran, and tetra-n-butyl ammonium bromide [21, 22].

2. EXPERIMENTAL



Figure 1. Biogas Digester



Annotation:

1. Frame Unit
2. Set Acrylic
3. Water Pump
4. Biogas Pump
5. Power supply
6. Scrubber
7. Storage
8. Biogas Inlet
9. Control Panel
10. Scrubber Temperature Indicator
11. Rivet Nail
12. Biogas Flowmeter
13. Storage Solution

Figure 2. Purification Biogas with packed bed scrubber

In this study the biogas from cow manure produced by the digester with a volume of 500 liters. Biogas raw materials consist of cow dung and water in ratio of 1:2 and its left to rest during fermentation process. Biogas analyzed the results composition by interval 5 days, biogas which is day 5, 10, 15, 20, 25, 30, and 35 to know the optimum composition of biogas, then once obtained optimum conditions biogas. The biogas digester used in this study can be seen in Figure 1.

Purification of the biogas with monoethanolamine (MEA) 7M, the flow rate of MEA solution 1.5 L/minute with variations in the biogas flow rate of 5, 10, 15, 20, 25 and 30 L/minute. The equipment used in this study can be seen in Figure 2.

The results of biogas production during the fermentation process are analyzed at interval every 5 days using the Shimadzu Gas Chromatography to determine the composition of biogas with parameters such as CH₄, CO₂, O₂, and H₂S.

3. RESULTS AND DISCUSSION

3.1 Biogas composition analysis

The fermented biogas product at intervals of 5 days are collected in a biogas bag before purification by using of a MEA. Biogas fermentation occurs due to the help of microorganisms that function as decomposers of raw materials, fermentation process occurs for 35 days with maintained temperature and pH. Biogas product can be seen in Figure 3.



Figure 3. Biogas Product

The results of the biogas composition using gas chromatography GC-2014 Shimadzu can be seen in Tabel 1.

Tabel 1. Biogas Composition Analysis Result From biogas at 25th day

Name	Ret. Time	Area	Height	Conc	Unit
CH ₄	1,155	59794472	17583630	68,18	%
Total		59794472	17583630		

Biogas composition before purified was analyzed using gas chromatography and the results in Table 2.

Table 2. Analysis of the biogas composition before purification

Day	CH ₄ (%)	CO ₂ (%)	H ₂ S (ppm)	O ₂ (%)
5	21.73	1.34	103	20.12
10	33.62	5.76	147	18.13
15	47.01	8.24	170	12.13
20	56.42	10.17	256	10.13
25	68.18	13.03	327	7.13
30	58.34	9.42	420	5.68
35	20.22	1.64	459	2.13

The fermented biogas product that has been accommodated in the biogas bag is purified using a packed bed scrubber with MEA solution as absorbent and stainless steel as packing. Purified biogas product can be seen in Figure 4.



Figure 4. Purified Biogas Product

The composition of the biogas after purification with 7M MEA solution and varying the biogas flow rate can be seen in Table 3.

Table 3. Analysis of the biogas composition after purification with 7M MEA solution

Biogas flow rate (L/min)	O ₂ (%)	CH ₄ (%)	CO ₂ (%)	H ₂ S (ppm)
5	7.26	87.6	0.07	4
10	6.50	85.63	0.11	15
15	6.53	83.21	0.26	31
20	6.72	80.25	0.41	46
25	7.20	77.72	0.72	51
30	6.93	73.63	1.06	63

The results of the biogas composition using gas chromatography for a biogas flow rate of 5 L/min can be seen in Tabel 4.

Tabel 4. Biogas Composition Analysis Result From Cow Manure at 25th day

Name	Ret. Time	Area	Height	Conc	Unit
CH ₄	1,225	59878123	17581741	87,60	%
Total		59878123	17581741		

3.2 Effect of biogas flow rate on methane gas content

When purifying the biogas produced with 7M MEA solution, the biogas flow rate was varied to see its effect on the amount of methane gas produced. The results of measurement and analysis of biogas purity based on the biogas flow rate can be seen in Figure 5.

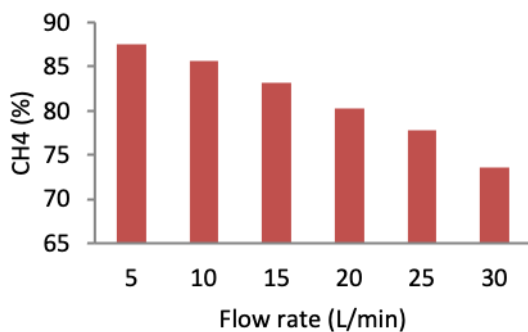


Figure 5. Effect of biogas flow rate on methane gas production

It can be seen in Figure 4 that the higher the flow rate will cause the absorption of CH₄ in the biogas to decrease, this is because the biogas flow rate causes the absorption between the MEA solution in the biogas to

be less than optimal. The results of biogas analysis after purification showed very significant at a biogas flow rate 5 L/min with concentration of 7M MEA able to reach 87.6% methane compared with a biogas flow rate of 10 L/min to 30 L/min.

3.2 Effect of Biogas Flow rate CO₂ Production

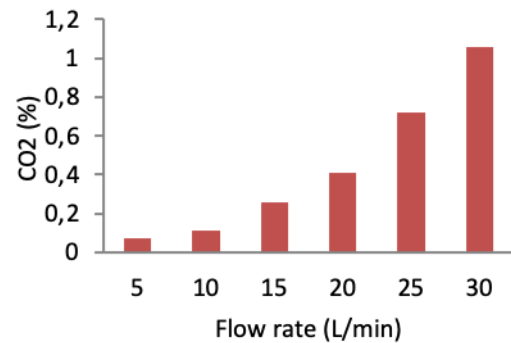


Figure 6. Effect of biogas flow rate on CO₂ gas production

According to Figure 6 that the higher flow rate will cause absorption of CO₂ in the biogas decreases this is caused because the flow rate of biogas cause absorption between the MEA solution becomes less optimal biogas. Increasing the flow rate of biogas makes the CO₂ content increases. From this research, it was found that the greater the biogas flow rate, the CO₂ production will also increase.

3.3 Effect of Biogas Flow Rate to H₂S production

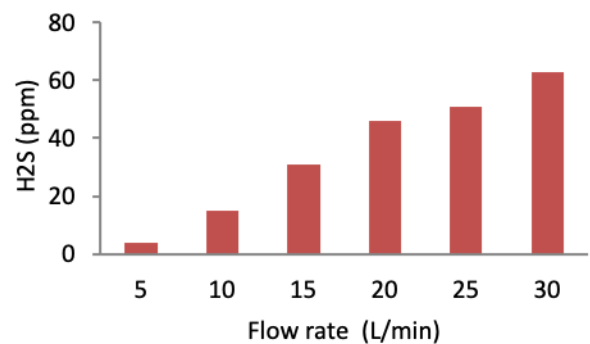


Figure 7. Effect of biogas flow rate on H₂S gas production

From the Figure 7, increasing the flow rate biogas make H₂S content increase. Concentration H₂S in biogas has increased from 4 to 63 ppm. From this research proved that the lower flow rate of biogas can reduces H₂S.

4. CONCLUSION

Biogas produced from cow manure can be obtained after 25 days with methane gas content reached 68.18% before purification. After being purified with 7M

monoethanolamine (MEA) solution, the amount of methane gas increased to 87.6% at a biogas flow rate of 5 L/minute. In this condition the H₂S and CO₂ levels decrease while the O₂ levels increase.

AUTHORS' CONTRIBUTIONS

All of the authors are involved in the process of designing the equipment and biogas product. The first and corresponding author contribution is responsible for data processing and manuscript writing. The second author is responsible for equipment design and data processing. The third and fourth authors are responsible for analysis biogas composition. The fifth author is responsible for funding arrangement.

ACKNOWLEDGMENTS

We would like to thank the Politeknik Negeri Sriwijaya for funding and facilitating the assignment research in 2020.

REFERENCES

- [1] Anindhita, I. Rahardjo, I. Fitriana, and R. Etie Puspita Dewi, *Outlook Energi Indonesia 2018*. Jakarta: Pusat Pengkajian Industri Proses dan Energi (PPIPE) Badan Pengkajian dan Penerapan Teknologi (BPPT), 2018.
- [2] R Ploetz, R Rusdianasari, and E Eviliana, *Renewable Energy: Advantages and Disadvantages Proceeding Forum in Research, Science, and Technology (FIRST)*, pp. E1-E4, 2016.
- [3] RAN Moulita, Rusdianasari, L Kalsum, *Converting Waste Cooking Oil into Biodiesel using Microwaves and High Voltage Technology*, *Journal of Physics: Conf. Series* 1167(012033), 2019
- [4] S Yunsari, Rusdianasari, A Husaini, *CPO Based Biodiesel Production using Microwaves Assisted Method*, *Journal of Physics: Conf. Series* 1167(1) 012036, 2019
- [5] P Dilia, K Leila, Rusdianasari, *Fatty Acids from Microalgae Botryococcusbraunii for Raw Material of Biodiesel*, *Journal of Physics: Conf. Series* 1095(012010), 2018.
- [6] Rusdianasari, A Syarif, M Yerizam, MS Yusi, L Kalsum, Y Bow, *Effect of Catalyst on the Quality of Biodiesel from Waste Cooking oil by Induction Heating*, *Journal of Physics: Conf. Series* 1500 (012052), 2020
- [7] Suminto, D. A. Susanto, R. Lukiawan, B. S. Nasional, and G. M. Wanabakti, *Standards Requirement in Supporting the Development of New Energy Sources (Biogas)*, pp. 9–19, 2013.
- [8] R. J. Teodorita Al Seadi, Domiik Rutz, Heinz Prassl, Michael Kottner, Tobias Finsterwalder, Silke Volk, *biogas HANDBOOK*. Esbjerg: University of Southern Denmark Esbjerg, Niels Bohrs Vej 9-10, DK-6700 Esbjerg, Denmark, 2008.
- [9] Fachagentur Nachwachsende Rohstoffe e. V., *Guide to Biogas: From production to use*. Eschborn: Fachagentur Nachwachsende Rohstoffe e. V. (FNR) FNR, 2012.
- [10] S. S. Mulyawan, D. W. Aghnia, E. Rianawati, and E. Damanhuri, *The Study of Rice Husk as Co-Digestion Together with Cow Dung in Biogas Production of Anaerobic Digester*, vol. 13, 2018.
- [11] M. Stucki, Matthias; Jungbluth, Niels; Leuenberger, *Life Cycle Assessment of Biogas Production from Different Substrates*, *ESU-services Ltd.*, p. 84, 2011.
- [12] H. Hadiyanto and R. Hendroko, *Integrated Biogas-Microalgae from Waste Waters as the Potential Biorefinery Sources in Indonesia*, *Energy Procedia*, vol. 47, pp. 143–148, 2014.
- [13] M. Khalil, M. Ali, R. Heryanto, and A. Rizalie, *Waste to energy technology: The potential of sustainable biogas production from animal waste in Indonesia*, *Renew. Sustain. Energy Rev.*, vol. 105, pp. 323–331, 2019.
- [14] 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* 1500(0120430), 2020.
- [15] S Susumu, R Rusdianasari, S Yusi 2018 *Biodiesel Production from Waste Cooking Oil using Electrostatic Method Indonesia Journal of Fundamental and Applied Chemistry (IJFAC)* 3(3)
- [16] JU Putra, L Kalsum, Y Bow 2018 *Effect of DC Voltage on Prototype of Biodiesel Electrostatic Separator with Glyserin from Waste Cooking Oil Indonesia Journal of Fundamental and Applied Chemistry (IJFAC)* 3(3)
- [17] E Anzar, S Yusi, Y Bow 2018 *Purification of Crude Glycerol for Biodiesel By-product by Adsorption using Bentonite Indonesia Journal of*

- Fundamental and Applied Chemistry (IJFAC) 3(3)
- [18] I N Daiyan, L Kalsum, Y Bow, Capturing CO₂ from Biogas by MEA (mono ethanolamine) using Packed bed Scrubber, *J. Tek. Kim. Ling.* 4(2), 2020
- [19] ES Yusmartini and Rusdianasari 2016 Separation process Biodiesel from Waste Cooking Oil using Ultrafiltration Membranes Proceeding Forum in Research, Science, and Technology (FIRST)
- [20] L. Kalsum, A. Hasan, Rusdianasari, A. Husaini, and Y. Bow, Evaluation of Main Parameter Process of Anaerobic Digestion of Cow Dung in Fixed Dome Biodigester on Methane Gas Quality, in *Journal of Physics: Conference Series* 1500(012060), 2020.
- [21] RAN Moulita, R Rusdianasari, L Kalsum 2020 Biodiesel production from Waste Cooking Oil using Induction Heating Technology Indonesia *Journal of Fundamental and Applied Chemistry (IJFAC)* 5(1)
- [22] Rusdianasari, Y Bow, RAN Moulita 2020 Temperature Effect on the Biodiesel Quality from Waste Cooking Oil by Induction Heating *Journal of Physics: Conf. Series* 1450 012003