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CO_2 and H_2S Absorption in Tofu Liquid Waste Biogas using Packed Bed Scrubber with Variation of MEA Concentration and Flow Rate

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Abstract: Biogas technology has become an alternative fuel that is often used in Indonesia. One of the raw materials for biogas that has the potential and is easy to obtain is waste from the tofu industry. Liquid waste still contains a lot of organic elements. The organic materials contained in the exhaust of the tofu industry are generally very high. The gases commonly found in tofu waste are nitrogen gas (N_2), oxygen (O_2), hydrogen sulfide (H_2S), ammonia (NH_3), carbon dioxide (CO_2) and methane (CH_4). These gases come from the decomposition of organic materials contained in wastewater. So that biogas produced from tofu liquid waste still contains CO_2 and H_2S gases which are quite high. Therefore, in this study the process of purification or refining of biogas products will be carried out using the absorption method through an absorber column using monoethanolamine (MEA) solution as a chemical absorbent through a 8 mm packed bed scrubber. The results showed that the best biogas flow rate in the purification process, which produced the highest CH_4 concentration of 95.12% was 40% MEA concentration and 0.8 L/min flow rate. The effect of MEA concentration on biogas purification causes the concentration of CO_2 and H_2S in the purified biogas to decrease as the MEA concentration increases. The best combination of 0.8 L/min biogas flow rate and 10 mm packing area reduces CO_2 and H_2S concentrations to 1.88% and 0 ppm.

Keywords: **A**bsorption, Biogas, MEA, Tofu Liquid Waste

1. Introduction

Biogas technology has become an alternative fuel that is often used in Indonesia [1]. Biogas is a renewable non-fossil fuel which can be used as an alternative to bioenergy. The biogas product consists of (CH_4) methane 50 – 70%, (CO_2) carbon dioxide 25 – 45%, and small amounts of (H_2) hydrogen, (N_2) nitrogen, and (H_2S) hydrogen sulfide [2]. Methane gas (CH_4) is the main component of biogas which is used as a fuel with many benefits. Biogas has a high calorific value, which is around 4800 to 6700 kcal/m^3, while pure methane gas contains an energy of 8900 Kcal/m^3 [3].

Biogas can be produced from a mixture of livestock manure such as cattle and liquid organic waste in industries such as tofu [4]. Apart from the fact that this material contains the elements carbon (C), hydrogen (H) and nitrogen (N), waste from the tofu industry is waste that has the potential to be reused because of the large number of tofu industries in Indonesia which have reached approximately 84,000 business units with production capacity of more than 2.56 million tons per year with the production of liquid waste of 20 million m^3/year [5]. The relatively high agricultural and livestock sector is also the reason why these resources must be processed in such a way as to produce more useful products [6]. The methane gas content produced from tofu industrial waste also varies. Adisasmito in his research, produced 56%

methane gas and 43% carbon dioxide gas [7]. While Harihastuti's research, the biogas digester produced a product containing around 46% methane gas, 30% carbon dioxide gas, and other gases, including ammonia, hydrogen sulfide and other gases [8],[9].

Furthermore, this biogas product will undergo a purification process from the content of acidic gases such as CO_2 and H_2S. CO_2 and H_2S elements in biogas are very detrimental to equipment made of metal because they are corrosive. Carbon dioxide (CO_2) is a dangerous gas that reduces the density and reduces the heating value of biogas but is not as toxic and corrosive as H_2S. This element is also harmful to the environment and is detrimental to metal parts of engines pumps, compressors, gas storage tanks, valves and reduces the life of equipment processes [10],[11],[12]. The amount of CO_2 and H_2S is expected to be below 1% in the presence of biogas. These conditions can be obtained through the biogas purification process. The biogas purification process to reduce CO_2 and H_2S gas can be carried out through an absorption process [13],[14]. Materials that can be used to absorb monoethanolamine (MEA). The MEA compound is a primary amine compound, in which the compound contains only 1 amine group. The amine solution can physically and chemically absorb CO_2 and H_2S gas, so that the mass transfer from the gas phase to the liquid phase of the two gases increases due to the chemical reaction [15],[16].

Based on information regarding the previous biogas purification process, this research will be carried out by purifying the biogas product using the absorption method through an absorber column with a solution of the chemical monoethanolamine (MEA) as a chemical absorbent which is injected from the top of the absorber column, then contact between the biogas and the MEA solution occurs along the packing column to the bottom of the column [17].

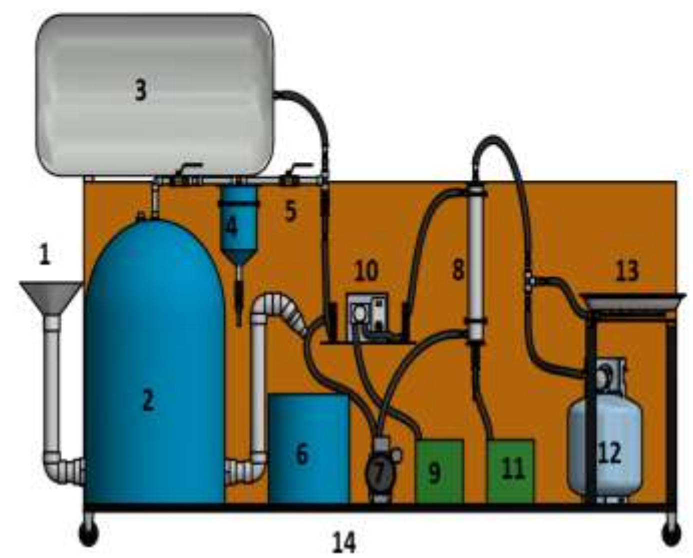
2. Research Method

2.1. Preparation

The raw material in the form of tofu industrial waste is the basic material used in this experiment. Prior to the biogas production process, the tofu industrial wastewater is subjected to biological and chemical analysis including the degree of acidity of pH, COD, and TSS.

2.2. Biogas

In research on the process of forming biogas in the biodigester. Experimental techniques refer to research [18], [19]. As a source of fuel, tofu liquid waste and cow dung starter are used in mixed variations. The temperature and pH of the biodigester were monitored and recorded for 30 days during the fermentation process [20].



Remarks

1. Inlet
2. Digester
3. Biogas Container
4. Liquid Container
5. Valve
6. Sludge Container
7. Vacuum Compressor
8. MEA Absorber
9. MEA Lean Container
10. Pump
11. MEA Rich Container
12. Purified Biogas
13. Portable Skid

Figure 1. Biodigester and Absorber Unit

2.2. Purification

The biogas purification method is carried out by absorption technique, it has good absorption power for the biogas purification process. The absorbent used is MEA solution which has a very high degree of selectivity to CO_2. Biogas purification has an optimum time on the 20^{th} day [21].

The power supply for the MEA pump and vacuum compressor is ensured that it is connected to a power source. Every valve from the biogas reservoir, absorber and MEA pump is ensured to be open before turning on the MEA pump. The MEA pump is turned on to flow MEA through the top of the absorber by pressing the ON button for the MEA pump on the control. panel. The MEA solution is allowed to circulate through the top of the absorber for 30 seconds. The biogas flow rate control valve into the absorber is opened and the vacuum compressor is turned on by pressing the ON button. by varying the research 0.2 L/min, 0.4 L/min, 0.6 L/min, and 0.8 L/min. After that, the biogas that has been purified in the absorber column is accommodated in a biogas storage tube. The results of the purification process were analyzed using a Multi Gas Detector Analyzer to determine the concentrations of CH_4, CO_2 and H_2S.

3. Result and Discussion

3.1. Characterization of Tofu Liquid Waste

Biomass characteristics such as tofu liquid waste have a high content of organic compounds such as proteins, fats and carbohydrates. So, at this stage, tofu waste analysis is carried out to determine the content of organic matter through several important organic physical and organic chemical parameters, Physical characteristics such as turbidity, temperature, solids, and turbidity, as well as organic chemical parameters, are the types of metrics that are utilized to demonstrate the characteristics of the wastewater produced by the tofu industry. Table 1 shows the organic content measured in terms of BOD, COD, total nitrogen, and pH values.

Tofu wastewater has a temperature of 35°C. This quantity can be utilized as raw material for biogas production, but it is high if it goes directly into water that is warm. This is since the temperature that must be maintained for aquatic organisms to survive in tropical waters ranges between (25-32) °C.

The total soluble solids concentration (TSS) of the raw material that was generated is 1938 mg/L, which is a somewhat high value in comparison to the quality requirement of 400 mg/L. A significant amount of TSS is present in the liquid excrement. The color of the wastewater, which is murky, is an indication that the excess TSS concentration value is too high; this coloration corresponds to a yield of 50.2cp.

The organic chemical content of COD results in a value that is still within the range of 11105 mg/L from 11200 mg/L, while for a BOD value of 5652 mg/L, total nitrogen is 268 mg/l higher than the literature 5500 mg/L and 200mg/L. Additionally, the resulting pH of 3.5 does not enter the quality standard range, which is 5-9 [22].

Because of the high concentration of organic compounds (COD and BOD), the oxygen levels in the water will drop, which will be detrimental to aquatic animals like fish. Because of the high nitrogen content, there is also an offensive odor due to the presence of ammonia gas. The water's quality will suffer as a result, as will the amount of sunlight that can reach aquatic plants; without adequate light, these plants would be unable to carry out photosynthesis correctly. People have a greater risk of developing skin ailments and stomach discomfort when they utilize the water for day-to-day activities. For the liquid waste from tofu used in this study to possess sufficient organic matter to enable the production of biogas [23].

Table 1. *Tofu Liquid Waste Analysis Result*

Parameters	Unit	Methode	Result
Physical Properties			
Temperatur	°C	SNI 6989.23-2005	35
Total Suspended Solids (TSS)	mg/L	Gravimetri	1938
Turbidity	cp	Viskometer	50.2
Chemical Properties			
COD	mg/L	Spectrophotometri	11105
BOD	mg/L	Winkler	5652
Nitrogen Total	g/L	Spectrophotometri	268
pH	-	SNI 6968.11-2019	3.62

*The data source is processed from Balai Besar Laboratorium Kesehatan Palembang

3.2. Biogas Composition before Gasification

The composition of the biogas produced depends on the organic source materials and the parameters established during the anaerobic degradation process. [21]. Figure 2 shows the initial content of the biogas produced as a result of the fermentation process that took place in the biodigester for a period of thirty days to produce high levels of CO_2 and H_2S gases. The CO_2 concentration in the biogas was 10.12% on day 30, whereas the H_2S concentration was 156% on the same day. The absence of an absorption mechanism is the reason for the high levels of CO_2 and H_2S that can be found in biogas.

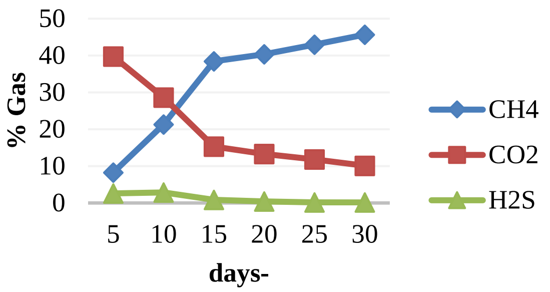


Figure 2. *Biogas Composition Before Purification*

Therefore, with the expectation of lowering CO_2 and H_2S levels while boosting CH_4 content in biogas, researchers will do absorption using biogas samples on the 30th day because this day creates the greatest pollutants. This day also conforms to prior studies [24], [25].

3.3. Biogas Composition after Purification

After the purification process is carried out, the H_2S and CO_2 content in the purified biogas is checked again. Checks are carried out every time the use of variations in MEA concentration and variations in MEA flow rate used in the absorption process. Figure 3 shows the relationship between H_2S and CO_2 content after the purification process and MEA absorption flow rate at each MEA concentration.

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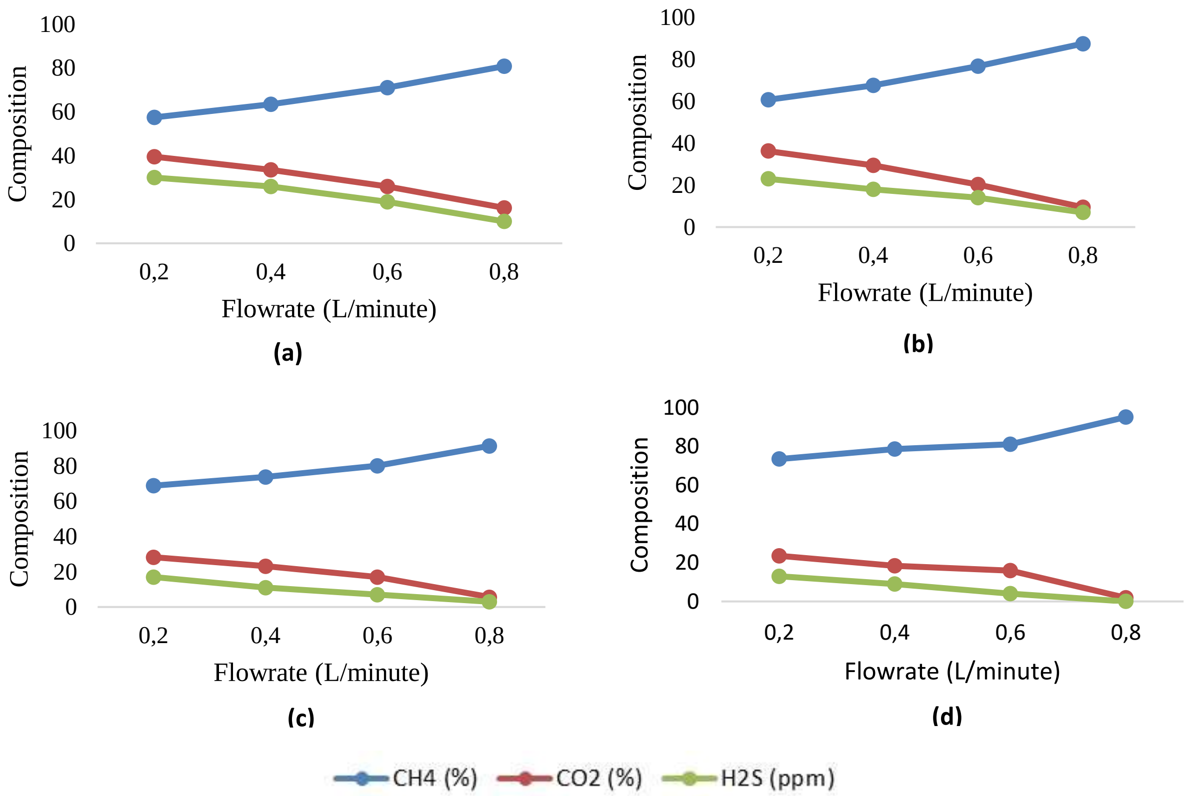

Figure 3. *Biogas Composition after Purification with MEA Concentration of (a) 10%, (b) 20%, (c) 30%, and (d) 40%*

The pattern that can be seen in Figure 3 is that the amount of CH_4 that is found in biogas after it has been filtered with MEA continues to rise. After purification with MEA, the quantity of CH_4 in the biogas grew to 80.82%; 8754%; 91.34%; and 95.12% at a mea flow rate of 0.8 L/min with a mea concentration of 10%, 20%, 30%, and 40% correspondingly. Prior to purification, the CH_4 content in the biogas was 45.67%. This suggests that the MEA content tends to rise with increasing MEA concentrations that are employed. In comparison to the other concentrations, the concentration of 40% generates the highest CH_4 content, which comes out to be 95.12%. The same is true for the mea flow rate that is being utilized; the longer the mea is flowed, the higher the ch4 content will be. This can be observed in one of the samples that was used when the mea concentration was 10%, where the CH_4 composition at a flow rate of 0.2 minutes was lower than the CH_4 composition that was utilized when the flow rate was 0.8 minutes. The quantity of CH_4 that is created is inversely proportional to the quality of the biogas produced.

As can be seen from Figure 3a through 3d, the composition of CO_2 tends to become decreased with increasing mea concentrations. The composition of CO_2 was 10.12% before it was purified, but after it was purified at 0.8 L/minute with a concentration of 40% MEA, it produced 1.88% CO_2, which is a substantial reduction from the original value. The quality of the biogas produced is directly proportional to the amount of CO_2 that is contained within it. Because the CO_2 content in biogas will lower the heating value of the fuel, which is related to the nature of CO_2 as a by-product of the combustion process; specifically, CO_2 is a substance that does not burn anymore [26]. It is also possible to see, as a result of looking at Figure 3 a-d, that the reduction in CO_2 content is significantly more substantial the more concentrated the concentration that was employed. At flow rates ranging from 0.6 L/minute to 0.8 L/minute, this phenomenon is observable at concentrations of 10%, 20%, 30%, and 40%, respectively. At these flow rates, there is a difference in the reduction of CO_2 composition by 9.72%; 10.77%; 11.26%; and 14.06%.

H_2S was found to be the final component to be discovered. It is imperative that the concentration of H_2S be decreased since it is detrimental to human health, particularly the sense of smell. This is since H_2S can produce a characteristically unpleasant stench. In addition to this, the removal of H_2S from biogas as part of the purification process will safeguard engine components from the corrosive effects of biogas [19]. The H_2S content in biogas, which had been as high as 156% before the purification process with MEA, was reduced to 0% at the MEA concentration. The purification procedure required a MEA concentration of 40% and a flow rate of 0.8 minutes. This suggests that there is no longer any H_2S present in the biogas that has been created.

4. Conclusion

The results showed that the best biogas flow rate in the purification process produced the highest CH_4 concentration of 95.12% was 40% MEA concentration and 0.8 L/min flow rate. The effect of MEA concentration on biogas purification causes the concentration of H_2S in purified biogas to decrease with increasing MEA concentration. The best combination of biogas flow rate of 1 L/min and packed bed scrubber of 8 mm reduces CO_2 and H_2S concentration to 1.88% and 0 ppm. This is because the slow flow rate will cause the contact time between biogas and MEA to be longer and the contact area to be wider; therefore, more impurities will be absorbed and this in turn will lead to higher CH_4 yields.

Acknowledgements

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