



Purification of Quality Biogas with Different Types of Animal Waste by Condensation and Multilevel Adsorption Method

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Abstract. Biogas is renewable energy that can be seen from technical, economic, and social aspects which can be used to supply energy that comes from fossil fuels. Biogas contains methane (CH₄) and carbon dioxide (CO₂) as well as several other gasses, namely hydrogen sulfide (H₂S), ammonia (NH₃), hydrogen (H₂) and nitrogen (N). Biogas can be made from livestock waste such as animal manure by ruminants, pseudoruminants and non-ruminants. Therefore, this study aims to compare the quality biogas before and after purification from different types of animal manure by condensation and multilevel adsorption method. Types of animal manure used in the research by cow dung, rabbit manure, broiler manure, and mix manure. Then all treatments will be purified with condensation and multilevel adsorption methods with 5 different adsorbents (roof tile waste (RW), CaO (CO), activated carbon (AC), iron powder (IP), and zeolite (Z)). The methods were the preparation of feedstock, purification tools, biogas production. The parameters measured were biogas content before and after purification. The research design used was a Completely Randomized Design (CRD). The results obtained were tested by One Way ANOVA followed by DMRT Test with a confidence 95% ($\alpha=0.050$). Furthermore, the effect of different types of animal manure on quality biogas is the highest CH₄, lowest CO₂ and lowest N₂O content resulting from purification using A3T6 for CH₄; CO₂ and A3T0 for N₂O.

Keywords: Biogas, Animal Waste, Purification.

1 Introduction

Livestock population in Indonesia is currently increasing from various types from ruminants, pseudo ruminants, non-ruminant and this population is in line with the amount of waste from three types of livestock. The amount of population and livestock waste in 2019 for broilers is 3.137.707.479/head and 380.376.615 kg/head/day, rabbit population is 1.349.894/head and livestock waste is 269.978 kg/head/day and cow dairy population are 565.001/head and livestock waste is 11.300.020 liter/head/day [1]. Therefore, livestock waste from all types that have not been used effectively and efficiently has an impact on environmental problems. To reduce the impact of environmental problems, the waste of the three types of livestock can be used as raw material for

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the biogas process. Biogas uses renewable resources as alternative energy to replace fossil fuels [2]. Methanogens (methane producing bacteria) are the last link in a chain of microorganisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy [3]. In general, the content of the biogas is a mixture of 50-70% methane (CH₄), 30-40% of carbon dioxide (CO₂), 5-10% of hydrogen gas (H₂) and the rest of other gasses such as ± 2% H₂S [4].

The higher methane, the higher calorific value produced. Conversely, low methane value can lower the heating and corrosiveness. The quality of biogas can be increased by several purifications, namely by removing impurity gasses in the biogas. As for some methods that have been carried out for biogas purification that combines condensation and multilevel adsorption methods with 5 adsorbents. Therefore, based on the problems that occur, it is necessary to conduct a study. This study aims to increase the quality of biogas production process. As a result, it can help understand the processes in purification biogas with combined condensation and multilevel adsorption methods with 5 different adsorbents. Furthermore, the effect of purification with different types of animal manure on quality biogas will be analyzed.

2 Materials and Methods

2.1 Feedstock and Adsorbent Preparation

This research made of livestock waste such as animal manure by cow dung, rabbit and broiler manure as raw material was obtained from Sumber Sekar Laboratory of Faculty Animal Science in Malang. 3 types animal manure and mix all of was combined with water to get 7-9% dry matter content as raw material for biogas. Animal manure as raw material biogas given in several treatments. Then, adsorbents such as roof tile waste (RW) from the home industry of roof tile in Malang, CaO (CO), activated carbon (AC), iron powder (IP), and zeolite (Z) from e-commerce. Self-designed manometer using banner and wood. The treatments of this study can be seen in Table 1 and Table 2.

Table 1. Types animal manure treatment in biogas.

Treatments	Animal Manure
T0	100% cow dung
T1	100% broiler manure
T2	100% rabbit manure
T3	50% cow dung + 50% broiler manure
T4	50% cow dung + 50% rabbit manure
T5	50% broiler manure + 50% rabbit manure
T6	33.4% cow dung + 33.3% broiler manure + 33.3% rabbit manure

Table 2. Types adsorbent treatment in biogas.

Treatments	Animal Manure
A1	20% Z+20% IP+20% AC+20% CO+20% RW
A2	30% Z+25% IP+20% AC+15% CO+10% RW
A3	25% Z+20% IP+15% AC+10% CO+30% RW
A4	20% Z+15% IP+10% AC+30% CO+25% RW
A5	15% Z+10% IP+30% AC+25% CO+20% RW
A6	10% Z+30% IP+25% AC+20% CO+15% RW

Data is presented in tabular and graphical form so that it can be seen an increase or decrease in purification quality and quantity biogas production due to different types of animal manure in condensation and multilevel adsorption method. The data obtained were analyzed using Completely Randomized Design Factorial One Way ANOVA with 7x6 treatments and 3 replicate then the DMRT test to see the effect between treatments.

2.2 Purification Tools Preparation

The tools used are self-designed tools using integrated methods between condensation and multilevel adsorption using 5 different adsorbent materials. The purification tools made up of PVC material. The following is a scheme for a tool used for biogas purification can be seen in figure 1.

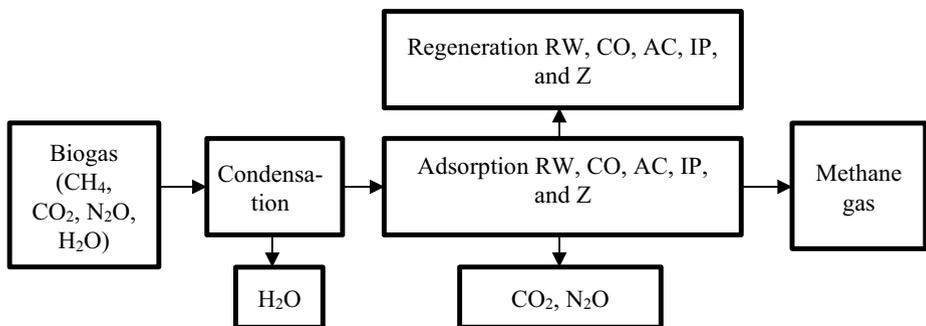


Fig. 1. Schematic diagram of experimental setup.

2.3 Purification Tools Preparation

In this experimental study, a lab scale 25-liter anaerobic type digester was used. The anaerobic digester was made up of plastic material, inlet and outlet chambers were made up of plastic pipeline material. The digested slurry was removed from bottom end of the bio digester. Biogas collection for purification at 21th day while the fermentation process was done in 50 days. The flowrate and pressure were monitored every day. The

temperature was kept at ambient temperature so that the fermentation was operated in mesophilic method.

3 Results and Discussion

The content of biogas produced from various mixtures of livestock manure before being purified using multilevel adsorption has a composition of CH₄, CO₂, and N₂O content, as shown in the following table:

Table 3. Effects of different types of animal manure for biogas content before purification.

Variables	Treatments before Purification						
	T0	T1	T2	T3	T4	T5	T6
CH ₄ (%)	59.22±0.01 ^g	15.75±0.01 ^a	24.68±0.01 ^b	38.28±0.01 ^c	58.01±0.00 ^f	47.87±0.03 ^e	47.49±0.01 ^d
P value	0.014	0.015	0.012	0.014	0.002	0.025	0.013
CO ₂ (%)	45.64±0.04 ^b	83.90±0.01 ^g	76.70±1.71 ^f	62.97±0.01 ^c	42.70±0.01 ^a	57.74±0.01 ^d	54.18±0.01 ^c
P value	0.515	0.607	0.702	0.967	0.247	0.732	0.208
N ₂ O (%)	0.02±0.00 ^a	0.65±0.00 ^e	0.16±0.00 ^b	0.02±0.00 ^a	0.03±0.00 ^a	0.05±0.00 ^a	0.04±0.00 ^a
P value	0.006	0.057	0.130	0.006	0.010	0.006	0.015

Note: Superscript (a-g) indicate a very significant difference (P<0.01) in the observed variables.

The highest CH₄ gas content before purification was obtained from the T0 treatment which was 100% cow manure, but the lowest CO₂ content was obtained from T4 which was a mixture of cow and rabbit manure. The presence of CO₂ gas can cause a decrease in energy value and cause the CH₄ content in biogas to decrease [5] so to obtain good quality biogas it is necessary to purify it to reduce CO₂ levels so that CH₄ gas levels increase. Besides CH₄ gas, N₂O gas is a gas that has good properties for combustion. The highest N₂O gas value obtained from the observations was owned by the T1 treatment which is biogas with 100% chicken manure as raw material. This is because chicken manure has a high enough N content for the formation of N₂O gas in the digester. Chicken manure has 1.70% of N content, this value is greater than the N content in cow manure which contains 0.4-1% of N [6]. The results of observations at HRT 3, 7, 14, 21, and 28 days of the anaerobic decomposition process of the substrate with cow dung base material in the digestion tank, obtained an increasing and decreasing trend in bio gas pressure with different significance of increase in the length of time the substrate stays. [10] the duration of anaerobic fermentation to be able to produce initial bio gas is highly dependent on the type of substrate or material to be put into the digestion tank.

Table 4. Effects of different types of animal manure for CH₄ content (%) after purification.

Animal Waste	Adsorbent						P value
	A1	A2	A3	A4	A5	A6	
T0	42.33±0.71 ^b	88.48±0.56 ^c	86.39±0.80 ^d	88.68±0.52 ^e	39.13±0.13 ^a	84.03±0.33 ^c	0.392
T1	46.87±0.24 ^b	93.11±1.19 ^c	98.57±0.53 ^f	87.84±0.65 ^d	31.31±0.53 ^a	85.04±0.29 ^c	0.772
T2	55.04±0.95 ^a	94.01±1.03 ^c	88.17±1.67 ^e	88.84±1.34 ^{cd}	57.18±0.99 ^b	90.54±0.50 ^d	0.783
T3	60.23±0.18 ^b	93.53±0.34 ^c	95.26±0.26 ^f	87.35±0.71 ^c	36.30±0.13 ^a	90.37±0.34 ^d	0.379
T4	44.14±0.03 ^a	95.56±0.45 ^c	96.93±0.76 ^f	88.96±0.27 ^e	52.30±0.79 ^b	91.26±0.33 ^d	0.353
T5	48.74±0.85 ^b	90.05±0.98 ^d	98.43±0.24 ^f	88.40±0.76 ^c	34.62±1.09 ^a	92.48±0.63 ^c	0.676
T6	43.28±1.19 ^b	93.49±0.62 ^c	98.73±0.88 ^f	86.42±0.69 ^c	29.55±0.66 ^a	90.28±1.17 ^d	0.943
P value	0.667	0.245	0.520	0.930	0.610	0.325	

Note: Superscript (a-f) indicate a very significant difference ($P < 0.01$) in the observed variables.

Based on the results of the biogas purification process using the multilevel adsorption method, it was found that the purification process from T6 biogas (a mixture of cow manure, chicken manure and rabbit manure) had no similarities or had very significant differences in each purification treatment, with the highest CH₄ content resulting from purification using A3 treatment of 98.73%, followed by A2 of 93.49% and 90.28%. Purification using the A3 treatment has a different effect from other purification treatments, but has similarities with the A4 purifier in purifying T2 biogas. The increase in CH₄ levels in biogas is caused by a decrease in CO₂ levels after purification. Natural zeolite has a high affinity for capturing CO₂ molecules in biogas thereby reducing CO₂ gas levels and increasing CH₄ gas levels [5]. In the process of making simple biogas, in addition to temperature stability, hydraulic retention time (HRT) or can also be called substrate residence time is one of the important variables that must be considered. This is because HRT is a determining variable during the anaerobic substrate decomposition process to ensure that the substrate (material) has been completely degraded which can later affect the process of converting the slurry-shaped substrate into gas form. Differences in HRT in the anaerobic decomposition process will affect the operating conditions of the digestion tank, the quantity of bio gas, and the composition of the gas contained in the bio gas produced [9].

As previously described, the increase in CH₄ levels was caused by a decrease in the biogas impurity factor in the form of CO₂. The T6 treatment with A3 purifier had the lowest CO₂ content of 0.70% and the highest CH₄ content (98.73%). Biogas purification using zeolite can reduce CO₂ and H₂S levels [5], and biogas purification using roof tile waste for 20 minutes can reduce CO₂ levels to 20.1% [7]. The A3 purifier has no difference with the A4 in the results of T2 biogas purification and has similarities with the A2 in the T3 and T4 biogas purification.

Table 5. Effects of different types of animal manure for CO₂ content (%) after purification.

Animal Waste	Adsorbent						P value
	A1	A2	A3	A4	A5	A6	
T0	37.58±1.35 ^e	6.82±0.46 ^b	9.11±0.18 ^c	5.74±0.65 ^a	39.35±0.56 ^f	10.46±0.52 ^d	0.581
T1	34.06±0.18 ^e	4.26±0.64 ^b	0.84±0.06 ^a	6.81±0.29 ^c	44.97±0.59 ^f	8.40±0.57 ^d	0.829
T2	24.83±0.96 ^d	3.26±0.22 ^a	6.56±0.42 ^c	7.00±0.47 ^c	25.96±0.83 ^e	5.19±0.80 ^b	0.360
T3	23.15±0.92 ^d	3.52±0.60 ^{ab}	2.82±0.27 ^a	7.83±0.89 ^c	36.55±0.64 ^e	5.30±0.77 ^b	0.369
T4	32.21±1.02 ^e	2.47±0.40 ^a	1.72±0.33 ^a	5.83±0.26 ^c	28.64±0.52 ^d	4.71±0.33 ^b	0.393
T5	30.42±1.04 ^d	6.02±0.25 ^c	0.88±0.21 ^a	6.49±0.70 ^c	38.47±0.64 ^e	3.88±0.90 ^b	0.589
T6	32.61±1.13 ^e	3.55±0.17 ^b	0.70±0.07 ^a	8.60±0.64 ^d	43.96±0.97 ^f	5.41±0.70 ^c	0.796
P value	0.510	0.158	0.331	0.104	0.720	0.235	

Note: Superscript (a-f) indicate a very significant difference ($P < 0.01$) in the observed variables.

N₂O is a gas produced from the overhaul of the protein content in waste [8]. The highest N₂O gas content after purification was 25.46% using A6 purifier (15% roof tile waste, 20% CaO (CO), 25% activated carbon, 30% iron powder and 10% zeolite) from T5 biogas which is a mixture of chicken manure and rabbit manure. The treatment of the A6 purifier in T5 biogas has a significant difference from other treatments. The results of N₂O gas content from purification using treatments A1 and A2 were not significantly different from treatment A5, while treatment A3 was not significantly different from treatment A4.

Table 6. Effects of different types of animal manure for N₂O content (%) after purification.

Animal Waste	Adsorbent						P value
	A1	A2	A3	A4	A5	A6	
T0	16.28±0.47 ^b	20.03±0.40 ^c	15.25±0.52 ^a	22.53±0.58 ^d	16.59±0.50 ^b	16.07±1.30 ^{ab}	0.85
T1	16.92±0.92 ^a	18.35±0.60 ^b	20.47±0.55 ^c	22.04±0.91 ^d	16.66±0.38 ^a	22.13±1.12 ^d	0.46
T2	22.77±0.70 ^c	23.39±1.37 ^c	22.61±0.75 ^c	17.80±0.29 ^a	19.10±0.13 ^b	23.03±0.11 ^c	0.90
T3	20.70±0.72 ^{bc}	23.38±0.81 ^d	19.88±0.19 ^{ab}	18.28±0.84 ^a	21.26±0.83 ^c	22.91±0.93 ^d	0.97
T4	22.31±0.33 ^b	22.54±0.57 ^b	22.33±0.68 ^b	25.43±0.64 ^d	19.48±0.30 ^a	23.78±0.95 ^c	0.96
T5	19.94±1.13 ^a	19.15±1.06 ^a	22.18±1.79 ^b	22.25±1.52 ^b	20.28±0.11 ^a	25.46±0.69 ^c	0.29
T6	21.18±0.97 ^b	24.43±0.99 ^d	22.81±0.83 ^c	17.37±0.72 ^a	17.98±0.37 ^a	22.51±0.35 ^c	0.82
P value	0.25	0.39	0.57	0.96	0.22	0.94	

Note: Superscript (a-d) indicate a very significant difference ($P < 0.01$) in the observed variables.

4 Conclusion

Based on the research on the purification of quality and quantity biogas with different types of animal manure by condensation and multilevel adsorption methods, it was concluded the highest CH₄ and lowest CO₂ content resulting from purification using adsorbent A3 and animal waste T6 treatment of 98.73% CH₄; 0.70% CO₂ then the lowest N₂O using A3 and T0 with value 15.25%.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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