

Analysis of Biogas Production from Cow, Chicken and Swine Manure

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Abstract

Biogas is a valuable renewable energy carrier. It can be exploited directly as a fuel for internal combustion engines. Methane (CH₄) and carbon dioxide (CO₂) are the main constituents, but biogas also contains significant quantities of undesirable contaminants such as hydrogen sulfide (H₂S). The existence and quantities of these contaminants depend on the biogas source. Their presence constitutes a major problem because of corrosion, erosion, fouling, and can generate harmful environmental emissions. The main objective of the present experimental investigation was to evaluate the biogas produced from different animal manure (chicken, cow, and swine) at same technical settings on the anaerobic digestion process. As a possible means to improve the biogas production, as well as reduce their pollution potential, the idea of using the iron sponge (steel wool) for the removal of hydrogen sulfide and water scrubbing for the removal of carbon dioxide, while operating the reactor at maximum retention period has been applied. Purification of the biogas produced was done using H₂S adsorption and CO₂ absorption; thus, improving its use as fuel for power generation. The results showed that among the (3) three manure studied, swine manure produces the highest total production of biogas with the rate at 1.30561 ft³. In the hydrogen sulfide removal, chicken manure yielded the highest impurities that range from 102-132 ppm. After purification, the concentration became 1 ppm. Thus, the hydrogen sulfide purification is effective. The carbon dioxide concentration in this study found out that the chicken manure produces more CO₂ at 9.99% volume. After the purification process, the reading ranges from 0.14 % to 0.08 % volume. In this study, chicken manure contained more impurities than swine and cow manure.

Keywords: biogas production, purification, removal treatment, hydrogen sulfide, carbon dioxide

1. Introduction

Biogas is a flammable mixture of different gases that are produced by the decomposition of biodegradable organic matters in the absence of air (no oxygen) and the presence of anaerobic micro-organisms. It can be produced from animal manure waste, wastewater, and solid waste. Biogas can be regarded as an alternative clean energy resource given its environmentally friendly nature. It consists of a mixture of methane and carbon dioxide which are produced naturally with a small amount of nitrogen, oxygen, hydrogen, water vapor, hydrogen sulfide and other traces of element. The percentage of methane varies on the feedstock and the completeness of the process. The biogas produced differs by type of substrates. Table 1 shows the typical components and percentage concentration of biogas.

Table 1. Typical components of biogas (Schiffer, 2011)

Components	Concentrations (%)
Methane	40-75%
Carbon Dioxide	25-55%
Water (Steam)	0-10%
Nitrogen	0-5%
Oxygen	0-2%
Hydrogen	0-1%
Hydrogen Sulfide	0-1%
Ammonia	0-1%

Table 1 shows that the combustible components of biogas are CH_4 and H_2S . The other components are not flammable under normal conditions and mostly useless for energy production. Among this component only CH_4 is essential. The higher the amount of methane means the higher the output of energy from biogas. This research focused on converting waste into a natural gas energy substitute which is to produce biogas. To burn biogas for its energy, CH_4 is required in a high concentration. However, biogas contains only 50% CH_4 while the other half is composed of CO_2 . Thus, to convert biogas into a natural gas substitute, the CH_4 content must be enriched. The H_2S and CO_2 are essential to be removed to prevent hazardous damage and corrosive in the system. The removal of CO_2 from biogas is an important process because it reduces the heating value of gas and the power output; it makes it uneconomical to utilize. Hydrogen sulfide must be removed because it produces toxic and corrosion to the system. This research aims to find out which of the three (3) manures give the highest potential of

generating biogas using a separate set-up with the removal of H_2S and CO_2 at the same technical settings and loading and acquiring its composition by the gas analyzer and flame test.

In the Philippines, the lack of power sources, especially in rural areas of developing countries, particularly Mindanao, necessitates the search for efficient power producing devices for small-scale operation. Also, the depleting fossil fuel based energy resources necessitate the search for new and renewable energy resources. Biogas can be regarded as an alternative clean energy resource because it has a lower impact on pollution compared to liquid fossil fuels. Power generation in rural areas using biogas produced by anaerobic digestion of manure is economically attractive.

2. Methodology

The study is a batch type. Each batch consists of 15 kg of manure mixed with water at 1:2 ratio. The study is composed of three processes. The first process is the production of biogas, followed by the removal of hydrogen sulfide and finally the removal of carbon dioxide. Each process is discussed subsequently.

2.1 Production of Biogas

Three organic biomass materials were used separately in different technical settings in a separate anaerobic digester. Chicken manure with rice hull, cow dung, and swine manure were substrates used to produce biogas by anaerobic decomposition. Each of the collected manure weighed 15 kg and was mixed with water in the ratio of 1:2. It was noted that no organic load was fed inside the digester because the research is a by-batch feeding process with 15 days retention time. After putting into the digester, the selected manures will be stirred daily to ensure that the bacteria and substrate were well-mixed and homogenous. Figure 1 shows the experimental set-up of the study. Each series component namely gas holder, removal of hydrogen sulfide and carbon dioxide removal has a gas sample ports to test the produced gas by the gas analyzer and by a flame quality test. The removal treatments data were gathered after 15 days retention time with three (3) trials. The gas produced (raw biogas) was stored in the gas holder before going through the hydrogen sulfide removal system.

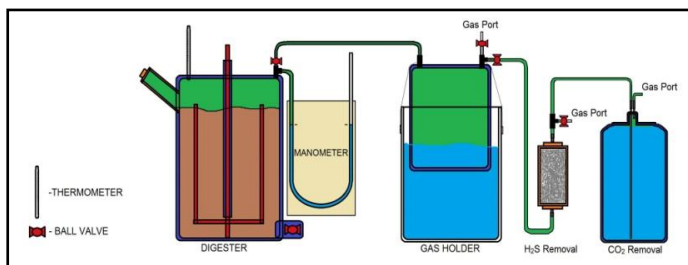


Figure 1. Experimental setup of the study



Figure 2. Test rig

2.2 Biogas Purification Systems: H₂S Removal

About 12 pieces of steel wool were inserted into a 5-in diameter PVC pipe with an 8-in length. The steel wool inside the removal was not compacted to allow the gas to move freely inside the removal system. Iron sponge method using steel wools was used in this study to purify the hydrogen sulfide from biogas (Magomnang & Villanueva, 2014). It is also one of the cheapest and most efficient methods for hydrogen sulfide removal of biogas system. The iron sponge can be regenerated by exposing the sponge to air. From the removal of H₂S, the gas flowed through carbon dioxide removal component.

2.3 Biogas Purification Systems: CO₂ Removal

The carbon dioxide scrubbed off the biogas by the use of carbon dioxide scrubber. Removing the carbon dioxide was a necessary step in cleaning the biogas due to its inhibitive quality of reducing the amount of volumetric energy. A 6-gallon container filled with water was used for the removal of carbon dioxide. In water scrubbing, the raw biogas was introduced at the

bottom of the column and flowed upward while fresh air was introduced at the top of the column flowing downward. Since CO_2 is the most abundant impurities in biogas, the researcher designed a small-scale biogas system that removes the CO_2 after the H_2S removal to prevent contaminant. The water in the water scrubbing can be regenerated by stripped of CO_2 by exposing the water to the atmospheric pressure.

3. Results and Discussion

The result of the experiment is presented in Figure 3. It indicates that after 15 days retention time the swine manure yielded the highest production rate of biogas at 1.30561 ft³ followed by chicken manure at 1.1431 ft³ and the cow manure at 0.07308584 ft³. On the first day, started on January 18, 2016, the chicken manure began to produce biogas and followed by the two (2) substrates on the 2nd day. The graphed also showed that in the 15 day retention time, the swine manure showed consistency in producing a high volume of gas among the three. During the three weeks of the experiment, the temperature in the digester of the three (3) manures ranges from 28-35°C with a constant pressure. Likewise, biogas quality was tested by flame quality test on the 2nd week of the experiment. And flame was produced in accordance to Prasad (2012).

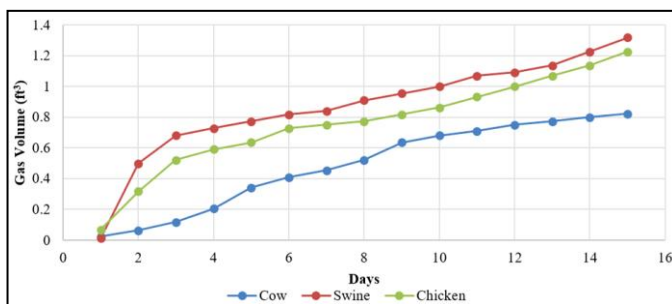


Figure 3. Biogas production of the cow, swine, chicken manures

As shown in Figure 4, the chicken manure has the highest hydrogen sulfide concentrations before purification that ranges from 102-132 ppm. The swine manure has almost zero ppm, no traces of H_2S is detected which means the swine manure is free from H_2S impurities, while the cow manure has 1 ppm reading. As Cherosky (2012) stated, substrates that are rich in protein produces large amounts of H_2S which the poultry manure can produce biogas containing up to 5000 ppm. After the raw biogas passed through purification,

the experiment results confirmed that the H_2S reading becomes 0-1 ppm. The result shows that after purification process impurities have been eliminated. The graph shows that about 90% of hydrogen sulfide has been removed. The study showed that using steel wool for hydrogen sulfide removal is effective and efficient - this supplements the results from previous studies regarding the use of steel wool which is easily available in the market.

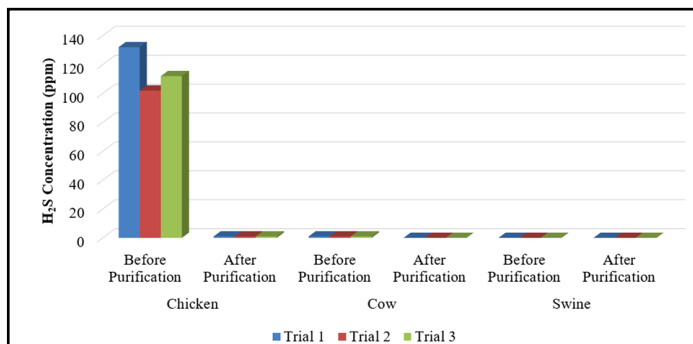


Figure 4. Hydrogen sulfide concentration of the biogas produced by the three manures before and after purification

Based on the observations in Figure 5, chicken manure yields the highest carbon dioxide impurities at 9.99% volume followed by cow manure ranges from 0.17 to 8.9 % volume and swine manure at 0.04 to 0.12 % volume reading. While on the other hand the after purification process of carbon dioxide the reading of each manure become 0.14 to 0 % volume. Apparently, the after the process, almost 90% of carbon dioxide was removed. This graph confirms that carbon dioxide removal using water scrubbing is effective. The process is also economical which is an advantage.

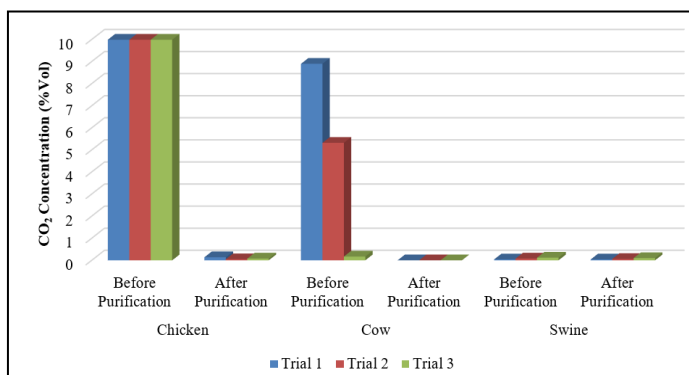


Figure 5. Carbon dioxide concentration of the biogas before and after purification

4. Conclusions and Recommendations

Anchored on the results of the experiment as shown in Figure 3 to Figure 5, the following conclusions are derived: (1) among the three manure studied namely cow, chicken and swine manure, swine manure produces the highest total production of biogas with gas volume of 13.0561 ft³; (2) in the hydrogen sulfide removal, chicken manure yielded the highest impurities that range from 102-132 ppm. After purification, the concentration became 1 ppm. Thus, the hydrogen sulfide purification is effective; (3) the carbon dioxide concentration in this study found out that the chicken manure produced more CO₂ at 9.99% volume. After the purification process, the reading ranges from 0.14 % to 0.08 % volume; hence, chicken manure contained more impurities than swine and cow manure in this study.

This study showed that various parameters are needed to understand more about the purification of biogas. The following are recommended for further studies: (1) use proper instruments like data logger, temperature, humidity and pressure transducers, calorific meter and gas analyzer to have accurate data; (2) investigation on the effect of removal of carbon dioxide from biogas using pressure swing adsorption (PSA); and (3) in order to determine the performance of removal of hydrogen sulfide and carbon dioxide from biogas, gathering of data must be done a day after the chicken, cow and swine manure were loaded.

6. References

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