Effect of filling frequency of substrate to optimized the production and quality of biogas as renewable energy

N Sari¹, H Purwanto², I Suliansyah³,4 and E Purwati²,4*

¹Postgraduated Student of Biotechnology Department, Andalas University, Padang, Indonesia
²Laboratory of Technology Animal Product Processing, Faculty of Animal Science, Andalas University, Padang, Indonesia
³Laboratory of Agronomy, Faculty of Agriculture, Andalas University, Padang, Indonesia
⁴Department of Biotechnology, Postgraduate of Andalas University, Padang, Indonesia

E-mail: purwati17@ansci.unand.ac.id

Abstract. The study was aimed to optimized the biogas produced with compare the measurement of gas production, gas quality, temperature and pH of filling frequency that performed by every 3 days as treatment A and every 6 days as treatment B. This research observed on fixed dome type digester with the system of filling as continuously and has retention time for 16 days. The substrate consists of cow manure and water that homogenized. The result of the research using a t-test showed there were very significant differences [p <0.01] between treatment A and treatment B with an average of gas production on treatment A 9.75 ± 1.22 liters and treatment B 8.72 ± 1.04 liters. Average of gas quality on treatment A 121.90 ± 3.86 watt and treatment B 113.59 ± 3.86 watts. Average of temperature on treatment A 28.12 ± 1.18°C and treatment B 27.25 ± 1.05°C. The average pH on treatment A was 6.68 ± 0.69 and treatment B was 7.37 ± 0.78. Based on the results can be concluded that the filing frequency of biogas substrate every 3 days is the best frequency to increase gas production and gas quality and to optimize the temperature and pH condition of slurry.

Keywords: frequency, filling, digester, fixed dome, biogas

1. Introduction

Biogas technology can help the rural society to solve the high price problem of fuel, especially for those who have the cow farming because its manure can be used as raw material to produce the biogas and also can reduce air pollution. Cow manure considered as the most suitable substrate for biogas production, because it already contains bacteria that support biogas formation, which is in the digestion part of the ruminant [1]. Implementation and development that concern biogas technology is very appropriate for applying to the rural area, it caused by the availability and inexpensive of cow manure. Also, using the biogas can reduce the effect of global warming, prevent pathogen disease and producing high-quality fertilizer [2].

The utilization of waste is very competitive economically along with the increasing price of fuel and inorganic fertilizer nowadays [3,4]. One of the farm groups has applied the biogas technology that observed in this research namely Tanjung Lurah Farm. They are located at Salimpauung Village, Tanah Datar Regency West Sumatera with altitude among 750-1000 above sea level [5]. There are 52 cows, which consist of 50 Simmental and 2 Limousin with the quantity of manure produced approximately of 10-15 kilograms per cow per day, most of the manure is processed into organic fertilizer as one of the main source income and as many as 15 kilograms per day are separately used for biogas raw
material. The farm group using a continuous system with retention time \([RT]\) of the substrate in the digester for 16 days, which calculated by the equation of digester volume per daily flow \([6]\).

A continuous system is more ideal and suitable for applying to the utilization of cow manure as a biogas substrate on a small quantity \([7]\). Filling frequencies that have been applied in Tanjung Lurah Farm are every day and every 2 days. Based on the data that we measured previously, showed that production of biogas with a filling frequency every day has an average of 6.48 liters per day and with a filling frequency every 2 days has an average of 7.55 liters per day. To more optimized, the authors will report about the filling frequency that modified into every 3 days and every 6 days which are expected can increase gas production and gas quality. We also report the effect of filling frequency to optimized the temperature and pH condition of slurry. We expected in the future that the result of this research can be applied by the farmer in utilizing biogas technology.

2. Material and method
Digester must be empty marked by no residue flowing into the outlet that purposed to obtained research data accurately. Filling frequency of substrate every 3 days as treatment A and filling frequency of substrate every 6 days as treatment B. As many of 15 kilograms cow manure and 30 liters of water homogenized on the inlet container. Then, put this substrate into the digester. Do the filling process every 3 days at 07.00 a.m. Measurement and observation of gas production, gas quality, temperature and pH of slurry are carried out every day for 16 days at 01.00 p.m. \([8]\). After the measurement and observation of treatment A are finished, make sure the digester is empty to start the treatment B. The quantity of substrate, the filling procedure, the measurement, and the observation process as well constant as treatment A.

2.1. Gas Production
The formation of gas can be observed using the principle of U manometer by looking alteration of height water \([\Delta h]\) in manometer when the gas is formed, the water will upwards be caused by the gas pressure that formed from the digester, the measurement can be counted based on the vessel law relates to the assumption that \(\rho_{\text{biogas}} = 0.71 \text{ kg/m}^3\), \(\rho_{\text{water}} = 1 \text{ kg/m}^3\) and mass of gas and water are constant or \(m_{\text{gas}} = m_{\text{water}}\) \([9]\). So,

\[
V_{\text{biogas}} = \frac{\rho_{\text{water}} - \rho_{\text{water}}}{\rho_{\text{biogas}}} \rho_{\text{biogas}} \cdot V_{\text{biogas}} = \rho_{\text{water}} \cdot V_{\text{water}}
\]

\[
V_{\text{biogas}} = \frac{141}{A} \Delta h
\]

Where: 
- \(V_{\text{biogas}}\) = volume of biogas \([\text{m}^3]\)
- \(V_{\text{water}}\) = volume of water \([\text{m}^3]\)
- \(\rho_{\text{biogas}}\) = density of biogas \([\text{kg/m}^3]\)
- \(\rho_{\text{water}}\) = density of water \([\text{kg/m}^3]\)
- \(A\) = area of measure hose \([\text{m}^2]\)
- \(\Delta h\) = height difference \([\text{m}]\)

2.2. Gas Quality
Gas has good quality when it has high heat \([Q]\) and power \([P]\). Gas quality can be measured with a water cooking test by using the biogas stove that modified. Cook 100 milliliters of water, observed the alteration of temperature for 3 minutes. Then, it can be calculated \(Q\) absorbed which produce by biogas. Meanwhile, \(Q\) released is the product of power and time. Referred to a Black Principle which \(Q_{\text{absorbed}} = Q_{\text{released}}\). So, the quantity of \(Q\) that released is the same as \(Q\) that absorbed. \([10]\). Mathematically its relation could be written as:
\[ Q_{absorbed} = P \cdot t \]

\[ Q_{released} = m \cdot c \cdot \Delta t \]

\[ m \cdot c \cdot \Delta t = P \cdot t \]

\[ P = \frac{Q_{absorbed}}{t} \]

Where:
- \( Q_{absorbed} \) = heat absorbed by water [J]
- \( Q_{released} \) = heat released by biogas [J]
- \( m \) = mass of water [kg]
- \( c \) = specific heat capacity [J/kg°C]
- \( \Delta t \) = temperature difference [°C]
- \( P \) = power of biogas [watt]
- \( t \) = time needed to cook the water [s]

2.3. Temperature and pH

The temperature of slurry measured by using a thermometer with the Celsius scale [11] and pH of slurry measured by using pH indicator that dipped on the slurry sample which takes from inlet [12].

3. Result and discussion

Tanjung Lurah Farm uses one unit of fixed dome digester which has a gas duct that connected to the modified stove for using the biogas. On fixed dome digester the gas container becomes one construction with the reactor, it has three main parts that consist of the inlet [use for stirring, homogenize and substrate entrance], the reactor [use for the fermentation process, gas container, gas duct] and the outlet [use for the residual output] [13]. The substrate consists of cow manure and water that homogenized with ratio 1:1 or 1:2, it depends on the texture of cow manure [14]. Based on the result of measurement and observation that was analyzed using a t-test by the SPSS app. It showed a very significant difference \([p < 0.01]\) between treatment A and treatment B that can be seen in Table 1.

| Parameter                  | Treatment A     | Treatment B    |
|----------------------------|-----------------|----------------|
| Gas Production [liter]     | 9.75 ± 1.22     | 8.72 ± 1.04    |
| Gas Quality [watt]         | 121.90 ± 3.86   | 113 ± 3.8      |
| Temperature [°C]           | 28.12 ± 1.18    | 27.25 ± 1.05   |
| pH                         | 6.68 ± 0.69     | 7.25 ± 0.66    |

Table 1. Measurement Data Analyzed by using a t-test on Treatment A and Treatment B.

Measurement of gas production and gas quality on filling frequency every 3 days is higher than every 6 days. Based on Figure 1 showed that the measurement of gas production and gas quality daily for 16 days for treatment A and treatment B assumed that when filling, the production and quality of gas are directly decreased caused by the incorporation of the raw substrate will decrease the fermentation activity in a digester. When filling time, the gas production will decrease caused by the addition of substrate into a digester, so the fermentation process by microorganisms in the digester becomes slow and its impacts for gas production which will also decrease [15]. Based on Table 1 also showed the effect of the filling frequency on temperature and pH slurry. The temperature of the slurry is an indicator that relates and affects the calculation of production and quality of gas. It associated that temperature in fixed dome digester whether on optimal condition. To observed the optimum
temperature in the fixed dome type digester which has a fixed building can be known by measuring the temperature of the residue in an outlet, slurry temperature which optimum range among 28°C until 30°C [16]. From this statement, filling the frequency of substrate every 3 days can make the condition of temperature more optimal than every 6 days. During the process of fermentation anaerobic of the substrate to produce biogas needed any group of bacteria which are all involved in the whole process of fermentation, There are cellulolytic bacteria, hydrolytic bacteria, fermentative bacteria of heterofermentative lactic acid bacteria [acetogen] and methanogenesis bacteria [17].

![Figure 1. The Differences in Gas Production and Gas Quality on Treatment A and Treatment B](image)

All of the bacteria in digester will work optimally at range temperature among 28°C until 35°C. The low temperature is also influenced by the environmental condition around where the digester is located on the plateau with altitude among 750 m up to 1000 meters above sea level with temperature among 22°C until 33°C [5,18]. Filling frequency of substrate also affect pH value. Based on Table 1 showed that filling frequency every 3 days can make pH conditions more optimal than every 6 days. The value of pH 6.6 is the ideal range for methanogenesis bacteria to establish biogas formation. Fermentation in the digester process will run well and can increase gas production on pH among 6.7 until 7.4 [19]. Biogas is formed caused by the activity of various bacteria involved in the degradation process of a complex substrate. The activity of microorganisms is strongly influenced by the pH of the substrate in a digester. Incompatible pH can decrease the role and function of microorganisms which can ultimately inhibit the process of biogas formation [20].

4. Conclusion
From this research can be concluded that the frequency of filling of biogas substrate gives the effect to gas production, gas quality, temperature, and pH. Filling frequency with a continuous system every 3 days is the best frequency for fixed dome digester which can increase the production and quality of biogas and can optimize the temperature and pH for the fermentation process.
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