Producing biogas from cow manure, chicken manure, and organic waste by batch system

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Abstract. Cow manure, chicken manure, and organic waste are solid wastes that can be used as an energy source through a biogas digester. This study aims to determine the production of biogas from waste in a batch digester system. This research uses a digester in the form of a plastic drum with a capacity of 220 liters. 3 treatments were consisting of digester 1 containing cow manure and water (50:50), digester 2 in the form of a mixture of cow manure, chicken manure, and water (30:20:50), digester 3 containing cow manure, organic waste, and water (30:20:50). The digester is then closed tightly for 130 days. The results showed that the daily temperature ranged between 26\(^{\circ}\)C and 31\(^{\circ}\)C and the acidity (pH) 7-7.62. The biogas production of each digester was then carried out a flame test with a biogas stove. The results of the gas stove flame test show that digester 2 has a longer total flame period of 4302 seconds, then digester 1 has a total flame period of 4034 seconds and lastly, digester 3 has a total flame period of 2370 seconds.

1. Introduction
Biogas is a colorless and odorless gas produced through the fermentation process of organic materials in conditions without the presence of oxygen, a biogas is flammable, and has a methane gas content of about 50-70%, has a high calorific value of about 6,400 to 6,600 kcal/m\(^3\), contents of 1m\(^3\) equivalent to 0.62 kg of kerosene or 0.46 liters of LPG [1]. Biogas can be developed for household and industrial needs. Biogas technology becomes the main choice that is environment friendly in reducing environmental waste, producing alternative energy, low production costs, and obtaining quality organic fertilizers.

Cow manure is a good starter and widely used as raw material for biogas production and cow manure has an ideal C/N ratio for biogas production of 26.5 [2]. Chicken manure has a low C/N ratio of 9.1 [3]. The potential of biogas development in Indonesia is quite large. The population of beef cattle is 17.1 million, 561 thousand dairy cows, 263.9 million laying hens, 3.4 million broilers, 312 million buras [4]. Organic waste is abundant in villages or cities.

The development of biogas for private breeders and livestock groups in the countryside is very strategic. Utilization of biogas in the countryside is most common for household gas stove fuel. In this study will use livestock waste from cow and chicken manure, as well as organic waste with a digester system batch. Digester system batch is used because it is commonly used for solid waste such as vegetables or forage [5].
2. Methodology

2.1. Digester preparation
This experiment uses a plastic digester with a volume of 220 L as presented in figure 1. A hole in the drum cap is provided to drain biogas into the storage tire through the pipe. The pipe is a facilitated manometer stop valve that serves to regulate the gas coming out of the digester to the tire shelter. In addition, before the reservoir, there is a manometer to determine the gas pressure. Another hole is also made to insert a thermometer to know the temperature inside the digester.

![Figure 1. 220-L drum digester prepared for the experiment.](image)

2.2. Substrate preparation
Fresh cow and chicken manure (about 1-2 days) are taken at the farm in Demak Regency. Organic waste comes from food waste, fruits and, vegetables. The water used for mixing and thickening comes from well water.

2.3. Treatments
There are 3 digesters made for 3 treatments. Digester 1 contains fresh cow manure mixed with water in a ratio of 1:1. Digester 2 contains a mixture of cow manure and fresh chicken manure then mixed with water with the ratio of 1:1. Digester 3 contains fresh cow manure mixed with organic waste. Organic waste consists of leftover rice, leftover vegetables, fruit peel, and elephant grass. Vegetables, fruit peels, and elephant grass are cut into pieces up to a maximum length of 3 cm. Mixing is done outside the digester, after mixing evenly, then in the pH test and temperature. Then it is taken several milliliters for analysis of samples in the laboratory. After that, the mixture is put in the digester. The digester is made airtight so that no outside air enters.

| Treatment | Cow Manure kg / % | Chicken Manure kg / % | Organic Waste kg / % | Water Liter / % | COD mg/L | TSS mg/L |
|-----------|-------------------|-----------------------|----------------------|-----------------|----------|----------|
| D1        | 75 kg / 50 %      | -                     | -                    | 85 L / 50 %     | 16,208.0 | 1,343.0  |
| D2        | 50 kg / 30 %      | 30 Kg / 20 %          | -                    | 95 L / 50%      | 31,930.5 | 7,090.0  |
| D3        | 50 kg / 30 %      | -                     | 30 Kg / 20 %         | 95 L / 50%      | 18,676.0 | 5,900.0  |

2.4. Analysis and calculations
C/N ratio, TSS, and COD analysis are conducted in the laboratory. Measurement of substrate pH values using a pH meter. In order to evaluate process condition, the temperature of the substrate during the experiment were also checked. The daily temperature was monitored from a thermometer inserted in the digester.
Biogas production can be known from the expansion of shelter tires and increased pressure in the manometer. When the shelter tire is full and the pressure on the manometer indicates 1 kPa then the test is then conducted with a biogas stove. The shelter tires are connected hoses to biogas compost. When the gas stove can turn on, the knob is set to maximum condition and then recorded the time, color, and size of the flame. The time for stove trials is done between 4-5 days once in week 1 to 3, 2-3 days once in week 4 to 13 and 3-4 days once in week 14 to 19.

3. Results and discussion

3.1. Operation condition

There are several factors that affect the process of biogas formation. Temperature and pH are among the important factors. Figure 2 shows the daily temperature of the digesters. All digesters operated in the mesophilic temperature region with a range of 29.0 – 30.0°C for D1, 28.90– 30.1°C for D2, 28.80– 30.1°C for D3. Between digesters, the temperature is not so much different because it is in the same place. The temperature inside this digester is higher than the outside temperature of the digester (24.0 – 28.0°C). This is because all digesters are placed on the terraces of buildings that are exposed to direct sunlight during the day. Measurements are performed in the noon and afternoon.

Figure 2. Average working temperature of batch drum digesters.

Figure 3 shows the initial pH condition of the substrate used in this experiment. Digester 1 has a pH of 7.5, Digester 2 pH of 7.39, and Digester 3 pH of 7.62. These three mixtures have an ideal pH for anaerobic processes. Budiyono et al [6] stated that the best method to produce biogas in the range of pH 6-8 and the highest biogas production at pH 7. C/N ratio measurement was conducted in the Laboratory of Nutrition and Feed Sciences, Faculty of Animal Husbandry, Diponegoro University. The results of the C/N ratio measurement are shown in Table 2.

Table 2. C/N ratio substrate.

| Treatment | Organic Material (%) | C Organic (%) | Nitrogen (%) | C/N Ratio |
|-----------|----------------------|---------------|--------------|-----------|
| D1        | 99.24                | 0.58          | 0.06         | 9.67      |
| D2        | 98.97                | 0.57          | 0.14         | 4.07      |
| D3        | 99.35                | 0.58          | 0.07         | 8.29      |

3.2. Biogas production by flame test

Biogas production can be seen from the flame test. The bigger the biogas production, the bigger and higher the flame will be. The process begins with a decrease in oxygen content in the digester, due to respiration. When the amount of oxygen decreases and disappears, an anaerobic process begins. During the first week, only digester 2 (D2) began to have signs of methane gas formation characterized by the
expansion of the shelter tires. In the second week digester 1 (D1) has begun to see the development of methane gas. While digester 3 (D3) methane gas formation begins in week 5. Delay in the formation of methane gas in D3 due to the material used is still new condition organic waste, so it makes the process of decomposition of organic waste is long.

Figure 3. Flame time from different treatments.

Figure 3 shows that during the anaerobic process, the three digesters show fluctuating biogas production characterized by changing stove flame times. The increase in flame time occurs in week 6 (D1), week 4 (D2), and week 8 (D3). Overall the peak of biogas production occurs in weeks 8 to 15. After the 15th week, biogas production began to decline.

During the first three weeks, the D1 and D2 digesters showed the lowest cumulative flash time. Then in the fourth week began to increase its biogas production which marked long the flames. In week 14, the time of the two digesters began to drop little by little. Up to day 130, D2 cumulative flash time is long than D1. Cumulative flame time D1 indicates 4031 seconds while D2 is 4032 seconds. Digester D3 until week 6 has not shown any signs of biogas formation shown yet to expand the shelter tire. When the 7th week, tire shelter has started to have contents so that it can be done flame trials. On day 130, the cumulative flash time is 3000 seconds and is the lowest of any other digester.
In the first month, the height of the digester D1 and D2 flames is still below 5 cm and the flame is blue and there is a little red, while in digester D3 has not been conducted flame test because there has not been formed gas in the reservoir (Figure 5). In week 6 the height of the D1 and D2 flames reaches a maximum (10 cm) and the flames are blue, while in D2 there is an increase in the height of the flames. In weeks 7-11 the flame height is relatively stable for D1 and D2 digesters. For digester D3 in the 7th-11th week, the height of the flame is about 8 cm, still lower than D1 and D2. Entering the 12th week there has begun to be a decrease in the height of the flames and also began to look red. It means that there has been a decrease in pressure and methane gas content.
3.3. Methane yield
Observations of high flame and color will give an idea of the amount of methane content in biogas. Overall, the flame of the results of all digesters sees the dominant color as blue.

Figure 6. Graph of flame time against flame height digester 1.

Figure 6 shows that digester 1 in the first week was able to produce methane gas, marked by being able to light a fire for 10 seconds, a fire height of ± 5 cm and a reddish blue color. The reddish blue color of the flame indicates that the CO$_2$ gas content in the biogas is quite high. Methane levels in the first week are relatively small, because the digester is entering an anaerobic process that requires several stages such as hydrolysis, acidogenesis and methanogenesis. The process of methane gas formation continues to increase which is indicated by the fast filling of the gas reservoir. The results of the flame time and flame height test also increased and the flame was blue. The peak of the formation of methane gas is estimated on day 76 which is marked by a peak time of 151 seconds of flame, a flame height of ± 11 cm and a bright blue flame color.

The methanogenesis process is estimated to begin to decrease on the 100$^{th}$ day which is marked by the decreasing flame time and flame height. The downward trend occurred until the end of the study (day 130). The test results on the 130$^{th}$ day showed that the flame time was still 90 seconds, but the flame height was only ± 3 cm and the fire was dominantly red. The low height of the fire and the red color of the fire indicate that the CO$_2$ level is quite high. This condition indicated that the methanogenic bacteria's activity began to decrease so that the production of methane gas also decreased.

Figure 7 shows that digester 2 on day 3 can produce a flame for 5 seconds, a flame height of ± 5 cm and a reddish-blue color. The reservoir tire from digester 2 is filled with biogas earlier than digester 1. The process of methane gas formation continues to increase and is estimated to reach its peak on the 53$^{rd}$ day marked by a flame time of 153 seconds, a flame height of ± 11 cm and a bright blue color. The formation of methane gas was seen to be constant on days 53 to 98, which was characterized by the gas reservoir being filled easily and the flame time/ flame height was relatively stable. The methanogenesis process is estimated to begin to decrease on the 102$^{nd}$ day until the end of the study (130$^{th}$ day). The test results on the 130$^{th}$ day showed that the flame time was still 120 seconds, but the flame height was only ± 3 cm and the flame was reddish blue.
Figure 7. Graph of flame time against flame height digester 2.

Figure 8. Graph of flame time against flame height digester 3.

Figure 8 shows digester 3 producing methane gas on day 33. The test results show a flame for 10 seconds, a flame height of ± 2 cm and a reddish-blue color. The formation of methane gas in digester 3 is slower than other digesters. The composition of raw materials containing organic matter makes the anaerobic process run slowly, because it takes time and energy to digest. Organic waste may contain lignin and cellulose so it is difficult to decompose. The process of methane gas formation continues to increase which is estimated to reach its peak on the 94th day marked by a flame time of 153 seconds, a flame height of ± 10 cm and a bright blue flame color. The methanogenesis process is estimated to begin to decrease from the 94th day to the end of the study (130th day). The test results on the 130th day showed that the flame time was only 42 seconds, but the flame height was only ± 7 cm and the flame was reddish blue. The level of methane gas on the 130th day shows that it has decreased drastically, while CO₂ is still high.

4. Conclusion
The addition of chicken manure to cow manure with a composition (30:20:50) has the potential to increase the time and height of the flame. Digester 2 cumulative flame is 4302 seconds, predominantly
blue color and peak of methane gas formation on 53rd day. However, the addition of organic waste to cow manure will decrease the amount of time and high flames. The cumulative flame of digester 3 is 4034 seconds, predominantly blue color and peak of methane gas formation on 94th day. A digester containing only cow dung and water will show a cumulative flame of 2370 seconds and peak of methane gas formation on 76th day.

References
[1] Ministry of Energy and Mineral Resources 2014 Waste to Energy Guidebook (Jakarta: Directorate General for New and Renewable Energy and Energy Conservation)
[2] Fairuz, A 2015 Jurnal Teknik Pertanian Lampung 4(2) 91-98
[3] Sanjaya D, Haryanto A and Tamrin 2015 Jurnal Teknik Pertanian Lampung 4(2) 127-136
[4] Badan Pusat Statistik 2019 Large and Small Livestock Establishment Statistics 2019 (Jakarta: BPS - Statistics Indonesia)
[5] Haryati T 2006 Wartazoa 16 160–169
[6] Budiyono, M E Pratiwi and I N Sinar 2013 Jurnal Penelitian Kimia 9(2) 1-12
[7] Chibuez U, Okorie N, Oriaku O, Isu J and Peters E 2017 Int J Mater Chem 7(2) 21-24
[8] Haryanto A, Hasanudin U, Afrian C and Zulkarnaen I 2018 IOP Conf.Series: Earth and Environ Sci 141(2018) 012011
[9] Imam F I A, Khan M Z H, Sarkar M A R and Ali S M 2013 Int J Nat Appl Sci 2(1) 13-17
[10] Rekha K, Kumar S, Priya KA and Mounika 2019 International Journal of Recent Technology and Engineering (IJRTE) 8 2S11
[11] Rajendran K, Aslanzadeh S and Taherzadeh MJ 2012 Energies 5(2) 2911-2942
[12] Iqbal S, Rahaman S, Rahman M and Yousuf A 2013 10th International Conference on Mechanical Engineering, ICM 2013
[13] Pound B, Don F and Preston T R 1981 Trop Anim Prod 6(1) 11-21
[14] Yahya Y, Tamrin and Triyono S 2017 Jurnal Pertanian Lampung 16(3) 151-16