Feasibility Study of Biogas from Banana Peel Waste and Livestock Manure Mixture as Renewable Energy Source

I R Rahim¹, A T Lando¹, K Sari¹, E Asriyanti¹, M Ihsan²

¹Department of Environmental Engineering, Engineering Faculty, Hasanuddin University, Makassar, Indonesia
²Department of Civil Engineering, Sekolah Tinggi Teknik Baramuli, Pinrang, Indonesia

*E-mail: irwanrr@yahoo.co.id

Abstract. Biogas energy can be obtained from waste of domestic, sewage, cattle, market, food industry etc. Banana peels contain chemical compounds such as cellulose, hemicellulose which contain acidic organic compounds that can be used as substrate for biogas production. Purposes of this study are to analyse the characteristics, the composition and the production cost of biogas made of mixtures of banana peel and livestock manure. The study used 6 biogas reactors where each reactor has 19 L capacity with ratio of 1:2.5 for solid and wastewater. The result shows that reactor E2, containing 7.1% of cow and chicken manure and 14.3% of banana peel, produced the highest rate of biogas (91.4%) when compared to other reactors. E4 reactor produced 209 ml of biogas as effective composition, consisting of 2.4% of cow manure, 7.15% of chicken manure, and 19.0% of banana peel. In terms of production cost, E2 reactors have the most effective composition, with the ability to produce 0.000174 m³ of methane by Rp. 5,747 per kg. Biogas made of organic material and livestock manure is relatively less expensive compared to 3 kg of LPG gas with a price of Rp. 18,000. E4 reactor biogas could produce 209 ml with a composition of 357 g of cow manure, 1,071 g of chicken manure, 2850 g of banana peel, 5.355 l of water for livestock manure and 5.355 l of water for banana peel.

1. Introduction

According to Indonesian’s Ministry of Energy and Mineral Resources [1], fossil energy in the form of oil reserves in Indonesia is estimated to run out in the next 12 years. Data of Indonesia's oil reserves shows that oil stock currently remains 3.65 billion barrels, with a production level of 800 thousand barrels per day [2]. In order to reduce dependence on fossil fuel, The Government of Indonesia has issued national energy policy to developed alternative source of energy in (Indonesian Government regulation No. 5, 2006) [3]. Renewable and environmentally friendly energy is therefore becoming the main option to overcome crisis of fuel where one of the sources is biogas. Due to its combustibility, this type of energy has the potentials to replace gasoline, kerosene, and diesel oil. The good point is, biogas energy can be obtained from domestic waste, manure of livestock, as well as organic waste from fresh markets, food industries and other sources [4].

Several previous studies have reported experimental results from the mixtures of cattle manure and banana peels. Banana peels contain chemical compounds such as cellulose and hemicellulose. These compounds consist of acidic organic compounds that can be used as substrates for biogas production. Labiba et al reported that a mixture of cow dung with banana peel could produce biogas of 3.6 L [5]. Yusiati et al found additional cattle manure in banana peel waste influenced concentration of methane gas production [6]. Bahite et al reported that volume of biogas production was higher with the addition of livestock manure [7].
2. Equipment and Materials

2.1. Equipment
This study used four (4) 19L reactor and 300 ml drinking plastic bottle as shown in Figure 1 and Figure 2. Beside the equipment, present study used also aquarium hose, rubber tire, balloons, plastic jars, measuring cup, pH meter, digital thermometer, modelling clay, rubber band, half-meter nets, and compressor faucet to support main equipment.

![Figure 1. Sketch of 19 L - Biogas reactor](image1)

![Figure 2. Sketch of 330 ml-plastic bottle as Biogas reactor Biogas](image2)

2.2. Material used
This research was conducted at Sanitation and Solid Waste Laboratory of the Faculty of Engineering, Hasanuddin University, Indonesia. Banana peel was collecting from banana sellers while livestock waste was taken from animal husbandry in Pangkep area. Composition of livestock manure and organic material to water was 1:2.5, which is also described in Table 1.

3. Laboratory Testing
3.1. Preparation, Mixing and Fermentation
After biogas reactor preparation completed, mixture material of livestock manure and banana peel is prepared based on designed composition by watered in separated containers and properly stirred as designed before mixed in larger media. Final mixture was placed into 330L-plastic bottles and 19L-reactors, while ensuring the reactors and bottle is properly confined and left to be fermented during observation. Values of pH, water content, solid total, temperature and COD of the waste mixture were recorded every day for 35 days.
### Tabel 1. Material composition

| Number of Sample | Cow manure (gr) | Chicken manure (gr) | Banana peel (gr) | Water for waste (L) | Water for banana peel (L) |
|------------------|----------------|---------------------|------------------|--------------------|--------------------------|
| E1               | 1608           | 536                 | 2145             | 4.290              | 6.435                    |
| E2               | 1073           | 1073                | 2145             | 4.290              | 6.435                    |
| E3               | 1073           | 0                   | 3216             | 4.290              | 6.435                    |
| E4               | 357            | 1071                | 2850             | 5.355              | 5.355                    |
| E5               | 714            | 714                 | 2850             | 5.355              | 5.355                    |
| E6               | 0              | 714                 | 3564             | 5.355              | 5.355                    |

#### 3.2. Initial composition design

Several steps were conducted to find the effective composition of biogas mixture.

- Literature review on effective volume biogas produced from each material in previous studies. There are several sizes of reactors used in biogas production which are 2.8L, 4L, and 14L for P1, P2 and P3 respectively. Volume of biogas production from each study is divided by 75% of reactor volume, as shown in Table 2. According to Nurdimansyah [8], biogas processed in reactor works effectively when substrate level is 75% of reactor volume.

- Define the percentage of composition for biogas based on previous studies. The percentage was then calculated by the amount of composition and divided by total composition input and then multiplied by one hundred. Calculation result is presented in Table 3.

#### Table 2. Volume biogas from previous studies

| No. research | Time (day) | Volume of Biogas (ml) |
|--------------|------------|-----------------------|
|              | 7          | 10                    | 14          | 20         | 21         | 28         | 30         | 35         |
| P1-1 (Cow manure)* | -          | 2                     | -           | 7          | -          | -          | 10         | -          |
| P1-2* (Horse manure) | -          | 3                     | -           | 4          | -          | -          | 43         | -          |
| P2-1 (A)** | 3050        | -                     | 3425        | -          | 3600       | 3750       | -          | 3725       |
| P2-2 (B)** | 3450        | -                     | 3550        | -          | 3775       | 3800       | -          | 4100       |
| P2-3(C)** | 2900        | -                     | 3000        | -          | 3025       | 3075       | -          | 3275       |
| P2-4 (D)** | 3100        | -                     | 3475        | -          | 3575       | 3750       | -          | 3675       |
| P2-5 (E)** | 3450        | -                     | 3550        | -          | 3775       | 3825       | -          | 4075       |
| P3-1 (A)*** | 2192        | -                     | -           | -          | -          | -          | -          | -          |
| P3-2 (B)*** | 998         | 1689                  | 3932        | -          | -          | -          | -          | -          |

Sources: *Yusiat*, et.al., [6] **Bahite*, et.al. [7], ***Labiba*, [5]

Note:

*P1 = Effect of Addition of Banana peel Waste on Gas Production of Methane in Methanogenic Fermented Livestock Manure.

**P2 = Mixture of laying hens and banana peels.

***P3 = Banana Skin Mixture and Cow Manure Using Anaerobic Bioreactors.
Table 3. Mixture composition of previous studies

| Material               | Composition of previous studies (%) |
|------------------------|--------------------------------------|
|                        | P1-1*  | P1-2*  | P1-3*  | P2-1** | P2-2** | P2-3** | P2-4** | P2-5** | P3-2*** |
| Cow manure             | 11     | 9      | 8      | 0      | 0      | 0      | 0      | 0      | 14       |
| Horse manure           | 11     | 9      | 8      | 0      | 0      | 0      | 0      | 0      | 0        |
| Chicken manure         | 0      | 0      | 100    | 0      | 50     | 67     | 33     | 0      |          |
| Banana Peel            | 0      | 3      | 7      | 0      | 100    | 50     | 33     | 67     | 14       |
| Waste water            | 33     | 33     | 33     | 0      | 0      | 0      | 0      | 0      | 29       |
| Banana peel mixed with | 44     | 44     | 44     | 0      | 0      | 0      | 0      | 0      | 43       |
| water                  |         |         |         |         |         |         |         |         |          |

Sources: *Yusiati et al., [6] **Bahite et al., [7] ***Labiba, [5]

- In Figure 3 it can be seen that the result of P2-5 and P3-2 were the most effective of results on previous study. Based on these results, the present study is following their initial composition of the abovementioned study.

![Biogas Production](image)

Figure 3. Biogas production of several studies

- The next step is to calculate the density of banana peel waste and cattle manure. As mention earlier, the most effective reactor volume was in P2-5 dan P3-2, therefore, by referring to the volume, this study applied 1:2.5 ratio of solid waste to water.

Table 4. Initial composition

| Sample          | Weight | %  | Density (gr/cm\(^3\)) | Vol. (cm\(^3\)) |
|-----------------|--------|----|-----------------------|-----------------|
| Cow manure      | 0      | 0  | 1.07                  | 0               |
| Horse manure    | 0      | 0  | 1.07                  | 0               |
| Chicken manure  | 714    | 4.76| 0.91                  | 785             |
| Banana Peel     | 3564   | 23.8| 0.48                  | 7425            |
| Sewage          | 5355   | 35.7| 1.00                  | 5355            |
Sample Weight % Density (gr/cm$^3$) Vol. (cm$^3$)

| Sample | Weight | %  | Density (gr/cm$^3$) | Vol. (cm$^3$) |
|--------|--------|----|---------------------|--------------|
| M      | 5355   | 35.7 | 1.00               | 5355         |
| TOTAL  | 14988  | 100  | 18920              |              |
| Waste to sewage | 1 : 7.5 | | 14.3 lt | |
| Banana peel to sewage | 1 : 1.5 | | 19.0 | |
| Solid waste to sewage | 1 : 2.5 | | 75% | |

- Final mixture composition is plotted in Table 5.

**Table 5.** Determination of initial composition

| Material                  | E1 | E2 | E3 | E4 | E5 | E6 |
|---------------------------|----|----|----|----|----|----|
| Cow manure                | 11 | 7  | 7  | 2  | 5  | 0  |
| Chicken manure            | 4  | 7  | 0  | 7  | 5  | 5  |
| Banana peel               | 14 | 14 | 21 | 19 | 19 | 24 |
| Wastewater                | 29 | 29 | 29 | 36 | 36 | 36 |
| Wastewater and banana peel| 43 | 43 | 43 | 36 | 36 | 36 |

4. Result and Discussions
Data collecting was conducted by direct measurement comprising of volume of biogas, temperature of COD reactor, total solid (TS), water content, initial and final pH of mixture, as presented in Table 6.

**Table 6.** Parameter of research

| Parameter            | Time of sampling | Analysis method | Authors            |
|----------------------|------------------|-----------------|--------------------|
| pH                   | O                | indicator of pH | -                  |
| Temperature          | Everyday         | Digital Thermometer | - |
| Content of Biogas    | 15th day         | GCMS type Gas Chromatography | Lab. of Chem. Eng. UII |
| Volume of Biogas     | Everyday         | Archimedes law | -                  |
| Water content        | Once in 7 days   | Gravimetry      | Abdullah, [9]      |
| Total Solid          | Once in 7 days   | Gravimetry      | Abdullah, [9]      |
| COD                  | Once in 7 days   | Closed reflux by titrimetry | SNI 6989.73:2009 |
4.1. Analysis of density and water content
Density measurement on investigated material as preliminary research, conducted in sanitation and waste laboratory in Engineering Faculty of Hasanuddin University, is presented in Table 7.

| Materials       | Average (gr/cm³) |
|-----------------|------------------|
| Banana Peel     | 0.5              |
| Chicken manure  | 0.9              |
| Cow manure      | 1.0              |

Density is a measurement of mass per unit volume. Accounting the special characteristics of material by density, the parameter can be used to determine substance type. The density is a very important property of material to determine the amount of composition to be incorporated into the reactor.

| No. Sample | Water content % | Average % |
|------------|-----------------|-----------|
| 15 (K.P)   | 62              |           |
| 15 (K.P)   | 61              | 61        |
| 15 (K.P)   | 61              |           |
| 10 (K.S)   | 72              |           |
| 10 (K.S)   | 71              | 72        |
| 10 (K.S)   | 72              |           |
| 14 (K.A)   | 36              |           |
| 14 (K.A)   | 35              | 35        |
| 14 (K.A)   | 34              |           |

While water can increase the degradation of organic material, its excessive portions can inhibit the activity of methanogen bacteria, since addition of water will increase the concentration of oxygen which is toxic to anaerobic bacteria. Conversely, disproportionally low water content will prevent acetic acid accumulation [10].

4.2. Temperature

![Temperature graph](image)
Temperature in reactors is ranging between 27° to 30 °C. Recent study was conducted in mesophilic conditions where temperature is ranging between 25° to 30 °C, despite its fluctuation following changes in environmental condition due to adaptation of microorganism [11]. According to Figure 4, temperature inside reactor tends to rise as seen in the day 19th observation although for day 5th to day 15th the temperature was very low, which is probably influenced by rainy weather at the time of observation.

4.3. **Value of pH**

![Figure 5. Measurement of pH](image)

Results of pH analysis can be seen in Figure 5. At the beginning of fermentation process, pH was constantly decreasing due to the alteration of organic waste into organic acids by microorganisms. However, pH value increased again at the 5th week, ranging from 6 to 6.6. This is because organic acid products were used as a source of nutrition by microorganisms.

4.4. **Water content**

![Figure 6. Determination of water content](image)

As can be seen in Figure 6, water content of E3 reactor was decreasing by 42% in the 1st week. This is probably caused by the adaptation process of bacteria in E3 into new environment, causing slow
degradation of organic materials. Water content was constantly decreasing to the range of 60% to 90% to day 5th. This shows that the bacteria contained in each reactor have undergone an adaptation process, leading faster degradation of organic materials [12].

4.5. Total Solid
Figure 7 shows differences of mean value of total solid reduction. While hydrolysis converted into water soluble compound, it was then used in acidogenesis reaction, causing the total dissolved solids to fell down. Data of E3 indicated a low decrease in TS because biomass contained not only lignin, but also other elements such as carbohydrates and cellulose [13].

![Figure 7. Total Solid measurements results](image)

4.6. Value of COD

![Figure 8. Measurement of COD](image)

It can be seen in Figure 8 that COD was fluctuating, which is probably due to unstable COD formation process which influenced by several factors. When the value of COD decreases, there is a hydrolysis process and when the value of COD increases, the substrate decomposition occurs. The low efficiency of COD reduction may be due to high content of organic substances, which indicates dominant waste contains complex organic compounds with high levels of pollution. The second possibility was some chemical material was taken during collection of sewage and organic waste for solid sludge mixture which have not been decomposed and therefore affecting the value of COD concentration.
4.7. Volume of biogas

Volume of biogas was measured every day for 35 days duration as depicted in Figure 9. Gas production was stored in balloons which were contained in bucket filled with water. The balloon was pushed against water in the bucket using nets then the water will come out from bucket as the measurement of the volume of gas production. Result show the highest volume and the lowest were 209.4 ml of E4 reactor and 134.5 ml of E6 reactor, respectively.

4.8. Biogas content

On the 15th day of observation, samples stored in gas-filled rubber tires were sent to Chemical Engineering Laboratory of the Islamic University of Indonesia, in Yogyakarta to be tested for biogas content using GCMS type gas chromatography. The results can be seen in Table 9.

| Samples | Biogas content | Percent (%) |
|---------|----------------|-------------|
| E1      | O$_2$          | 15.14       |
|         | C$_2$H$_6$ N$_2$ O | 29.88    |
|         | C$_4$H$_8$ O   | 29.45       |
|         | C$_{12}$H$_{10}$ N$_4$ O$_3$ | 25.54     |
| E2      | C$_2$H$_6$ N$_2$ O | 91.73    |
|         | C$_{16}$ H$_{32}$ O$_2$ | 5.02     |
|         | C$_{12}$H$_{10}$ N$_4$ O$_3$ | 3.24     |
| E3      | C$_8$ H$_8$ O$_4$ | 2.63       |
|         | C$_2$H$_6$ N$_2$ O | 90.84     |
|         | C$_{16}$ H$_{32}$ O$_2$ | 6.5      |
| E4      | C$_{16}$ H$_{32}$ O$_2$ | 49.85    |
|         | C$_2$H$_6$ N$_2$ O | 50.15     |
| E5      | C$_{16}$ H$_{32}$ O$_2$ | 48.78    |
|         | C$_2$H$_6$ N$_2$ O | 51.22     |
| E6      | C$_2$H$_6$ N$_2$ O | 51.43      |
|         | C$_8$ H$_8$ O$_4$ | 48.57      |

*Source: Result from laboratory in Chemical Engineering University of Islamic Indonesia, Yogyakarta*
Furthermore, there were two components detected in the samples which were Oxygen (O₂) and Acetyl hydrazide (C2H6N2O). Oxygen (O₂), a chemical element, has no odour, colour, taste, and not flammable but it can help combustion by oxidizing. Acetyl hydrazide or acetyl hydrazine (C2H6N2O) is a compound of aromatic hydrazides or hydrazine. Hydrazine can be used as gas fuel due to its flammability, and it can be easily obtained from synthesis. This compound is a flammable, colorless liquid with a smell like ammonia. In addition, the hydrazine reaction produces a large amount of heat energy compared to the reaction of propane (LPG gas material in general) with oxygen because the hydrazine property is a good reductor agent.

4.9. Value of pH
Initial and final pH values were plotted in Table 10.

| Sample | Initial pH | Final pH |
|--------|------------|---------|
| E1     | 6          | 6,3     |
| E2     | 6          | 6,1     |
| E3     | 6          | 6,3     |
| E4     | 6          | 6       |
| E5     | 6          | 6,6     |
| E6     | 6          | 6       |

Source: Measurement result in Environmental laboratory of Environmental engineering UNHAS

Reduction of initial pH value indicates the action of microorganisms due to process of acid formation or acidogenesis, while in the stage of methane formation (methanogenesis), bacteria which not produce methane and not sensitive to the changing of pH can work at a pH between 5 and 8.5. Based on this fact, the best composition was in E2 reactor, comprising 7% cow manure, 7% chicken manure and 14% banana peel.

4.10. Water content

| Sample | Initial water content (%) | Final water content (%) |
|--------|---------------------------|-------------------------|
| E1     | 96,3                      | 81,2                    |
| E2     | 94,2                      | 61,9                    |
| E3     | 46,5                      | 45,8                    |
| E4     | 89,9                      | 90,2                    |
| E5     | 65,0                      | 67,4                    |
| E6     | 91,2                      | 70,6                    |

Source: Measurement result in Environmental laboratory of Environmental engineering UNHAS

Result analysis indicated water content was high at the initial stage but low at the final process as seen in Table 11. This is because at the initial stage it was still in the hydrolysis stage. Normal activity of methane microbes requires about 90% water. The high moisture content will facilitate the decomposition process, while the low water content results in the accumulation of acetic acid which inhibits the growth of methanogenic bacteria. Based on this explanation, composition of E2 reactor, 7% cow manure, 7% chicken manure, 14% banana skin is the closest composition.
4.11. Value of total solid
Decrease in evaporating solids occurs because of rapid formation of acid. A few days before the end of the fermentation process, condition would be stable and lead to increase of the rate of cumulative gas production. At the state of anaerobic fermentation, total solid values would decrease between 3.1-3.5% during biogas production process.

Table 12. Condition of total solid

| Sample | Initial total solid (%) | Final total solid (%) |
|--------|-------------------------|----------------------|
| E1     | 3.68                    | 18.8                 |
| E2     | 5.76                    | 38.1                 |
| E3     | 53.53                   | 54.19                |
| E4     | 10.17                   | 9.77                 |
| E5     | 34.97                   | 32.62                |
| E6     | 8.97                    | 29.41                |

Source: Measurement result in Environmental laboratory of Environmental engineering UNHAS

Inconsistent decrease of total solid affects gas production. Result of total solid value ranging from 13% to 57% with fluctuation of percentage decrease as depicted in Table 12. Based on this explanation, the closest mixture composition was 7% cow manure, 7% chicken manure and 14% banana peel of E2 reactor.

4.12. Value of COD

Table 13. COD conditions

| Sample | Initial COD (ppm) | Final COD (ppm) |
|--------|-------------------|-----------------|
| E1     | 4400              | 2000            |
| E2     | 5600              | 2800            |
| E3     | 8000              | 2600            |
| E4     | 4000              | 800             |
| E5     | 3200              | 1200            |
| E6     | 8000              | 2000            |

Based on observation results of COD value (Table 13), it appeared that the value rose in the beginning and diminished at the end. There was an indication of substrate breakdown by bacteria or other microorganisms during reducing of value. On the contrary, increasing of COD is due to presence of simple organic compounds which led to hydrolysis of organic polymers, but the compound was not further overhauled by bacteria into biogas. Based on this fact, the closest mixture composition was from E2 reactor with 7% of cow manure, 7% of chicken manure, and 14% of banana peel.

4.13. Cost Analysis
The volume of produced methane (CH4) can be seen in Table 14.

Referring to Table 15, the usage of biogas as source of energy in the household is considerably more efficient compared to subsidized LPG or kerosene. It costs Rp. 5,747 to produce biogas while it needs Rp. 18,000 to have a 3 kg subsidized LPG. However, investment costs for installing biogas equipment can vary depending on the selected material and the volume of the reactor.
Table 14. CH4 content (% methane)

| Sample | Cow manure (%) | Chicken manure (%) | Banana Peel (%) | Water mixed with livestock manure (L) | Sewage mixed with banana peel (L) | Volume (m³) | CH₄ (% methane) | Volume of methane product (m³) |
|--------|----------------|-------------------|-----------------|------------------------------------|--------------------------------|-------------|----------------|-----------------------------|
| E1     | 11             | 4                 | 14              | 4                                  | 6                             | 0.00018     | 29.5           | 0.000053                    |
| E2     | 7              | 7                 | 14              | 4                                  | 6                             | 0.00019     | 91.7           | 0.000174                    |
| E3     | 7              | 0                 | 21              | 4                                  | 6                             | 0.00018     | 90.8           | 0.000163                    |
| E4     | 2              | 7                 | 19              | 5                                  | 5                             | 0.00021     | 50.2           | 0.000105                    |
| E5     | 5              | 5                 | 19              | 5                                  | 5                             | 0.00015     | 51.2           | 0.000076                    |
| E6     | 0              | 5                 | 24              | 5                                  | 5                             | 0.00013     | 51.4           | 0.000067                    |

Table 15. Consumption comparation between Biogas and LPG

| Sample | Methane production (m³) | 1 m³ = 0.50 kg LPG | Cost of LPG 3 kg (Rp) | Cost of biogas (Rp) |
|--------|-------------------------|--------------------|-----------------------|---------------------|
| E1     | 0.000053                | 0.50               | 18000                | 18868               |
| E2     | 0.000174                | 0.50               | 18000                | 5747                |
| E3     | 0.000163                | 0.50               | 18000                | 6135                |
| E4     | 0.000105                | 0.50               | 18000                | 9524                |
| E5     | 0.000076                | 0.50               | 18000                | 13158               |
| E6     | 0.000067                | 0.50               | 18000                | 14925               |

5. Conclusion

Based on experimental results, current study can conclude some points as follows:
1) There are several characteristics which could be defined from biogas produced from a mixture of banana peel and livestock manure, such as, pH, water content, COD, and total solid (TS). Initial pH condition was 6, but it increased up to 6.1 after 35 days of fermentation in E2 reactor.
2) Water content of biogas at the beginning was 94.2% before decreasing to 61.9% after 35 days in E2 reactor. Total solid was 5.76% and 38.1% at the beginning and the end of observation, respectively. Initially, COD of mixture in E2 was 5600 ppm but reduced into 2800 ppm after 35 days. The highest biogas content was 91.4% (E2 reactor), composed of cow manure (7.1%), chicken manure (7.1%), and banana peel (14.3%).
3) The most effective composition for reforming biogas was mixture in E4 reactor. The mixture was composed of banana peel waste (19.0 %), cow manure (2.4%) and chicken manure (7.15%). This mixture could produce 209 ml of biogas. The lowest production was 135 ml which found in E6 reactor composed of 0% of cow manure, 4.76% of chicken manure, and 23.8% of banana peel waste.
4) Based on cost analysis, compared to other source of energy, mixture composition in E2 was more efficient since it costs Rp. 5,747 while LPG costs Rp. 18,000 for a 3 kg tube.
5) Compared to previous research, the highest volume of biogas produced in the P3-2 study was 3932 ml with a composition of 1000 grams of cow manure, 1000 gr of banana peels, 2000 ml of water for cow manure and 3000 ml of water for banana peels, while for research done to produce biogas volume of 209 ml in the E4 reactor with a composition of 357 grams of cow manure, 1071 grams of chicken manure, 2850 grams of banana peel waste, 5,355 L of water for livestock manure and 5,355 L of waste water for banana peel waste.
6. Recommendation

It is necessary to conduct further research on usage of waste material as biogas to find effective composition. It is better to check the C/N ratio of samples, since it can affect substances in samples. It is recommended to stir properly all material in reactor, because some raw materials are difficult dilute and lead to form clumping or deposition of organic matter and finally inhibit biogas formation.

References

[1] Directorate General of Oil And Gas, 2017. *Oil and Gas Statistic 2016*, Ministry of Energy and Mineral Resources, Jakarta.

[2] Setiawan rakhmat, 2017. *Cadangan energi indonesia menipis, saatnya melek energi terbarukan* (Indonesian energy reserve running out, time to renewable energy literacy) (https://www.kompasiana.com/cakmat/599aefc15af02c183e6ca1d2/cadangan-energi-indonesia-menipis-saatnya-melek-energi-terbarukan, accessed 4th February 2018).

[3] The Republic of Indonesia, 2006, *Indonesian Government Regulation No. 5, 2006 on National Energy Policy*, Jakarta.

[4] Azhari, F, 2015. Kualitas Biogas yang Dihasilkan dari Substrat Kotoran Sapi dan Penambahan Starter Buah-Buahan dengan Menggunakan Reaktor Kubah. (Biogas Quality Produced from Cow Substrates and Addition of Fruit Starters by Using a Dome Reactor) *Jurnal Wahana-Bio* Vol. 14 (2-2) pp. 69-77.

[5] Labiba, Q. and Wulandari, C., 2017. *Pembuatan Biogas dari Campuran Kulit Pisang dan Kotoran Sapi Menggunakan Bioreaktor Anaeobik*. (Biogas production from banana peel and cow manure mixture using anaebic bioreactor) Institut Teknologi Sepuluh Nopember, Surabaya.

[6] Yusiaty, L.M. et al, 2012. Pengaruh Penambahan Limbah Kulit Pisang (Musa sp) terhadap Produksi Gas Metan dalam Fermentasi Metanogenik Kotoran Ternak. (The Effect of Addition of Banana Skin Waste (Musa sp) on Methane Gas Production in Methanogenic Fermented Livestock Manure) *Buletin Peternakan* Vol. 36(2): 87-94.

[7] Bahite, R. et al, 2014. *Pengaruh Campuran Kotoran Ternak Ayam Petelur dan Kulit Pisang Kepok Terhadap Volume Biogas*. (The influence of mixture of chicken manure and kepok banana peel on biogas volume) Universitas Negeri Gorontalo, Gorontalo.

[8] Nurdimansyah, et al, 2015. *Analisis Pengaruh Level Substrat Pada Digester Anaerob Skala Laboratorium terhadap Produksi Metana*. (Analysis of the Effect of Substrate Level on the Anaerobic Digester on the Laboratory Scale of Methane Production) *E-Proceeding of Engineering* ; Vol.2, No.2 p. 3260.

[9] Abdullah, N.O., 2017. *Peningkatan Produksi Biogas Sampah Pasar dengan Penambahan M-A6 dan Pengadukan Menggunakan Reaktor Anaerobik*. (Increasing Biogas Production of Market Waste by Adding M-A6 and Stirring Using Anaerobic Reactors) Institut Teknologi Sepuluh November. Surabaya.

[10] Lestari, D.I., 2016. *Efektivitas Rumput Laut Sargassum sp. sebagai Sumber Alternatif Penghasil Biogas*. (Effectiveness of Sargassum sp. as an Alternative Source of Biogas Production) Universitas Airlangga. Surabaya.

[11] Ramdiana, 2017. Pengaruh Variasi Komposisi pada Campuran Limbah Cair Aren dan Kotoran Sapi terhadap Produksi Biogas (Effect of Composition Variations on Palm Sugar Liquid Waste and Cow Manure on Biogas Production) *Ekserti*, Vol 14, No.2. ISSN : 1410-394X.

[12] Mariyani, S., 2016. *Potensi Campuran Sampah Sayuran dan Kotoran Sapi sebagai Penghasil Biogas (Potential of Vegetable Waste and Cow Manure as Biogas Producer)*. Universitas Islam Negeri Maulana Malik Ibrahim, Malang.

[13] Saktiyudha, R.P., 2014. Produksi Biogas dari Pencernaan Anaerob Serasah dan Eceng Gondok (Eichornia Crassipes) dengan Sumber Inokulum Kotoran Sapi dan Kotoran Ayam. (Biogas Production from Litter and Hyacinth Digestive Anaerobic Digestion (Eichornia Crassipes) with Inoculum Source of Cow and Chicken Manure) *Bioteknologi* vol. 11 (2): pp. 23-27 EISSN: 2301-8658, DOI: 10.13057/biotek/c110201.