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Effect of Variation of Mixture Leachate with Fluid in Cattle Rumen Formation of Biogas

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Abstract

Composting in addition to producing fertilizers also produce leachate containing organic material, the leachate can pollute the environment if not managed properly. This study uses leachate as the main substance of biogas, mixed with cattle rumen fluid as the biostarter. This study aims to determine the optimal composition of biogas and to determine the effect of variations in the raw material mixture to the volume of biogas, volatile solid, temperature, pH, and flame. The study was conducted over 43 days using three types of batch digester with a capacity of 27 L. Comparison of a mixture consisting of leachate composting organic waste with cattle rumen fluid in each digester with variations in material composition of the mixture of 70%: 30%, 50%: 50%, 100%: 0%. During the study was observed it the volume of biogas daily, daily pH, temperature daily, weekly flame test and volatile solid test every 10 days. The volume of biogas using the principle of cylinder volume and volatile solid test using USEPA 1684 method. The results show the variation of 70%:30%, which resulted in a final volume of 2.78 L of gas, as well as a decrease in the volatile solid 23.29%, 12.82% increase in the pH. In a variation of 50%:50% produces a final volume of gas that is 0.537 L, as well as a decrease in volatile solid 42.35%, 12.82% increase in the pH. Variations 100%:0% produces a final volume of gas that is 1,247 L, a decrease in volatile solid 21.83%, 5.19% increase in the pH. All three digesters are at mesophilic temperatures and produce blue flame. Based on the results of this study concluded that the composition of the mixture that are in the most optimal is composition of 70%:30%.

Keywords: *biogas; lindi organic waste composting; rumen fluid beef*

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INTRODUCTION

The volume of waste in big cities in Indonesia continues to grow along with the relatively high population growth. Waste becomes an environmental problem because its quantity and level of danger can interfere with human health. Organic waste from household activities such as leftovers (vegetables) and fruits are the biggest contributors to waste generation. The amount of waste originating from household activities is estimated to increase 5-fold by 2020. The increase in the amount of waste is not only because of population growth, but also because of the increase in waste generation per capita caused by improvements in economic and welfare levels. In urban areas, only 11.25% of waste is transported by officers, 63.35% is piled up or burned, 6.35% is composted, and 19.05% is dumped into rivers or dumped carelessly (Hambali *et al.*, 2007).

Waste is not always as a negative thing. However, with good waste management will provide benefits and add economic value, for example is composting. Organic waste produced from household waste can be used as compost. In addition, leachate produced from composting can be used as liquid fertilizer. According to Sabari *et al.* (2010), leachate contains organic compounds, especially carbon, so leachate can be used as a raw material in making biogas which is a renewable energy source. In the study of Sabari *et al.* (2010), leachate from organic waste utilized as raw material for biogas production. In addition, organic waste from the local market can be used as a mixture of raw materials for the formation of biogas with cattle manure with certain variations in the mixture ratio (Yananto *et al.*, 2009).

The Integrated Waste Processing Site or Tempat Pengolahan Sampah Terpadu (TPST) has several functions, namely as a place for collecting activities, sorting organic and inorganic waste, recycling, processing and initial processing. Separation process between organic and inorganic waste is a waste management activity in TPST. Organic waste is used as compost while inorganic waste is collected for recycling. The process of composting organic waste in addition to producing compost also produces leachate which containing organic matter. Leachate cause water and soil pollution if it is not managed properly because leachate has high BOD and COD characteristics.

In this study, leachate produced from the composting process of organic waste in TPST was used as raw material in biogas formation using cattle rumen fluid as biostarter, to produce biogas as an alternative energy source in addition to fossil fuels.

RESEARCH METHODS

The main material used is leachate composting TPST organic waste and cattle rumen fluid obtained by squeezing cattle rumen to separate fiber and rumen fluid. The equipment used in the study is the Anaerobic Digester, which is equipped with a manometer, gas reservoir, thermometer and outlet sludge faucet. The batch system of Anaerobic Digester is used in this research, the raw material is fed only once during the experiment and is monitored until the biogas is formed.

Three Anaerobic Digesters with a capacity of 27 L each are used in this study. Leachate mixed with cattle rumen fluid according to the composition as in Table 1. These two ingredients are put into a bucket, stirred until homogeneous, and then put into each digester using a funnel.

Table 1. Raw materials composition

Anaerob Digester	Feed Composition		Ratio
	Leachate	Cattle Rumen Fluid	
A	13.3 L	5.7 L	70% : 30%
B	9.5 L	9.5 L	50% : 50%
C	19 L	0 L	100% : 0%

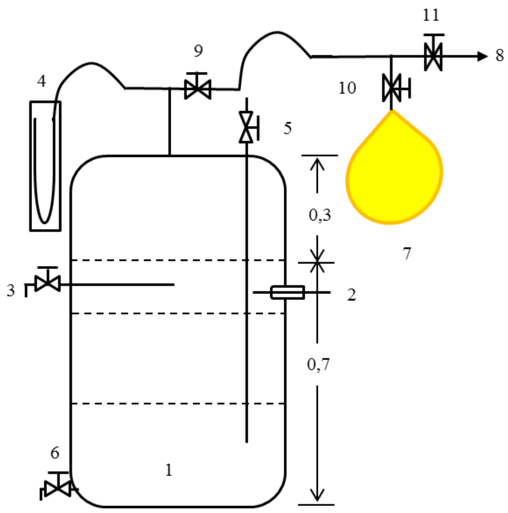

Figure 1. Design of anaerobic digester: (1) anaerobic digester, (2) thermometer, (3) sampling valve, (4) U tube manometer, (5) inlet valve for feeding raw materials, (6) outlet valve for draining sludge, (7) gas storage, (8) gas distribution pipes, (9) manometer valve, (10) gas storage valve, (11) gas distributor valve for flame test

The initial characteristics of variations in mixtures included in the Anaerobic Digester have a range of pH values between 6.8-7.8. The temperatures of the anaerobic digester A, B and C are 30, 30, and 31ºC, respectively. Moreover, the volatile solid values of anaerobic digester A, B, and C are 38.57, 47.97, and 34.08%, respectively.

Biogas volume measurement is carried out by observing the increase in water in the U tube manometer, where biogas volume measurements are measured every day to determine the trend of produced biogas. Each digester had a gas storage to hold the methane gas produced. Methane gas that was hold in the gas storage was tested using a one-eyed stove. The flame test results use the one-eyed stove as an illustration of the biogas application in daily life.

RESULTS AND DISCUSSION

Biogas Production

The total volume of biogas production in the digester A for 6 weeks or 43 days was 2.78 L, for digester B was 0.357 L, and digester C was 1.247 L. Based on the results of volume measurements of biogas produced from the three digester, digester A with a mixture ratio of 70%: 30% produced the highest biogas production compared to others. This is affected by the leachate composition in composting organic waste as much as 70%, with a C/N ratio reaching 57.01%. As mentioned by Subramanian (1978) in Yonathan *et al.* (2013) the amount of biogas produced depends on the number of substrate, therefore the volume of biogas produced also increases along with the increase in the amount of substrate used. The volume of biogas production in the digester B was lower than the other digester. The presence of scum is thought to inhibit biogas production. In addition, organic waste containing fiber would be difficult to digest and would float on the surface so that the gas couldn't flow. According to Ojolo *et al.* (2007) in Ghevanda and Triwikantoro (2013), fibrous materials with different sizes and types caused some problems such as increasing scum (layers of crust on the surface of the mixture), difficult to digest by bacteria, and would float on the surface.

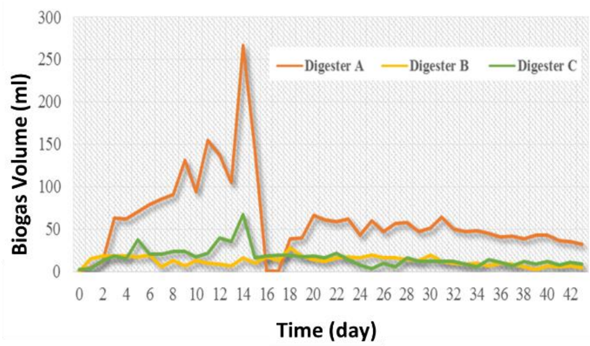

Figure 2. Biogas production volume from each digester

Changes in pH

The pH has an important role in the biogas production process. The pH plays an important role in anaerobic decomposition because in an inappropriate pH range, microbes cannot grow to the maximum and even can cause death.

In digester A, the pH on day-0 was 6.8 then on the day-43 increased to 7.8. The increase in pH from the beginning of the study to the end of the study was 12.82%. The pH value in the digester B more or less similar with the pH value of the digester A. On the day-0, pH was 6.8 and then increased to 7.8 on the day-43. Increased pH of 12.82%. Digester C has a pH value of 7.3 on day-0 and then gradually increased until 7.7 on day-43. The increase in pH value from the beginning of the study to the end of the study was 5.19%.

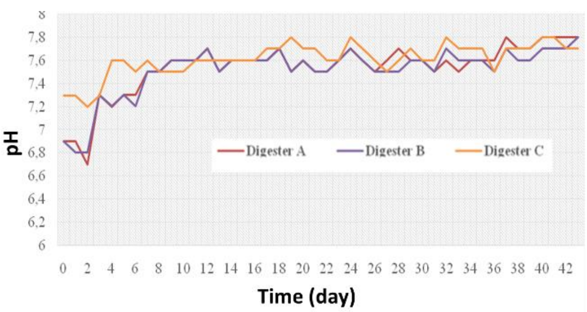

Figure 3. Changes in pH during the experiment

During the study, the pH value produced by each digester gradually increased and then stabilized at a pH value of 7.8. The pH fluctuations caused by the fermentation process of organic matter in a digester which produced acidic and basic compounds. This phenomenon is in accordance with a study from Wagiman (2007) that an increased in pH was caused by fermented or acetogenetic compounds that have been converted into H_2, CO_2, H_2O, and CH_4, and the breakdown of proteins into NH_4^+ which then easily formed alkaline compounds. The same thing was stated by Wagiman (2007) that the pH value in the initial period tends to be low and then rised in the next period which showed that the process of acetogenesis and metanogenesis took place separately.

Solid Volatile Changes to Biogas Production

Volatile solid is one of the important parameters used to calculate the productivity of biogas. Volatile solid value is the result of the combustion process of dry solid content (Total Solid) and its value is expressed in percent (%).

The volatile solid value in Digester A on day-0 was 38.37% and produced 0 ml biogas. While on the day-10, volatile solid value became 48.24% resulting in 834.34 ml biogas. On day-20, volatile solid value was 38.75% and produced 857.1 ml biogas, then on the day-30, volatile solid value was 34.61% and produced 546.48 ml biogas. Finally, on the day-40, volatile solid value was 29.34% and produced biogas of 441.6 ml. Digester A on the day-20 was the optimum day in producing biogas.

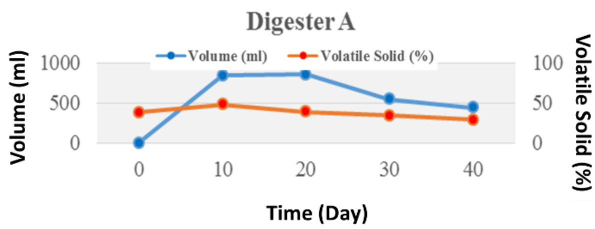

Figure 4. Volatile solid value changes on production biogas in digester A

Digester B has a solid volatile value of 47.97% and produces 0 ml biogas on day-0. On day-10, the volatile solid value was 47.79% and produced biogas 134.36 ml. On day-20, the volatile solid value was 36.05% and produced biogas 141.35 ml. Then, on the day-30, the volatile solid value was 32.41% and produced 129.83 ml biogas. Finally, on day-40, the volatile solid value was 27.65% and produced a volume of biogas 81.06 ml. Day-10 was the optimal day that produced the highest biogas production. On the day-10 to day-40, there was an insignificant volatile solid decline.

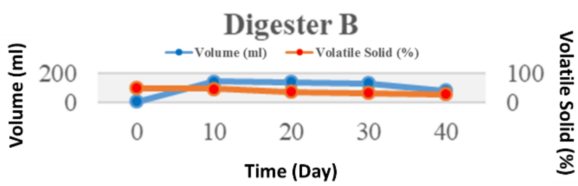

Figure 5. Volatile solid value changes on production biogas in digester B

Decreasing the volatile solid value was not accompanied by the volume of biogas produced because this microorganism was still at the adaptation stage to the substrate. According to Sjafruddin (2011), the decline in volatile solids in the early stages of the process did not indicate an increase in methane gas products. This indication illustrated that methanogenic microorganisms underwent a period of adaptation to changes in carbon sources from a mixture of biogas materials.

Digester C on day-0 produced 0 ml biogas, then on the day-10, volatile solid value was 42.32% and produced biogas 190.91 ml. Day-20 was the optimal day in biogas production where the produced biogas was 271.34 ml with a volatile solid value of 35.55%. On the day-30, the volatile solid value was 30.12% and produced biogas 118.74 ml. Finally, on the day-40, with a solid volatile value of 26.64%, the resulting biogas was 103.03 ml.

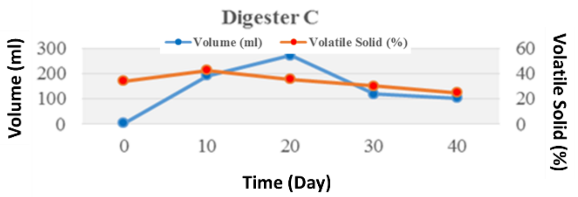

Figure 6. Volatile solid value changes on production biogas in digester C

Volatile solid value on day-0 was 34.08% and at the end of the study or day-40 was 26.64%. Decrease in volatile solid value on day 0 to day 40 was 21.83%. According to Sjafruddin (2011), a decrease in volatile solid indicated an increase in biogas production or the level of methane gas produced. The decrease in volatile solid showed that there had been a degradation process of organic compounds in the biodigester.

Biogas yield was calculated to determine the efficiency of using raw materials to produce biogas. Mixture variation of 70%:30% resulted in a volume of biogas of 2.78 liters with a mixture of 19 liters for 43 days. So, the biogas yield was 14.63%. Every one liter of raw material with 70% of leachate and 30% of cattle rumen fluid could produce biogas of 0.1463 liters.

Mixture variation of 50%:50% produced biogas of 0.536 L with raw materials of 19 liters for 43 days. So the yield was 2.82%. Every one liter of raw material with a variation of 50% leachate and 50% of cattle rumen fluid could produce biogas by 0.0282 liters.

The variation of 100% leachate mixture without the addition of cattle rumen fluid produced 1.247 liters with a mixture of 19 liters for 43 days. So, the yield of biogas in a mixed variation of 100%:0% was 6.56%. Each one liter of mixed raw material with a variation of 100% leachate and 0% of cattle rumen fluid could produce biogas by 0.065 liters.

Flame Test

A flame test was carried out to determine the methane gas content produced in each digester. The formation of methane gas could be seen in the presence of blue color in the flame. Methane gas is an important and main component because it has a fairly high caloric content, and can burn if the gas produced from the anaerobic process. According to Luthfianto et al (2012) biogas could burn if there was a minimum methane level of 57%. Digester A with a mixed variation of 70%:30% just starting to produce a flame at the 3rd week, this was due to the low content of methane gas. Digester B with a mixture of 50%:50% starting to produce a flame at the 2nd week. While digester C with 100% leachate without the addition of rumen began to produce flame at the 4th week.

Figure 7. Flame test

Temperature Fluctuations in Anaerobic Digester

One of the factors that support the process of forming biogas is temperature. The ideal temperature will make bacteria easy to develop so that the formation of methane gas will be fast. During the observation study, the temperature was carried out every day using a thermometer mounted on the digester.

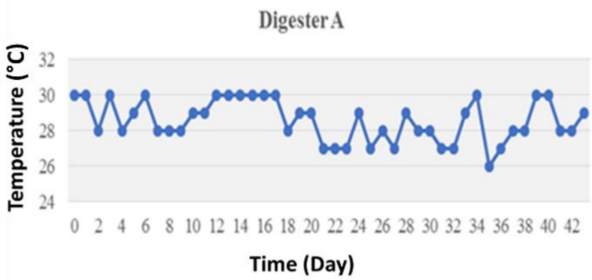

Figure 8. Temperature change in digester A

Based on the results of the observation, the temperature of each digester was in the temperature range of 26-31ºC. At digester A the highest temperature is 30ºC and the lowest temperature was 26ºC.

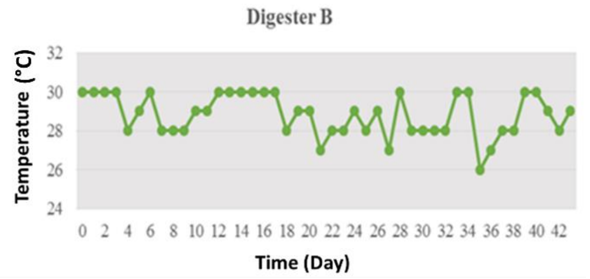

Figure 9. Temperature change in digester B

Digester B produced the highest temperature of 31ºC and the lowest temperature of 27ºC. The temperature range was the optimum temperature range in biogas formation, where the range enters the mesophilic temperature between 25-50ºC. Mentioned by Sanjaya *et al.* (2015) good temperatures in the biogas formation process ranged from 20–40ºC.

In Digester C, with a variation of 100% leachate, the lowest temperature was 27ºC and the highest temperature of 31ºC. The temperature during the study was at a temperature (25-45ºC) and was mesophilic temperature, where the temperature is the optimum temperature for methanogenetic bacteria in forming methane gas. Similar to statement by Sjafruddin (2011), anaerobic bacteria worked on mesophilic temperatures (25-45ºC) with an optimum temperature of 35ºC. Changes in temperature in all three digesters were also influenced by fluctuations in environmental temperature, and the results of the study showed that the ambient temperature is in the range of 28-32ºC.

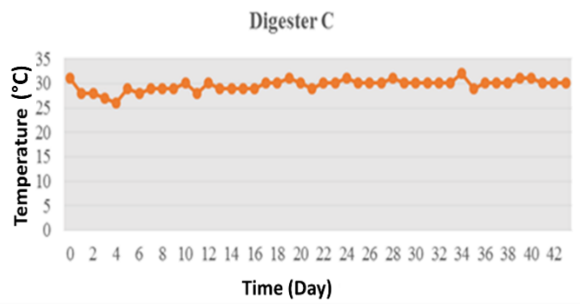

Figure 10. Temperature change in digester C

CONCLUSIONS

The most optimal composition of raw materials ratio is 70% leachate and 30% cattle rumen fluid with the total volume of gas produced which is equal to 2780.21 ml for 6 weeks, producing a flame at the 3rd week with blue color flame quality. Variation of leachate mixture with cattle rumen fluid affects the volume of biogas, pH, temperature, solid volatile and flame test.

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