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OPTIMIZING THE VOLUME OF STARTER AND THE TIME OF FERMENTATION IN THE PRODUCTION OF BIOGAS FROM VEGETABLE WASTES WITH MAXIMUM CONTENT OF METHANE GAS

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ABSTRACT

National energy deposit is only available for the next 23 years. This matter is getting worse with the availability of annual waste production as the impact of rapid rate of population which is around 1.49 % per year. To cope with both matters, waste can be utilized as energy resources through fermentation technology. The urban waste dominated by organic waste like vegetable is potentially produce able to be biogas. The worst utilization of natural starter and the time spent for fermentation are among the existing obstacles to develop energy resources in urban areas. For this purpose, research was carried out to optimize ratio of urban waste, feces and water combined with the time for fermentation. The research employed experimental method with completely randomized design (CRD) of two—factor pattern. The factors are ratio of waste, feces, water and the time for fermentation that consists of 3, 6, 9, 12, 15, 18, 21, 24, and 27 days. The research indicated that optimum proportion to produce maximum biogas volume is 500: 200: 300 for waste, feces, and water respectively. Additionally, three-day fermentation produced the highest volume of biogas.

Key Words: Optimization, Starter, Fermentation, Vegetable waste, Biogas, Methane

INTRODUCTION

The rapid rate of population growth all over the world affected the increase of fossil fuel use. Consequently, this leads to the decrease of global energy resource deposit. Indonesian population growth rate which achieves 1. 49% per year is one of causal factors why fossil fuel resource deposit decreases. According to Prasetyo (2010), national deposit of fossil fuel will be only available for next 23 years. One of government efforts to cut its dependence on fossil fuel is by issuing the regulation of Indonesia Republic President No. 5 year 2006 on National Energy Policy. The policy stresses on the development and utilization of alternative energy resource as substitute energy for oil fuel (General Directorate of PPHP, 2010). In addition to this, the rapid rate of population is correlated with the increasing amount of waste. Up to the present, urban waste is still considered complicated problem in the country. Urban waste dominated by organic waste from vegetable for example provides us with the opportunity to cope with the scarcity of energy resource. Through fermentation technology, along with the help of methane bacteria from natural starter such as the feces of ox, the vegetable waste is convertable to produce biogas However, in its development, the process of fermentation has not been fully carried out due to the lack of natural starter. Besides, the optimum time for fermentation to optimally produce biogas is not intensively noticed yet. Whereas, it is closely interwoven with the effectiveness and efficiency of effort and finance. The best solution to cope with the obstacles is optimizing starter volume through dilution and the time of fermentation to produce maximum methane gas.

REVIEW OF LITERATURE

Waste generates some problems in urban area. It creates natural and environmental damage which, in turn, negatively effect on the society. The problem of waste happens due to annual growth of population, the lack of infrastructure, the development of urban area, insufficient human resource, poor managerial system of waste processing, the limited area to discard waste, the absence of environmental education in the society, especially on the waste, and the lack of understanding on the part of our society related to the significance of maintaining environment (Basuki *et al.*, 2007).

Utilizing waste is a strategic way to train society how to use an alternative energy. Developing an alternative energy in the condition where oil fuel deposit decreases and the price of oil fuel goes up is a beneficial tride (Nisandi., 2007). It is in line with the theory of reuseu, reduse, and recycle on which we are able to recycle useless waste to become something benificial. The implementation of 3R system (reuse, reduce and recycle) is one of the solutions to overcome accumulated waste problems. Reuse means to recycle usefull waste for its same or distinct advantage. Reduce means to decrease all things resulting in waste. Recycle means to reproduce waste to become other advantageous product (Alamendah., 2010).

The organic waste such as vegetable, livestock, and sugar cane waste is excessively available at traditional markets. In general, the organic waste is not fully utilized, and tend to be neglected by our society so as to accumulate and to decay, so that it can disturb people‘s sight and destroy our environment. One of best solutions to cope with organic waste which can be potentially developed in the country is applying anerobic technology to produce biogas (Setiadji., 2009).

Naturally, biogas is excessively availabe at the rice field and swamp. It is produced by anaerobic methanogonic bacteria (bacteria producing methane gas that only lives at place with free condition of oxygen) from the process of reorganizing organic materials. Biogas consists of various gases dominated by methane gas (55-75%) and carbondioxide (25-45%). Biogas has sufficiently high caloric value that is 6000 watt per hour (equal to a half liter of diesel oil), so that it can be utilized as alternative energy resource for the society (KLH., 2010).

Biogas is alternative energy resource which is secure and renewable in nature. It can be burnt like LPG and utilized as generating energy resource of electricity, biogas petromax, heaterroom or hatchery and so on (General Directorate of PPHP., 2010). Scientifically, biogas produced from organic waste is flammable gas (Setiadji., 2009).

Suyitno. (2010) states that to accelerate production of biogas in anaerobe fermenation, starter is required since to produce biogas, bacteria colony producing methane is needed. The raw material of starter containing many bacteria that producemethane is feces of ox; since bacteria producing methane is naturally available in the gastron of ox. A large amount of organic waste as raw material of biogas is available in urban areas primarily in big cities. Nowadays, to get waste of "ruminansia" is quite difficult considering the lack of livestock business in urban areas. Hence, materials containing culture of methane bacteria are required to gain starter. Among of other things can be obtained from liquid in the biodigester which has previously existed such as that at Griya Taman Lestari Housing, Tanjungsari, Sumedang. The liquid of biodigester trustingly contains methane bacteria, because substratum and bacteria are allied in the liquid. To be efficient, the use of starter liquid requires mixturing with water considering a large number of starters needed. It is expected that water becomes good media to accelerate the process of anaerobic fermentation (Personal Communication, 2010).

Waste is undesirable residual materials after the end of process (Writing Team of PS., 2008). The kinds of waste consist of organic, unorganic, and B3 waste (poisonous and dangerous material) (Sinaga, 2009).

Waste is life consequence frequently leading to the problem. Its amount will go up along with the increase of human population and his activities. The more human population increases, the more the amount of waste rises and the more human has his various activities, the more various kinds of waste will be. Therefore, waste must be effectively seen as resouces. It means that the habit to discard waste must be altered to process it. The concept that can be implemented to process waste is 4R. They are:

1. Reduce: to reduce the use of product bringing about waste.
2. Reuse: to recycle, to sell or to donate the useful goods.
3. Recycle: to modify useless goods to be useful
4. Recovery: to take advantage of useful materials (Anonym., 2003).

According to Hadiwiyoto (1983) in Yulistiawati (2008), waste handling can be carried out by recycling it to be useful goods. For instance, vegetable and homogeneous organic waste can be recycled to be primary material for anaerobe fermentation in order to yield biogas as alternative fuel.

Biogas is combination of gases from the process of anaerobe fermentation from ox waste. The compound gases produced are CH_4 (methane), CO_2 (carbondioxide), N_2 (nitrogen) and so on. The methane gas can produce energy which can be utilized to fulfill household need such as cooking (Maarif and Arif, 2007).

The process of biogas production from anaerobe fermentation process can be divided into three stages. The first is hydraulic phase. On this phase, biomass containing cellulose, hemicelluloses, and extractive materials such as protein, carbohydrate, and lipids will be splitted to be compound with shorter chain. The second is acidizing process. On this stage, bacteria will produce acid serving to alter short compound as result of hydrolysis process to be acetate acid, H_2 and CO_2. These bacteria are anaerobe bacteria that can grow at acid condition. To produce acetate acid, the bacteria require oxygen and carbon gained from oxygen dissolved in the solution. In addition to that, the bacteria also alter compound with low molecule values to be alcohol, organic acid, amino acid, CO_2, H_2S, and little CH_4 gas. The third is the phase of CH_4 formation in which methanogenesis bacteria take the major role. The bacteria will form CH_4 and CO_2 from H_2, CO_2, and acetate acid produced in the acidizing phase (Suyitno., 2010).

Methane (CH_4) is the biggest gas component from various gases produced by particular bacteria when fermented organic materials such as animal, organic waste and so on is soaked in water with anaerobe condition. Methane gas is always naturally formed as it happened to vegetable wastes. However, it needs starter and specific condition to accelerate the gas formation, because environment provides great influence on microorganism growth rate in the process of anaerobe fermentation (Maarif and Arif, 2007).

In the process of anaerobe fermentation, the concentration of substratum can affect the work of microorganism. The optimum condition can be achieved if the number of microorganisms is equal to substratum concentration. The content of water in the substratum and homogeneity of organic waste also influences the work of microorganism. Besides, the time of fermentation also really affects the work of microorganism. The longer the time is, the higher the activity of microorganism to utilize substratum is, so that it influences the result of fermentation. Water is carbon and oxygen solvent that enables microbe to grow on substratum solution. Meanwhile, the homogeneity of waste can accelerate the process of disentanglement in fermentation, because the contact between microorganism and substratum is so intense that microbe can easily work to disentangle organic materials (Anonym., 2003).

Microorganism required in the process of fermentation to produce biogas is a type of methane bacteria. These bacteria are excessively available on feces of ox. Because the feces of ox generally contains 30% organic material, it consists of organic compound such as carbohydrate, protein, fat, vitamin, nucleate acid, and organic acid that can be easily decomposed by microorganism like methane bacteria (Mc Donald et.al. and 1989 in Rizki Ananda., 2006). In addition to this, because there is gland on the gastro of ox, on omasum, which produces enzyme that will mix with bolus (food which mostly consists of fiber), bolus will be proceeded to abomasums, the real abdomen.

And here bolus gets digested chemically by enzyme. Cellulose enzyme produced by the bacteria not only serves to digest cellulose become fat acid but also to be able to produce biogas in the form of CH_4 which can be used as alternative energy resource. It is possible that bacteria in scum will come out from the body of organism along with feces, so that organic material contained in the feces will be disentangled and CH_4 will be released (Anonym., 2003).

RESEARCH METHODOLOGY

The materials used in this research are feces of ox, vegetable waste, clean water, and aquades. Moreover, the tools used are plastic bottles with the size of 1500 ml, hose with the diameter of 2 mm, tube with the size of 54 X 93 X 43 cm^3, water circulator, thermometer, super adhesive, analytical scale, stirring rod, calibrated breaker with the volume of 500 ml, Vaseline, bottle cap from rubber, PH meter, and syringe with the size of 1 ml.

The research used experimental method with completely randomized design (CRD) of two—factor patterns that consist of the treatment of feces and water proportion for the first factor and the time of fermentation for the second factor. The treatment of feces and water proportion consists of five treatments. They are:

T0 = 500 g waste + 0 + 500 water mL (control)
T1 = 500 g waste + 100 g feces + 400 mL water
T2 = 500 g waste + 200 g feces + 300 mL water
T3 = 500 g waste + 300 g feces + 200 mL water
T4 = 500 g waste + 400 g feces + 100 mL water
T5 = 500 g waste + 500 g feces

Meanwhile, the time spent for fermentation consists of 3, 6, 9, 12, 15, 18, 21, 24, and 27 days. The research used 162 trial units consisting of first—six—factor treatment, second—nine—factor treatment with three times of trial. Here the combination of treatment used is:

Observation barometer of the research is the amount (volume) produced. Meanwhile, pH of each treatment sample was measured. The data gained, then was statistically examined by Analysis of Variance (ANOVA). When the influence of treatment happened to the observed variable, the analysis was proceeded by Duncan's double continual test on 5% degree using SPSS computer program version 12.0. To know correlation between pH and biogas volume gained, the data of pH was examined with correlation test.

Table-3.1. General Concept of Trial Design

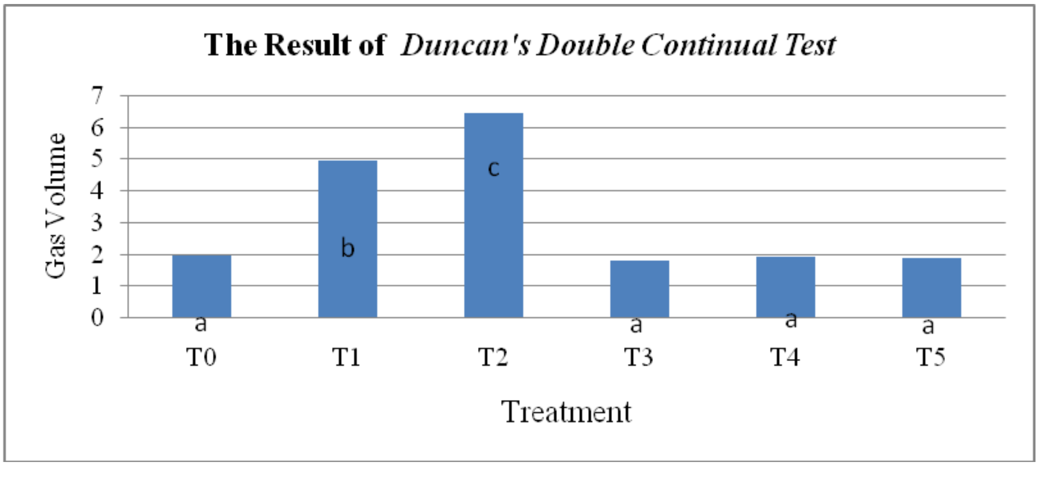
The Time of Fermentation (Day)	Treatment					
	T_0	T_1	T_2	T_3	T_4	T_5
3	T_{03}	T_{13}	T_{23}	T_{33}	T_{43}	T_{53}
6	T_{06}	T_{16}	T_{26}	T_{36}	T_{46}	T_{56}
9	T_{09}	T_{19}	T_{29}	T_{39}	T_{49}	T_{59}
12	T_{012}	T_{112}	T_{212}	T_{312}	T_{412}	T_{512}
15	T_{015}	T_{115}	T_{215}	T_{315}	T_{415}	T_{515}
18	T_{018}	T_{118}	T_{218}	T_{318}	T_{418}	T_{518}
21	T_{01}	T_{121}	T_{221}	T_{321}	T_{421}	T_{521}
24	T_{024}	T_{124}	T_{224}	T_{324}	T_{424}	T_{524}
27	T_{027}	T_{127}	T_{227}	T_{327}	T_{427}	T_{527}

RESULT AND DISCUSSION

The result of testing variant of dilution and the time of fermentation on 5% testing degree indicates that dilution and the time of fermentation are obviously influential on gas volume produced ($P<0.05$). However, it hasn't been the case with the interaction between dilution and the time of fermentation. Based on testing variant on 5% testing degree, the result is $P>0.05$. It means that there is no interaction between them.

The result of Duncan's continual test is as follows:

Picture-4.1. The Influence of Dilution on Gas Volume



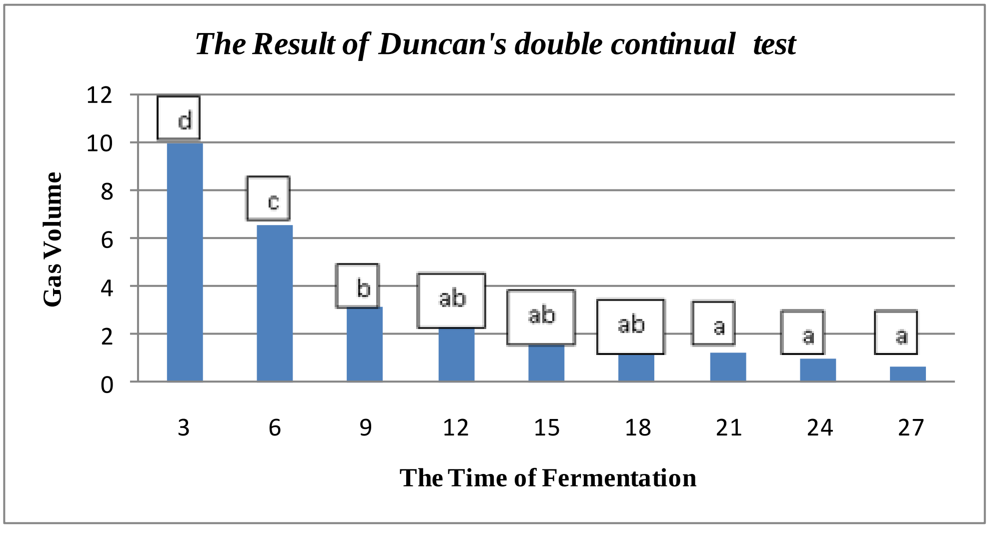
Description:

T0 = 500g waste + 0 (starter) + 500 mL water (control); T1 = 500g waste + 100g feces + 400 mL water; T2 = 500g waste + 200g feces + 300 mL water; T3 = 500g waste + 300g feces + 200 mL water; T4 = 500g waste + 400 g feces + 100 mL water; T5 = 500 g waste + 500 g feces. The picture with different letter indicates the distinction of 5% testing degree.

Duncan's analysis on the treatment of dilution (Picture 4.1) indicated that the treatment of T2 with the composition of 500 g waste + 200 g feces + 300 mL water was the best dilution. The condition happened because the proportion used on the treatment is ideal. The amount of nutrition compared with that of bacteria was on optimum proportion, so that the growth and development of bacteria ran well.

In addition to this, the proportion of water made provides conducive environment for the growth of bacteria. On the converting process from organic acid to be acetate acid, water molecules are required, so that by adding more water, the formation of acetate acid will increase and it eventually will be changed to bimethane gas on the next phase (methanogenesis). The more water is added in the system, the more biogas will be produced (Saputro and Putri, 2010). From the proportion of waste, feces, and water shown on T2, it can be concluded that the proportion of feces (starter) given must be less than that of water. The result of Duncan's continual test for the time of fermentation indicates that the longer the fermentation time is, the less the volume of biogas will be produced. The complete data is as follows:

Picture-4.2. The Influence of the Length of Fermentation toward Gas Volume



Picture 4.2 indicates that the third day was the day which produced the most biogas volume. Based on the assumption, it was because vegetable waste that functioned as nutritious resource had been completely used, so that on the third day biogas could be maximally produced. It results in the longer the fermentation is, the less biogas volume is produced, since vegetable waste that functions as nutritious resource has been completely used (Hikmiyati and Yanie, 2006).

The result of pH measurement to trial unit indicates different pH. In accordance with this, Pearson correlation test was carried out to know the correlation between pH and biogas volume produced. The result of data computation is as follows:

Table-4.1. Pearson Correlation Test

Correlations			
		pH	Gas Volume
pH	Pearson Correlation	1	-.214**
	Sig. (2-tailed)		**.006**
	N	162	162
Gas Volume	Pearson Correlation	-.214**	1
	Sig. (2-tailed)	.006	
	N	162	162
** Correlation is significant at the 0.01 level (2-tailed).			

Based on Table 4.1, there is correlation between pH and biogas volume produced. It is indicated by significance of value which is less than 0.05, and the value of coefficient at Pearson correlation is negative. Negative value indicates that the higher pH is (base), the lower biogas volume will be. The increase of pH will intrude on the development of methane bacteria, so that when pH rises, reorganizer bacteria of acetate acid will grow and develop minimally. And it has consequence to the production of biogas. Anaerobe reorganizing is extremely strong biological process which is affected by environmental factors such as pH.

CONCLUSION AND SUGGESTION

The proportion of 500 g vegetable waste + 200 g feces + 300 mL water results in maximum gas volume. The optimum time spent for fermentation to gain maximum biogas volume is three days. The production of methane gas is affected by the proportion of water and feces. The big proportion of water will result in maximum methane gas. With a limited number of substrata, it is suggested to use short time of fermentation with basic proportion of among substratum: feces: water as much as 5 : 2 : 3. To cope with the problem of waste energy, the utilization of waste is necessarily carried out. To optimize the process of fermentation with maximum production of biogas, optimizing environmental factor must be applied.

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