Effect of Bio-activator Addition and Stirring on Biogas Production from Rice Husks and Cow Dung

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Abstract. Indonesia as the world's third-largest paddy producer generates abundant agricultural wastes. Approximately, 20% of those wastes obtained in the rice milling process are rice husks that have not been fully utilized. Rice husks contain cellulose, hemicellulose, and lignin. Therefore, it can be used as an alternative source of energy. In addition, an increase in the cattle population has increased the waste produced. Disposal of livestock manure, that has not been handled properly, has caused environmental pollution. The abundance of cow dung is an energy potential which is very beneficial for the community. Therefore, rice husk, cow dung, and bio-activator EM-4 were used as the main material in this study. The objectives of this study were to analyze the volume of biogas produced from (1) each composition of rice husk and cow dung, (2) addition of bio-activator EM-4, and (3) the amount of stirring in the digester. The ratio of rice husk and cow dung waste is 70%: 30% with a solid and water ratio of 10%: 90% and 20%:80%. The addition of EM-4 and stirring frequency is made with various composition aimed to accelerate the rate of increase in biogas, which can be used as alternative energy in society.

Keywords: **waste; biogas; rice husk; cow dung; EM-4.**

1 Introduction

Alternative energy is a term that refers to all energy that can replace conventional fuels without unexpected consequences. Generally, this term is used to reduce the use of hydrocarbon fuels which cause environmental damage due to high carbon dioxide emissions, which contribute significantly to global warming. Therefore, we should concern to develop low carbon society to reduce climate change and global warming in the world.

Moreover, various environmental pollution caused by various activities such as industrial, hospitals, agriculture, livestock, transportation, markets and households activities, produces carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), and nitrogen oxides (NO) that are high in the air causing a greenhouse effect and global warming throughout the world. Reduction of waste by these activities can be done by processing it through anaerobic digestion so that the results of the processing no longer pollute the environment.

Global warming will affect global climate conditions and influence on maritime continents. The Indonesian maritime continent is an area that is vulnerable to the impacts of climate change. This is because the territory of Indonesia is located in the tropics between two continents and two oceans. With such a layout, the maritime continent is one of the control centers of the world climate system. Previous research from Lando et al., 2015 [1], Lando et al., 2016 [2] and Lando et al., 2017 [3] showed that methane concentration and emissions, as one of the largest potential greenhouse gases in global warming, from Tamangapa landfill in Makassar city are 12 - 425 ppm for methane concentrations and 2.44 - 18 Gg / year for methane emissions. Methane concentration and emissions of this magnitude can be used to be alternative energy called biogas.

Biogas is one of the high-energy renewable fuels that can be used as a substitute for fossil fuels, one way to develop a low carbon society. Biogas is a mixture of methane and carbon dioxide gas, formed from anaerobic digestion carried out by bacteria without the presence of oxygen. Anaerobic digestion has great benefits for the environment, mainly in producing "green" energy and natural fertilizers that will reduce organic waste in nature. The process of changing from waste to biogas can improve the function of fossil fuels and artificial fertilizers so that it will reduce the production of greenhouse gases in the atmosphere. Sri Wahyuni, 2015 [4] explained that the calorific value of 1 m^3 of biogas is equivalent to 0.6 - 0.8 liters of kerosene. To produce 1 kWh of electricity, it takes 0.62-1 m^3 of biogas which is equivalent to 0.52 liters of diesel oil.

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Various types of waste can be used as biogas raw materials such as plantation waste (e.g. cocoa peels), industrial waste (e.g. waste from the wood, palm oil, and tofu industry), aquatic waste (e.g. water hyacinth), agricultural waste (e.g. straw and rice husks), and livestock waste (e.g. cow manure and chicken manure). These wastes can be used as biogas raw materials both individually and in combination with more than two types of waste [4].

In this study, biogas will be made with various variations of the composition by using rice husk and cow manure as a starter, adding EM-4 as an activator, and the influence of the amount of stirring in the reactor so that the rice husk decomposes faster. This study is entitled "Effect of stirring and addition of EM-4 on biogas production from rice husk waste and cow manure". Utilization of organic waste in biogas production is expected to contribute positively to the environment to reduce waste concerning quantity and quality as the use of alternative energy in the community.

The objectives of this study are: To analyze the biogas volume generated from each (1) composition comparison of rice husk and cow manure and (2) variation of the addition of EM-4 bio-activator. The benefits of this study are to make a positive contribution to the environment by reducing the quantity and quality of waste. It could increase the income of society, and save the use of fossil fuels.

2 Methods

The study method was experimental using a mixture of rice husk waste and other bio-activators. This study aims to analyse the process of biogas production from the addition of EM-4 (Effective Microorganism-4) to cow dung and rice husk, which is given a stirring with certain intensity and duration. In this study also compared the effect of adding EM-4 on cow dung and rice husk waste on the biogas production process. The study was conducted in four stages: (1) the initial preparation, (2) simple digester construction, (3) the experimental, and (4) the biogas analysis stage, as seen in the flowchart in Figure 1.

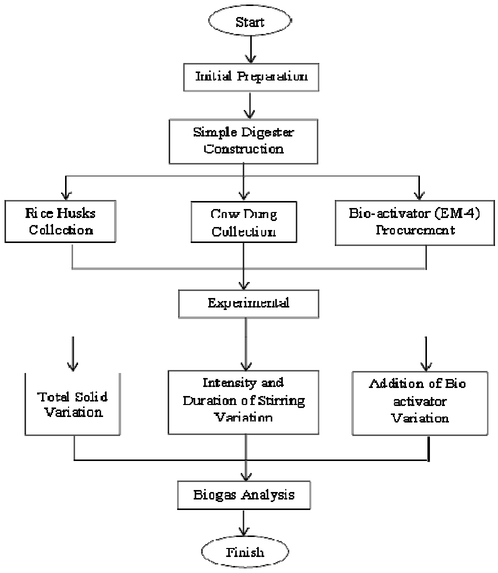

Fig. 1. Study Flowchart

2.1. Simple Digester Construction

Digester (reactor) is a means used in making biogas which functions to maintain humidity and temperature so that microbes can decompose optimally. The materials used in making a digester: 1.5 liter mineral water bottle, 1000 ml measuring cylinder, 1/2 inch hose, digital thermometer, gun glue, funnel, plasticine, rubber, and bucket, as shown in Figure 2.

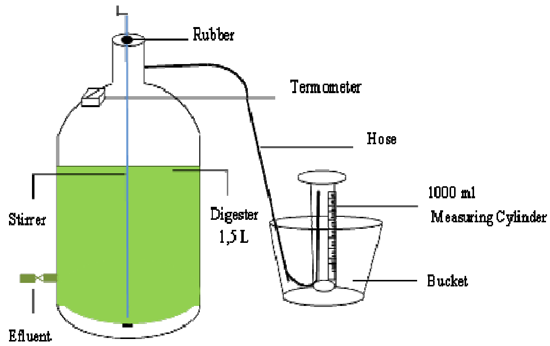

Fig. 2. Biogas Digester Construction

2.2 Experimental methods

After the digester construction was completed, biogas production was carried out with the following steps:

1. The mixture of rice husk that has been chopped with cow dung with a mixture composition was 70%: 30%.
2. Addition of EM-4 bio-activator
3. The dilution was made with the composition of total solids (a mixture of rice husk and cow dung) and the addition of water by 10%:90% and 20%:80%. After dilution of up to 1000 mL, the solution was homogenized by stirring. Then the digester was tightly closed so that the fermentation process occurs.

Normal activity of methane microbes required about 80-90% of water [5].

4. Measurement of pH, biogas volume and temperature
5. Total solid analysis.
6. Stirring was carried out based on predetermined variations in the digester to increase contact between microorganisms and substrates and increase the ability of the bacterial population to absorb nutrients [6].

2.3 Analysis of Decomposition Results (Biogas)

Measurement of temperature, pH, and volume of biogas is carried out each day during the decomposition process until the completion of the fermentation process. As for fermentation, the total solid level is tested in every five days.

This study used descriptive statistical methods, the method by calculating the measured parameters is then presented in the form of tables and graphs. There were three variables in this study, as seen in Table 1: variation in total solid composition, the addition of EM-4 bio-activator, and stirring frequency in each reactor, where RH is Rice Husks and CD is Cow Dung. Furthermore, the data obtained is used as a reference for biogas analysis.

Table 1. Study variables

Total Solid Composition (A)	Without Bio-activator (B)		With Bio-activator (C)	
	Without Stirring (1)	8 times Stirring (2)	Without Stirring (1)	8 times Stirring (2)
10% (1)	**A1B1** 900 ml of water + 1.5 gr of RH + 14 gr of CD	**A1B2** 900 ml of water + 1.5 gr of RH + 14 gr of CD	**A1C1** 900 ml of water + 1.5 gr of RH + 14 gr of CD	**A1C2** 900 ml of water + 1.5 gr of RH + 14 gr of CD
20% (2)	**A2B1** 800 ml of water + 3 gr of RH + 28 gr of CD	**A2B2** 800 ml of water + 3 gr of RH + 28 gr of CD	**A2C1** 800 ml of water + 3 gr of RH + 28 gr of CD	**A2C2** 800 ml of water + 3 gr of RH + 28 gr of CD

3 Results and Discussion

Biogas production experiments are carried out for 20 days according to the duration of the fermentation process which refers to various reactions and interactions that occur between methanogen bacteria and organic matter mixed into the reactor. Biogas will be formed on days 4-5 after the reactor is filled and reaches the peak on 15-20 days. Organic matter mixed with cow dung will accelerate the fermentation process in the reactor, which is only about 13-20 days [4]. Therefore, observation of fermentation time in this study was carried out for 20 days.

3.1 Temperature Condition

Temperatures measured daily during retention times tend to be stable. Based on the measurement of temperature in the mixture, it could be seen in Fig. 3 that the temperature in the reactor fluctuates every day in each composition. Generally, there are three types of microorganisms in the anaerobic degradation process which work in three temperature conditions namely psychrophilic (10-30ºC), mesophilic (25-45ºC) and thermophilic (50-75ºC).

Conventional anaerobic digestion was undertaken at mesophilic temperatures, 35–37°C. However, the thermophilic temperature range could be considered because it will give faster reaction rates, higher gas production, and higher rates of the destruction of pathogens than the mesophilic temperature range. However, the thermophilic process is more sensitive to environmental changes than the mesophilic process [7].

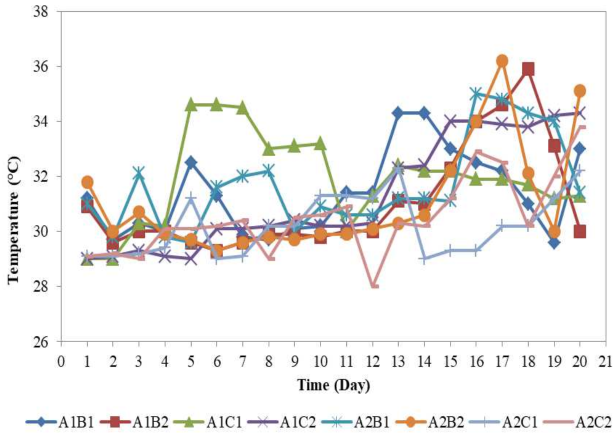

Fig. 3. The Range of Temperature in the Digester

Figure 3 shows the temperature in the digester is classified as low until day 12 with an average of 30.7ºC (mesophilic condition). It caused by the influence of temperature from outside, especially at night or rain conditions where the room temperature can reach 24 ± 1ºC. However, on day 13 until 20, the temperature is mesophilic (30-40ºC). The increase in temperature shows that at this stage microorganisms begin to multiply rapidly and the process of organic material decomposition by microorganisms. The highest temperature is in the digester A2C1, followed by the digester A2B1 at 35.9ºC. Therefore, only mesophilic bacteria work on all digesters. According to [4], temperatures between 25-35ºC could be optimum to support biological reaction rates. Moreover, based on [8], a temperature of 35ºC (mesophilic) can increase CH_4 production by 51-61% which was initially operated at 25ºC.

3.2 Degree of Acidity (pH) Condition

The degree of acidity (pH) has an essential role in the process of methane gas production. Biogas production can be optimally achieved if the pH value of the input mixture in the digester is in the range of 6-7. In this study, pH is also a function of time in the digester. Moreover, the pH value is an important indicator to determine the stability and activity of acidogenic and methanogenic microorganisms.

Figure 4 shows pH values in the methanogenesis process are in the range of 5.6 - 7. It could be seen that the composition with bio-activator addition and stirred eight times (A1B2, A1C2, A2B2, and A2C2) in the anaerobic digester process have different pH conditions, tend to higher than others.

In the A2C1 reactor on days 10-15, there was a decrease in pH of 5.6. A reduction in pH can be caused by a very low pH of a substrate that is dominated by organic waste which is ± 5.0. The formation of organic acids accumulated due to the reaction of high organic content and the quantity of acidogen and acetogen microorganisms exceeds the number of methanogen microorganisms. The low pH value at the beginning of the digester operation causes the activity of acidogen bacteria to increase and produce several types of inhibitors. The inhibitor can interfere with the balance of the microorganism population and result in inhibition of the metabolism of microorganisms to decompose organic solids.

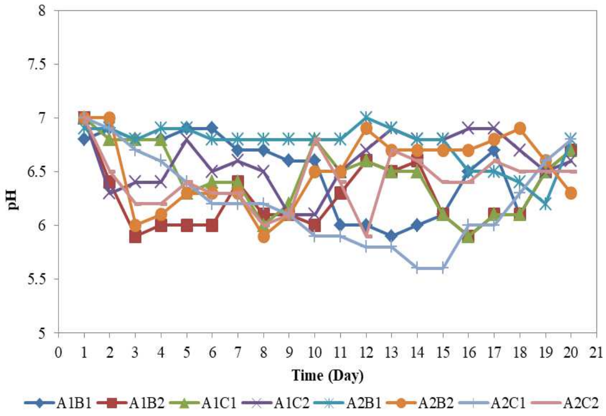

Fig. 4. The Range of pH in the Digester

3.3 Biogas Production

Anaerobic degradation process involves many different bacteria, but the process is driven mainly by two types of reactions namely acidogenesis and methanogenesis. In the first stage of acidogenic, organic matter is broken down into Volatile Fatty Acid (VFA), then metabolized to methane in the next stage by methanogenic bacteria to produce methane (biogas).

Each reactor measured its biogas volume every day, at the same time. This measurement keeps the biogas volume data obtained from biogas production every day. Figure 5 illustrates the production of biogas produced by eight digesters.

On the first day, biogas production has not occurred because of hydrolysis. At this stage, the bacteria decompose the dissolved organic matter, and the digestion of complex organic matter becomes simple and changes the structure of polymer forms (glucose, fat, and protein) into monomeric forms (fatty acids, monosaccharides, amino acids), so as not to form biogas.

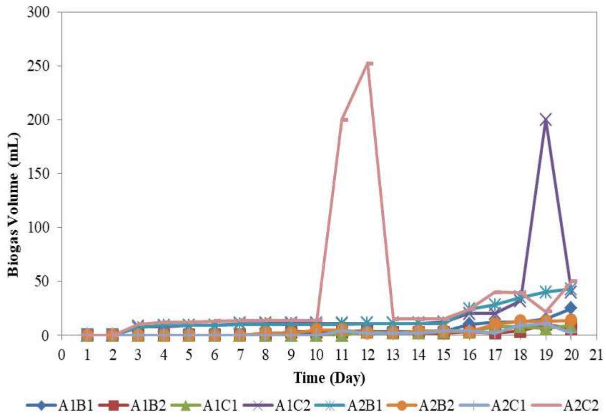

Fig. 5. Biogas Production in the Digester

After that, there is a process of acidification by acid-forming bacteria using the substrate produced by hydrolysis to produce acetic acid, hydrogen, and carbon dioxide.

Generally, biogas production on day 5 to day 12 shows that until the 12th day the biogas produced still contains CO_2 and H_2. After day 12, it gradually decreases until day 15. On day 15 this is the stage of methanogenesis or the step of making methane (CH_4) begins to occur. This stage occurs from day 15 to day 20 by producing the main biogas component continuously. However, in the digester A2C2, biogas production started in day 10 until 12, then decrease at day 13. This reduction is probably due to the addition of bio-activator, eight times stirring, and total solid 20%.

Lignocellulose degradation naturally runs slowly and can only be done by a few microorganisms due to its complex and heterogeneous constituent polymer structures. Lignocellulose degradation involves the activity of some extracellular enzymes secreted by microorganisms.

3.4 The Effect of Bio-activator Addition and Cumulative Volume of Biogas Production

The addition of EM-4 as a bio-activator in the anaerobic digester process is expected to increase the activity of microorganisms to decompose organic matter. In this study, optimization of anaerobic degradation process is accelerated biologically. Biological treatments are carried out using enzymes secreted by bio-activator. Natural bio-activator is obtained from cow dung while artificial bio-activator is Effective Microorganism-4 (EM-4). The EM-4 solution contains a large number of fermented microorganisms, about 80 types and microorganisms can work effectively in the fermentation of organic matter. In Figure 6, it can be seen the cumulative biogas in the digester.

Figure 6 shows the cumulative volume of biogas production in a total solid of 10% for 20 days was at an A1C2 reactor of 446 mL and for total solid of 20% for 20 days was in the A2C2 reactor of 775 mL.

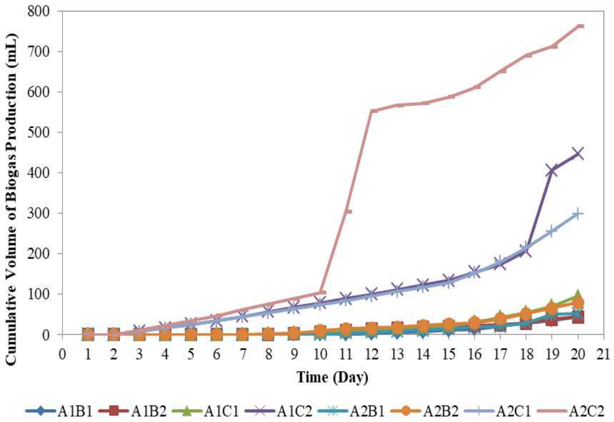

Fig. 6. Cumulative Volume of Biogas Production in the Digester

Overall, the reactor with a stirring frequency of eight times with a total solid of 20% and the addition of EM-4 produces the highest volume of biogas.

The effect of adding EM-4 to biogas production is found in the digester with a total solid of 20% with stirring eight times. Digestion microorganisms contained in EM-4 can produce biogas. This is because EM-4 includes Rhodopseudomonas spp, Lactobacillus spp, Saccharomyces spp, which can balance the acid content contained in rice husk waste and process it into biogas.

3.5 Biogas Production with Stirring Frequency

To determine the effect of variations in stirring frequency on biogas production, a comparison between reactors is needed. The best reactor with a total solid treatment of 10% is in the A1C2 reactor of 446 mL, and for a total solid of 20%, there is an A2C2 reactor of 775 mL.

The best stirring frequency in biogas production is in the reactor with stirring eight times/day for five minutes and with the addition of EM-4 at a total solid of 20%. In line with the research conducted by [5], the variation of stirring frequency resulted in the most biogas production. Reactors with a stirring frequency of eight times could assist the fermentation process to be evenly distributed, the homogeneous condition of the substrate, reduction of maximum degradation on the substrate, and avoiding semi-solids and foam on the surface of the material in the digester.

If the substrate is not stirred, it will separate between solids and water. The weight of lighter solids due to degradation will be on the surface of the slurry in the reactor. When stirring, the particle size of the substrate becomes very small and uniform. It indicates that the stirring frequency makes the fermentation process always uniform, degradation is faster, and the biogas is easier to get out of the material. Also, by mixing the inoculum contact with the substrate more intensively so that the inoculum works more optimally.

4 Conclusions

Based on the study result, it can be concluded that:

1. The addition of EM-4 bio-activator is very influential on biogas production
2. The highest biogas formation with a total solid of 10% EM-4 bioactivator was found in the A1C2 reactor with a stirring frequency of eight times/day for five minutes at 446 mL.
3. The highest biogas formation with a total solid of 20% with the addition of EM-4 found in the A2C2 reactor with a stirring frequency of eight times/day for five minutes at 775 mL
4. The stirring frequency eight times/day for five minutes can increase biogas production.
5. Total solid levels affect biogas production. The reactor with a total solid content of 20% produces biogas four times greater than the total solid 10%.

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