Indonesian Journal of Microbiology Vol: 1, No 1, 2024, Page: 1-12

Analysis of Anaerobic Digestion Installation Testing for Tofu Liquid Waste Utilization into Biogas with the Addition of Cow Manure Variations

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DOI:
https://doi.org/10.47134/ijm.v1i1.2472
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Received: 01-02-2024
Accepted: 15-03-2024
Published: 30-04-2024

Abstract: The purpose of this study is to convert tofu wastewater into biogas using an anaerobic digester with varying cow dung mixtures (10%, 15%, and 20%). The study method entails creating digesters including independent, dependent, and controlled variables. Variations in pH, temperature, biogas pressure, and biogas volume were detected throughout the course of a 15-day fermentation. The data show that in the 10% fluctuation, the greatest pH was on day 7 (7), whereas the highest temperature was 32°C on days 6 and 7. Biogas pressure emerged on day 6 (89.2 cmHg), resulting in a volume of 90 liters by day 15. In the 15% variation, the highest pH (7.2) occurred on day 8, with the highest temperature (34°C) on days 9 and 10. Biogas pressure began on day 5 (89.9 cmHg), with a biogas volume of 95 liters on day 15. The 20% variance resulted in the highest pH (7.4) on day 8 and the highest temperature of 35°C from days 9-11. Biogas pressure began on day 5 (90.7 cmHg), resulting in a biogas volume of 100 liters on day 15. This study sheds light on how to manage tofu waste into biogas with varying degrees of effectiveness and efficiency.

Keywords: Biogas, Anaerobic Digester, Tofu Liquid Waste

Introduction

Currently, the process of making tofu and tempeh is still done in a traditional way and mostly uses human labor. The main raw material for making tofu and tempeh is soybean. In 1995, Indonesia consumed up to 2,287,317 tons of soybeans (Budiarto, 2005). Boljanovic (2004) also estimated that in Indonesia, especially on the island of Java, the number of tofu and tempeh entrepreneurs is around 10,000 entrepreneurs, most of which are still household scale, as a comparison in Japan around 38,000, in China 158,000, in Taiwan 2,500, in Korea 1,470 (Osman, 2022; Karki, 2021; Kumar, 2021; Nguyen, 2021; Zamri, 2021).

In the process of making tofu, the use of water is very much as a washing material and boiling soybeans. As a result of the large amount of water used for the tofu and tempeh making process, there will also be a lot of waste generated. For example, the tofu and tempeh industry in Semanan, West Jakarta contained BOD5 reaching 1,324 mg/l, COD 6698 mg/l, NH4 84.4 mg/l, nitrate 1.76 mg/l, and nitrite 0.17 mg/l (Joseph, 1992). When viewed from the wastewater quality standards for tofu and tempeh processing businesses or processes according to the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards, the maximum allowable levels of BOD5, COD, and TSS are 150 mg/l, 300 mg/l, 200 mg/l with PH 6-9, respectively. Most of the tofu liquid waste is directly disposed of without prior treatment. It is very unfortunate, tofu liquid waste contains more than 50% Methane (CH4), so it is very possible to be used as biogas (Farid, 2013).

In the current technological era, the increasing demand for fossil fuels has resulted in global warming and the greenhouse effect (Prasetyo, 2007). Therefore, there is a need for renewable energy, one of which is biogas. Biogas is a gas formed due to the anaerobic process or fermentation of organic compounds by anaerobic microorganisms (Du, 2021; Jin, 2021; L. N. Nguyen, 2021; Pan, 2021; W. Zhao, 2021). To be able to produce biogas energy, an anaerobic digestion method can be used. This method utilizes many types of microbes that can convert biomass and waste by degrading organic material without the use of oxygen and the help of bacteria (Abbas, 2021; Cremonez, 2021; Liu, 2021; J. Zhao, 2021; Sari, 2014).

Research entitled "Tofu Liquid Waste Processing as an Environmentally Friendly Alternative Biogas Energy" which has been conducted by (M. Wang, 2021; R. Wang, 2021; Sofwan, 2011). In this study, tofu liquid waste was processed using anaerobic methods and using anaerobic reactors. Where the tofu liquid waste is fermented in the reactor tube in the absence of oxygen. The conclusion of this study is the processing of 90 liters of tofu liquid waste obtained biogas results as much as 82.04 liters of biogas. To produce biogas according to the test, it takes 28 days. In this study it is known that the reactor must be given a stirrer so that the waste can still be decomposed. There has been a lot of research on the design of liquid waste processing equipment.

Sutigno (1994) in his research on the design of a biogas conversion tool for tempeh liquid waste and testing with the addition of a variety of rice husk mixtures, this study concluded that the highest amount of biogas calorific value was produced from a variety of rice husk mixtures. In this study, there were obstacles, namely the need for a larger reactor tube capacity of more than 120 liters, and the need for an automatic stirring system in the reactor tube. Theryo (2009) in his research on optimizing the design of tofu liquid waste processing equipment technology. In this study concluded about the existence of several stages of filtration so that tofu liquid waste can meet the quality standards of liquid waste and can then be discharged into the environment.

Based on observation data, several shortcomings were found for the tofu liquid waste treatment system, namely the inaccurate choice of starter material to accelerate the fermentation of tofu liquid waste so that the fermentation time is relatively long. There is no automatic stirring system in the reactor tube so that the tofu liquid waste will be difficult to decompose. Therefore, it is necessary to develop a tofu liquid waste processing tool to be more efficient and appropriate. By looking at the shortcomings above, this research chose the theme "Design of Anaerobic Digestion Installation for Utilization of Tofu Liquid Waste into Biogas" with the hope that this research can reduce environmental pollution and can produce alternative biogas energy by utilizing tofu liquid waste.

Methodology

In planning the design of the tofu liquid waste processing plant into biogas must determine the design concept of the tool to be the basis of thought in the process there is a sequence of work processes, namely determining the design, then selecting components and also calculating the dimensions of the components.

Based on the design concept that has been prepared and refers to previously existing references, the design that the author proposes for the design of the tofu liquid waste processing plant design into biogas must be efficient and function properly for the process of processing tofu liquid waste into biogas, the author uses the following design.

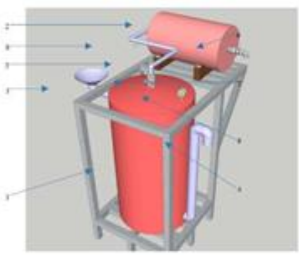

Figure 1. Digester Design

Picture Description:
1. Fermentation Tube
2. Gas Storage Tube
3. Inlet Pipe
4. Outlet Pipe
5. Gas Inlet Pipe
6. Outlet Gas Pipe
7. Valve
8. Manomater
9. Pitot Tube

The planning of digester components is based on the selected design that meets the concept selection criteria. At this stage, product design and development will be carried out including the application of design concepts, material selection processes, and product assembly. This is done to determine whether the design concept is in accordance with expectations. The components of the tofu liquid waste processing installation into biogas that need to be planned include.

a. Polyethylene tube material
b. Pitot tube
c. PVC pipe
d. ST 42 steel
e. Valve
f. PVC glue
g. Manometer
h. Seal tape

The manufacture or assembly of tools is carried out at the Mechanical Engineering Laboratory, Faculty of Science and Technology, University of Muhammadiyah Sidoarjo. The tools needed in assembling the tofu waste liquid processing installation into biogas include:

a. Welding
b. Wrench
c. Hand Grinders
d. Pliers
e. Hand Drill
f. Hammer
g. Saw

A. Research Variables

Research variables are anything that has been determined by the researcher in any form that has a purpose so that it is studied to obtain information about it and conclusions can be drawn. All of these are conditions that have been controlled, manipulated, and observed by researchers in their research.

Research variables can be divided into 5 according to their nature. One of them is the relationship between variables. The relationship between these variables consists of 3 types, namely independent variables, dependent variables, and controlled variables.

B. Independent Variable

This variable has an influence or can cause changes in other variables. So it can be stated that changing this variable is assumed to make other variables change.

In this study, the independent variable that will be used is the composition of the material. Testing of this research there are variations in the composition of mixed materials for fermentation of tofu liquid waste using cow dung with a mixture variation of 10%, 15%, and 20% by weight of the material to the overall weight of the tofu liquid waste.

C. Bound Variable

The dependent variable is a variable that exists or is formed due to the existence of an independent variable. It can be called a dependent variable because its variation or condition is influenced and bound to variations in other variables.

The dependent variables contained in this study include the following:

1. Calorific value

The variation in calorific value formed is due to the variation in the weight of the composition of the fermentation mixture. Calorific value testing in this study was carried out by boiling water with a capacity of 1.5 liters with a certain time.

2. Efficiency

The percentage of calorific value that has been produced in this study against the standard calorific value that has been set.

D. Controlled Variable

Controlled variables are variables whose influence is controlled and limited so that they cannot affect the symptoms being studied, it can also be stated that the impact of the independent variable on the dependent variable cannot be influenced by external factors that are not studied.

Testing in this study, the fermentation time of several variations in the composition of mixed materials is limited to 15 days.

Result and Discussion

During the fermentation process, the pH measurement results were obtained with changes that were not too significant. It can be seen in Figure 1 that there are differences in pH values in each variation of mixed materials. This is due to the quantity of the mixed ingredients.

During the pH measurement process with an intensity of 2 times a day for 15 days, namely at 06.00 WIB and 16.00 WIB, it can be seen that in the 10% variation of the mixed material, the highest pH value was obtained on day 7, namely with a pH value of 7 and decreased on day 14, which was 6.8. For the 15% mixed material variation, the highest pH value was obtained on day 8 with a pH value of 7.2 and the lowest pH value of 6.9 was obtained on day 15. While in the variation of 20% mixed material, the highest pH value was obtained on the 7th and 8th day which amounted to 7.4 and decreased on the 13th day by 7. To produce methane gas, the optimal pH value ranges from 7.0-7.2 but the pH value in the range of 6.6-6.7 gas can still be produced (Wiraatmadja, 1995).

A. Digester Temperature Measurement

The temperature measurement process in this study was carried out using a lab thermometer by taking the lowest liquid through the outlet pipe. Temperature measurements on each variant of mixed materials were carried out twice a day at 06.00 WIB and 16.00 WIB for 15 days. Changes in temperature during the fermentation process in each variation of mixed materials experienced small changes.

Based on the graph above, the highest temperature obtained in the 10% mixed material variation was 32oC on days 6 and 7. The lowest temperature is obtained on the 3rd day which is 28oC. In the 15% variation of mixed materials, the highest temperature was 34oC obtained on the 9th and 10th day of measurement. The lowest temperature was obtained on day 2, which was 28oC. As for the 20% variation of the mixture, the highest temperature was obtained on day 9 to day 11, which amounted to 35oC and the lowest temperature was obtained on days 2 and 3, which amounted to 29oC.

Temperature affects the process of methane gas formation. As stated by Monnet (2003) that anaerobic processes can occur in two temperature range conditions, namely mesopilic conditions, the temperature is in the range of 20-45oC, and thermopilic conditions, the temperature is in the range of 50-65oC.

B. Biogas Pressure Measurement

In this study, biogas pressure measurements were made by observing changes in water pressure in an open manometer hose. This measurement is carried out to determine when biogas begins to form and to determine the amount of biogas volume.

During the fermentation process, the biogas pressure increased significantly. Measurement of biogas pressure was carried out twice a day at 06.00 WIB and 16.00 WIB for 15 days.

It can be seen in Figure 3 above, in the 10% variation of mixed materials, biogas pressure began to appear on the 6th day with an amount of 76.02 cmHg and continued to grow until the 15th day of measurement with an amount of 89.2 cmHg. Then in the 15% variation of mixed materials, biogas pressure began to appear on the 5th day with an amount of 76.04 cmHg and continued to increase until the 15th day measurement of 89.9 cmHg. While in the variation of 20% mixed material, biogas pressure began to appear on the 5th day with an amount of 76.07 cmHg and continued to rise to 90.7 cmHg on the 15th day of measurement.

Calculation to determine the value of pressure in (cmHg) on an open manometer (water fluid). The data used as an example is the result of measuring the pressure of biogas variation of 10% mixed material on the 8th day. In the measurement results, the height difference on the open manometer scale is 16 cm. So that the pressure value can be determined by the following calculation.

$\rho_{air} = 1000 \frac{kg}{m^3}$

$g \quad = 9{,}8 \frac{m}{s^2}$

$h = 16cm = 0{,}16m$

$1Atm = 101.325\ Pa = 760\ mmHg$

$$P_{gauge} = \rho \cdot g \cdot h$$
$$P_{gauge} = 1000 \frac{kg}{m^3} \cdot 9{,}8 \frac{m}{s^2} \cdot 0{,}16\ m$$
$$P_{gauge} = 1568 \frac{kg}{m.sec^2}$$
$$P_{gauge} = 1568\ Pa$$

$$P_{gas} = P_{Atm} + P_{gauge}$$
$$P_{gas} = 101325\ Pa\ + 1568\ Pa$$
$$P_{gas} = 102893\ Pa$$

Tekanan gas dalam cmHg.

$$\frac{102893\ Pa}{1} \times \frac{760\ mmHg}{101325\ Pa}$$
$$= 771{,}76\ mmHg$$
$$= 77{,}18\ cmHg$$

C. Measurement of Biogas Volume

Measurement of biogas volume is carried out using a 50ml disposable syringe. As shown in Figure 4.18 below, the measurement of biogas volume is carried out by connecting the biogas outlet valve with a 50ml disposable syringe and then observing the open manometer scale.

In this study, it was found that the scale on the open manometer dropped by 1mm when the biogas flowed into the disposable syringe with a scale on the disposable syringe of 50ml. So, it can be interpreted that every change in the scale on the open manometer by 1mm, a biogas volume of 50ml will be obtained.

After fermentation for 15 days, differences in biogas volume were obtained in each variation of mixed materials. In the 10% variation of mixed materials, a volume of 90 liters was obtained. In the 15% variation of mixed materials, on the 15th day, a volume of 95 liters was obtained, while in the 20% mixed material variation, a biogas volume of 100 liters was obtained.

D. Flame Test

In this study, the flame test was intended to determine whether or not the biogas formed in the fermentation process for 15 days.

Figure 1. Biogas flame test

As in Figure 1, the flame test was carried out by striking a match to the biogas outlet valve and carried out using a biogas stove. It can be seen that the flame produced by biogas can be blue. As stated by R.R. Vienna Sona and Djoko Sungkono (2012), high and stable fire temperature is a flame with a blue color. This also indicates that the fermentation process of tofu liquid waste with variation materials in the form of cow dung can process perfectly.

E. Calorific Value Comparison

In this study, the comparison of calorific value is done by comparing the calorific value obtained during the testing process of 3 variations of mixed materials. The test was carried out by boiling 0.5 liters of water with a time limit of 5 minutes. In this experiment, there was no difference in calorific value between each variation of mixed materials.

Figure 2. Measurement of water temperature after boiling with fire from biogas

Calculation of calorific value is obtained by boiling water that has an initial temperature of 28oC heated by using a biogas stove on a medium fire setting for 5 minutes, and obtained a final temperature of 60oC. From the data obtained, the calorific value of biogas can be determined with the following calculation.

It is known:

$m = 0{,}5\ kg$ $\quad$ $Q = m \cdot c \cdot \Delta T$

$c = 4200 \frac{J}{kg^oC}$ $\quad$ $Q = 0{,}5\ kg \cdot 4200 \frac{J}{kg^oC} \cdot 38^oC$

$\Delta T = 65^oC - 27^oC = 38^oC$ $\quad$ $Q = 79800\ J$

So, to heat 0.5 kg of water for 5 minutes requires 67200 J of heat. Where Q is the amount of heat received or released by an object, it can be interpreted that in the process of boiling water for 5 minutes, the heat value produced by biogas is 67200 J.

F. Calorific Value Efficiency

The efficiency of the heating value is determined by comparing the average heating value produced by the 3 variations of mixed materials with the heating value produced by LPG gas in an experiment to boil 0.5 liters of water with a time limit of 5 minutes.

Figure 3. Measurement of water temperature after boiling with LPG fire

In the process of testing the comparison of calorific value between each variation of mixed materials, the results of the calorific value of biogas have been obtained, which is 67200 J. To determine the efficiency of the calorific value, data is obtained from the results of boiling water using LPG stoves. The initial temperature of the water before boiling is 28oC, after boiling for 5 minutes, the temperature is 65oC. Then the LPG calorific value can be determined by the following calculation.

It is known:

$m = 0{,}5\ kg$

$c = 4200 \frac{J}{kg^oC}$

$\Delta T = 72^oC - 29^oC = 43^oC$

$Q = m \cdot c \cdot \Delta T$

$Q = 0{,}5\ kg \cdot 4200 \frac{J}{kg^oC} \cdot 32^oC$

$Q = 90300\ J$

So, after testing the efficiency of the heating value by comparing the heating value of biogas with the heating value of LPG, it can be interpreted that the heating value produced by the LPG stove is higher than the biogas stove.

Conclusion

Based on the results of the biogas reactor design process, it can be concluded that, a fixed dome type biogas reactor has been successfully made outside the tube with an anaerobic system. The reactor is made using polyethylene tubes with dimensions of 105 cm high and 60 cm in diameter so that it has a volume of 297 liters. In experiments using 3 variations of fermentation mixtures, the results of biogas formed were significantly different. In the 10% variation of mixed materials, for

15 days produces 90 liters of biogas, at 15% variation of mixed materials can produce 95 liters of biogas, then at 20% variation of mixed materials can produce 100 liters of biogas.

In the flame test, the results obtained are blue flame. The highest calorific value is obtained from the 20% mixed material variation with a composition of 80% tofu liquid waste mixed with 20% cow dung, resulting in a calorific value of 79800 Joules.

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