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The Innovation of Tofu Waste Liquid Biogas Reactor Technology as an Alternative Energy Resource

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Abstract - *Increased production capacity of the tofu factory has an impact on increasing waste. Tofu liquid waste is one of the untapped wastes and is even just thrown away. Besides, the tofu industry needs water for its processing, so more wastewater produces more than tofu solid waste. Wastewater from the making tofu process produces liquid waste which is a source of pollution for humans and the environment that will disrupt the ecosystem and environmental health. The right process for handling tofu wastewater is by an anaerobic process that converts the liquid waste fermented by bacteria into methane gas. This methane gas can be used as a new energy resource and this energy can be used for cooking or frying tofu. The results of the research are from 500 liters of tofu liquid waste treated, 149.6 liters of biogas were obtained in 21 days. It increased the quality of biogas as seen from the increase in CH_4 levels by 70%, temperature in the digester by 32°C, volume in 149.6 liters, and decreasing H_2S levels by 9 ppm, CO by 13 ppm, O_2 by 15.1%. Based on the test results, the maximum fermentation time is 21 days.*

Keywords *–renewable energy, design, tofu liquid waste, digester, biogas*

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1. Introduction

Soybean production in Indonesia in 2015 reached 963,183 tons [1]. Based on data from the Central Statistics Agency, around 38% of soybeans in Indonesia are consumed in the form of tofu products [2]. Based on soybean production data, tofu production in 2015 reached 366,009 tons. According to L. Guruswamy, one kg of soybean processed in the tofu industry produced 10 liters of liquid waste and 250 g of solid waste [3]. Tofu liquid waste obtained in Indonesia in 2015 was about 9 billion liters.

The disposal of tofu liquid waste without prior treatment can lead to the death of living things in water including microorganisms which play an important role in regulating the biological balance of water. The tofu industry is a small-scale industry, it requires a waste treatment plant with simple tools, low operational costs, economic value, and environmentally friendly. Tofu waste treatment must be managed properly and maintained routinely.

Energy demand keeps increasing and dependency on fuel as coal is still incredibly high, predicted coal reserves in Indonesia would run out in seventy years or even faster [4]. Indonesia has the potential for abundant resources to produce alternative energy. Therefore, the use of alternative renewable and environmentally friendly energy resources is an option. One of renewable energy is biogas, biogas has a big opportunity in its development.

One waste that has the potential to be a source of biogas is tofu liquid waste. Many tofu industries in Indonesia have not utilized their waste well and environmentally friendly. The factory owners were usually unwilling to treat their wastewater because of the complexity and inefficiency of the waste treatment process, and the waste itself has value. Tofu factory liquid waste has high organic compound content which has the potential to produce biogas through an anaerobic process. In general, biogas contains 50-80% methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and a little water, which can be used as a substitute for kerosene or LPG. By converting tofu waste into biogas, the owners not only contribute to protecting the environment but also increase their income by reducing fuel in the tofu-making process.

The right process for handling tofu wastewater is by an anaerobic process (biogas), which process converts the liquid waste fermented by bacteria into methane gas. This methane gas can be used as a new energy resource, for cooking or frying tofu, it minimizes the cost of purchasing fuel or can be used as a substitute for sawdust fuel and reduces the level of environmental pollution.

2. Materials and Methods

Tofu waste comes from tofu residual product that is wasted because it is not formed properly into tofu. Tofu waste products consist of two types, liquid waste, and solid waste. Liquid waste is the biggest residual product and has the potential to pollute the environment. It forms because of the remaining soy whey that does not clot, pieces of tofu that are destroyed due to imperfect clumping process, and yellowish turbid liquid which can cause unpleasant odors if it is discharged. The tofu industry generally uses a lot of water in the process for washing tools and soybean. Most of the water used is immediately discharged into the environment [5].

Organic materials contained in tofu production liquid waste are very high. These organic compounds consist of protein, carbohydrates, and fats. Protein compounds have the greatest amount, reaching 40-60%, carbohydrates 25-50%, and fat 10%. The longer the organic materials in the tofu liquid waste, the more its volume increases [6]. Biogas is a mixture of gas produced by methanogenic bacteria that occurs in the materials that decomposed naturally in anaerobic conditions. Biogas consists of methane gas (CH_4) 50-70%, carbon dioxide (CO_2) 30-40%, hydrogen (H_2) 5-10%, and other gas in small amounts [7]. Biogas is a type of renewable energy that is expected to significantly contribute to achieving the ambitious goal of ensuring universal access to modern energy services by 2030; domestic biogas is considered a clean cooking alternative for the poor in developing countries [8].

The method used in research is the engineering method which is an engineering design, so there are new contributions, such as the form of processes and products or prototypes, tool design, tool manufacturing, and tool testing with tofu wastewater. Biogas digesters are converters of organic waste to natural gas. The organic waste used in this biogas digester is tofu liquid waste. Organic waste contains various nitrogen and other organic compounds. The compound still is processed even if it comes from organic waste.

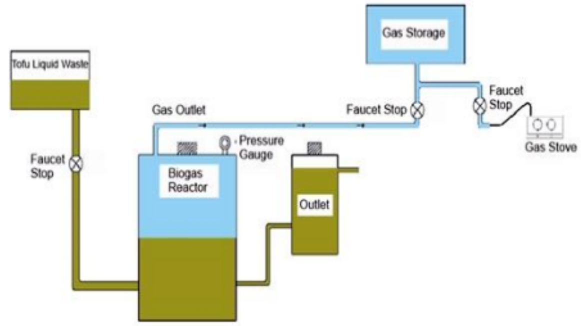

Figure 1. Design of tofu waste liquid biogas reactor

The process in a biogas digester is called an anaerobic process because it does not need oxygen. The process begins with extraction at a temperature of 70°C for one hour so that no bacteria comes from the waste. Furthermore, organic waste will be digested by anaerobic bacteria which is inserted into the biogas digester to produce natural gas. The natural gas will be distributed to other places so it can be utilized further.

To produce biogas from a digester, operating a household scale biogas digester is not different from other digester units. The steps in operating a digester are:

a. Pour tofu liquid waste into the digester through the inlet and the biogas production process will take place in the digester.
b. After the liquid waste is entered into the digester/reactor then the liquid waste will be processed through anaerobic conditions (free of oxygen) so that the organic material can be fermented by methanogenic bacteria to produce biogas.
c. After the methane gas is formed, it will experience pressure in the reactor to push liquid waste out of the outlet, for the rest of the processing results of the biogas material can be used as liquid fertilizer.
d. Gas collected in the reactor will be flowed up to the gas storage through the gas outlet pipe.
e. Gas in the storage flows back to the biogas stove through a regulator hose. Before the gas flows to the stove, the gas faucet stops are opened so that the gas can be used.

3. Result and Discussion

3.1 pH value

One of indicator how the digester works is pH value. The pH value can be measured with a pH meter or universal pH indicator paper. The result of measuring pH from the research is 7 which is measured using a digital pH meter (HANNA). pH fluctuation did not dramatically change, i.e., 6.4-7.2 [9].

The value was on the optimum pH for the anaerobic digestion, thus this condition was not the limiting factor in producing the biogas. The ideal limit is recommended between 6.8 to 8 so that the quality of the biogas produced can be better.

3.2 Temperature

There are two temperatures measured in this study, the outside temperature of the digester and the inside temperature of the digester. The outside temperature of the digester greatly affects the inside temperature of the digester.

The measured temperature acting on the reactor shows the numbers 28–32˚C. At this temperature, bacteria or microbes will grow so that they can produce biogas. This is reinforced by the statement of Feiz et al which states that the heat demand of the digestion system depends on several factors, including the working temperature of the digesters, which is commonly around 35˚C for mesophilic systems and about 55˚C for thermophilic systems [10].

Mesophilic microbial growth is 30˚C or slightly higher. The measured temperature on the digester shows the numbers 28-32˚C which is presented in Table 1.

Table 1. Biogas temperature research result

Days	Room Temperature (˚C)	Digester Temperature (˚C)
3	28	28
6	29	31
9	30	31
12	29	30
15	28	30
18	30	32
21	31	32

Based on Table 1, the inside of the digester and the outside of the digester or room temperature on the 3rd day until the 9th day has increased to 31˚C on the inside of the digester and 30˚C on the outside of the digester. On the 15th day, the temperature decreased to 30˚C for the inside of the digester and 28˚C for the outside of the digester. Then on the 21st day, the temperature increased by 32˚C on the inside of the digester and 31˚C on the outside of the digester.

3.3 Biogas volume

The volume of biogas produced from the fermentation process is stored in the gas storage and measured every 3 days until the 21st day. The results are presented in Figure 2. Based on the graph, the volume of biogas produced on the 3rd day is 22.7 liters. Then has volume increased on the 6th day that is 29.3 liters. The volume produced in the fermentation process continues to increase until the 21st day (149.6 liters), and it continues to increase.

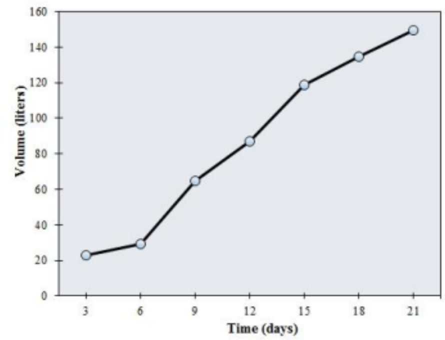

Figure 2. Biogas volume graph with fermentation time.

This happens because the temperature in the digester affects the production of biogas. The best temperature for mesophilic microbial growth is 30˚C or slightly higher. The measured temperature in the digester is 28-32˚C. This shows that the longer fermentation time can increase biogas production or biogas volume. This is reinforced by the statement of Malik et al which states the volume of biogas produced further increased [11]. This was due to the stabilization of the process. The increment in the amount of biogas generation was due to the availability of more organic content.

3.4 Methane gas (CH_4) content

The CH_4 gas content produced from the fermentation process is measured once every 3 days until the 21st day. The CH_4 level produced on the 3rd day is 13%, then increasing on the 6th day is equal to 17%, and it continues increasing until the 21st day (70%). The ideal CH_4 gas content in biogas is between 60-70%.

Methane composition in the biogas ranged between 55% and 65% with methane yield of about 0.14 m^3/kg vs removed [11]. These results indicate that biogas from tofu wastewater has reached the expected value, which is presented in Figure 3.

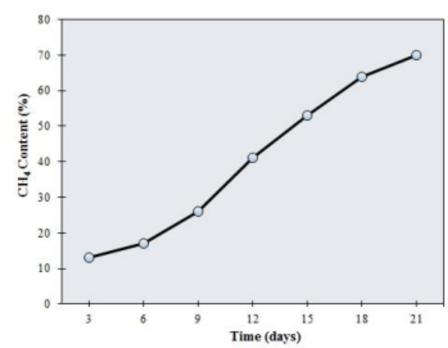

Figure 3. Graph of CH_4 levels for fermentation time.

3.5 Oxygen gas (O_2) content

Oxygen gas content produced from the fermentation process is measured once every 3 days until the 21st day, which is presented in Figure 4. Based on the graph, the O_2 content produced on the 3rd day is 23.2%, then decreasing on the 6th day (22.6%) until the 21st day (15.1%). Biogas production will be more optimum if anaerobic fermentation is in conditions without oxygen (O_2).

Displacing oxygen and other gases by biogas, anaerobic conditions in reactors were achieved and maintained [12]. Other contaminants such as nitrogen, water vapor, and oxygen can be present in raw biogas. This shows that the less oxygen produced, the better the quality of biogas.

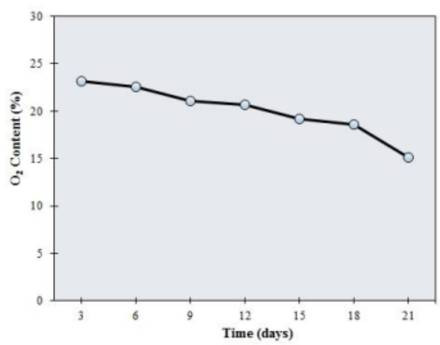

Figure 4. Graph of oxygen content on fermentation time.

3.6 Hydrogen sulfide (H_2S) content

Hydrogen Sulfide gas content produced from the fermentation process is measured once every 3 days until the 21st day. The results are presented in Figure 5. Based on the graph, the H_2S content produced on the 3rd day is 60 ppm. Then decreasing on the 6th day (47 ppm) until the 21st day (9 ppm). The increase in CH_4 gas content is caused by the absorption of CO_2 gas and H_2S gas contained in biogas. Furthermore, CO_2 gas will be decomposed into one C atom and two O atoms, while H_2S gas will be decomposed into two H atoms and one S atom.

Rendering industry streams reduced H_2S generation, which could be a promising topic for further exploration in the future since high H_2S concentration during combustion produces high amounts of SO_2, which affects biogas engines on the appearance of corrosion [12]. This shows that less H_2S gas content will increase the CH_4 gas content.

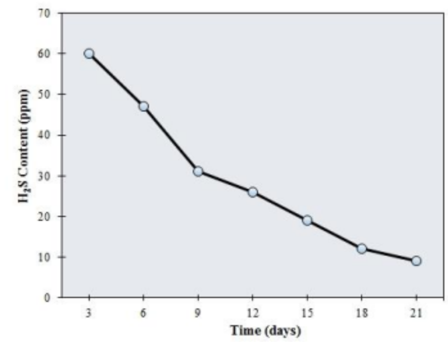

Figure 5. Graphs of Hydrogen Sulfide levels for fermentation time.

3.7 Carbon monoxide (CO) content

Carbon monoxide gas content produced from the fermentation process is measured once every 3 days until the 21st day. The results are presented in Figure 6. Based on the graph, the CO content produced has increased on the 3rd day (18 ppm) and 35 ppm on the 9th day. Then decreasing on the 12th day (27 ppm) until the 21st day (13 ppm).

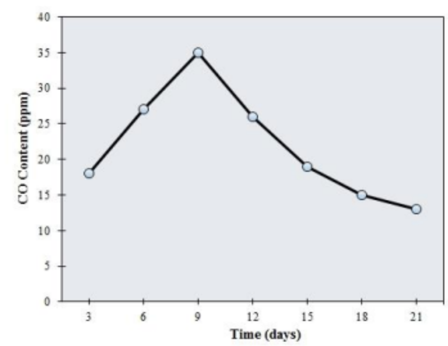

Figure 6. Graph of CO content on fermentation time.

The smaller CO gas in a digester, the more efficient in forming CO_2 gas so air pollution caused by the digester is smaller [13]. This is reinforced by the statement from Prastya that the level of carbon monoxide (CO) decreases with increasing load and the value of CO_2 will be even greater [14].

4. Conclusion

From 500 liters of tofu liquid waste treated, 149.6 liters of biogas is obtained in 21 days. The tofu industry wastewater has biogas quality increased in CH_4 content by 70%, temperature in the digester by 32°C, volume by 149.6 liters, and decreased H_2S levels by 9 ppm, CO by 13 ppm, O_2 by 15.1%. Based on the test result, the maximum fermentation time is 21 days.

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