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Analysis of the Utilization of Tofu Liquid Waste as a Biogas Electricity Power Plant

(Case Study of BK Tofu Industry at Payakumbuh City West Sumatra)

Galuh Putra Rajabya[1], Novi Gusnita[2]
[1,2]Sultan Syarif Kasim State Islamic University Riau, HR. Soebrantas Street, Pekanbaru, Riau, Indonesia

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ABSTRACT

The increase in population from year to year causes an increase in the need for food such as Tofu. This also has an impact on the number of tofu industries in Indonesia. Nevertheless, it arises that the environmental problems posed by the tofu industry are waste generated from the liquid tofu waste manufacturing process. When discharged into the environment, it can cause a foul odour and pollute the environment. The utilization of tofu liquid waste into electrical resources is one of the steps that can be developed in reducing pollution and increasing electrification. This study aims to determine the potential value of tofu liquid waste and electrical energy for PLTBG fuel as an effort to apply clean technology. The method in this study using anaerobic fermentation with SuperPro Designer simulation. The results of this study, from 500 litres per day of tofu liquid waste can produce methane gas (CH4) of 141,97 m^3 per day and total electrical energy of 129,03 kWh. It can be concluded from this study. tofu liquid waste can be used as biogas to fuel a generator set with an output power of 12.000 Watts which fulfills industrial electricity needs for 11,73 hours.

Corresponding Author:

Galuh Putra Rajabya
Sultan Syarif Kasim State Islamic University, Riau, HR. Soebrantas Street, Pekanbaru, Riau, Indonesia
Email: galuhrajabya@gmail.com

1. INTRODUCTION

The increase in population has an impact on food needs, such as primary needs in the form of tofu. Tofu is a traditional food made from soybeans. The development of tofu consumption from 2002 to 2018 fluctuated with an average value of 7.41. Tofu consumption is estimated at 8.38, 8.52, and 8.67 in 2019, 2020, and 2021, respectively [1]. This has caused an increase in the tofu industry. The increase in the tofu industry has an impact on the accumulation of waste has increased [2].

The tofu industry in its formulation produces two wastes, namely liquid waste and solid waste. Liquid waste comes from the process of washing, boiling, and molding while solid liquid waste in the form of dregs arises from the way of filtering soybean porridge [3]. Tofu liquid waste with a high organic matter composition, if discharged directly into the water, can harm the environment around the industry. The amount of tofu industry in Indonesia is quite large, with around 84,000 small and medium-scale tofu industries, and usually family-owned with a total yearly production of more than 2.56 million tons [2]. Payakumbuh city, West Sumatra has 7 tofu industries. BK Tofu Industry is one of them. It is located on the riverbank of Batang Agam. After making observations with the owner, in one day it can produce tofu liquid waste around 500 liters and 2000 kg of tofu solid waste. Solid waste in the BK tofu industry is sold as livestock feed while liquid tofu waste in the BK tofu industry has no further process. So the industry needs a waste processing that aims to reduce the negative impact of tofu liquid waste [4].

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Based on observations and interviews with Mr. Yusril as the owner, his tofu industry has not been able to process tofu waste and waste disposal is not following existing regulations, causing pollution. This pollution will negatively affect the health of the people around the industry. This issue involves many groups that use tofu liquid waste to be processed into various useful products, thereby reducing the risk of pollution [2]. Biogas fuel is one product that can reduce the risk of pollution. The use of tofu liquid waste to produce biogas can be made using the anaerobic fermentation method. The fermentation method is a process of processing organic ingredients through fermentation without the use of oxygen. The main components of biogas are carbon dioxide and methane gas. This methane gas will be used as fuel for a generator set that converts it into electricity [4].

Related research on biogas from tofu liquid waste has been done several times, these studies include examining the potential of tofu liquid waste in clean technology endeavors [5]. This study [6] The study examined the results of one-stage and two-stage anaerobic treatment of organic matter shrinkage as seen from the Chemical Oxygen Demand (COD) parameter, bacterial development monitored from the Volatile Suspended Solid (VSS) parameter, Volatile Fatty Acid (VFA) production, and biogas production. This study [7] has a topic of calculating the potential biogas that can be produced, the duration of fermentation, and the construction of the reactor.

Based on these studies, all studies only focus on the processing and production of biogas from tofu liquid waste. Therefore, this study calculates the potential of electrical energy from tofu liquid waste biogas and electrical energy for the manufacture of wind power plant fuel by anaerobic fermentation method. Utilization of tofu liquid waste can increase the efficiency of waste that is not used anymore. Tofu liquid waste which is the raw material produced by the BK Tofu Industry then used to form biogas, then converted into electrical energy. This study uses an anaerobic fermentation method with the help of Superpro Designer Software to produce biogas. This study takes advantage of the anaerobic fermentation process combined with Superpro Designer software to produce biogas. The potential benefits of biogas were calculated and the value of electrical energy produced from tofu liquid waste was established.

2. RESEARCH METHOD

The substance of this study is to calculate the potential of biogas and electrical energy of tofu liquid waste with an anaerobic fermentation method assisted by Superpro Designer Software to produce biogas. Where the results of the potential biogas from tofu liquid waste are converted into electrical energy.

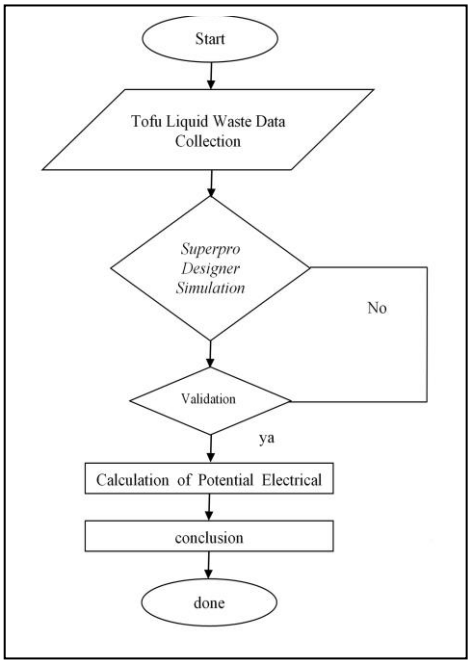

Figure 1. Research Series

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2.1. Collection of Research Data and Process Parameters

Stages of data collection and process parameters were carried out in two stages, namely by survey (interviews with resource persons) at the BK Tofu Industry location in Payakumbuh City and with related parameter data from the literature review.

2.1.1. Data Collection

According to the Payakumbuh City Industry and Trade Office, the tofu industry has 7 tofu industries. The development of the tofu industry in Payakumbuh City has increased from year to year.

Table 1. Data of Tofu Industry Liquid Waste Payakumbuh

Number	Tofu Industry Liquid Waste Data	
	Industries	Total Waste (L/day)
1	Industri Tahu BK	500
2	Industri Tahu Urang Awak	300
3	Industri Tahu DF	300
4	Industri Tahu Jaya Bersama	250
5	Industri Tahu Kapatar	450
6	Industri Tahu AA	130
7	Industri Tahu Sumedang Saitana	110

BK Tofu Industry is one of the tofu industries in Payakumbuh City, it is located on the riverbank of Batang Agam which is operating from 06.00 WIB to 18.00 WIB. After a survey with the industry owner, in one day the BK Tofu Industry can produce 500 liters of tofu liquid waste.

The BK Tofu Industry has an electric power of 11.000 VA and has electrical equipment consisting of 5 units of 1-phase electric motors, 3 units of water pumps, and 7 units of lamps. So that the total electrical load of the industry is 94,383 Watt or 94,383 kWatt. The equipment operates for around 10 hours per day.

Table 2. BK Tofu Industry Expense Data

Number	Industry Expense Data				Power Amount (Watt)
	Equipments	Active Time (Hours)	Power (Watt)	Total (Unit)	
1	Motor 1 Phase	9	1850	5	83.250
2	Water Pump	9	372	3	10.125
3	LED Light	10	18	7	1.008

2.1.2 Process Parameters

The parameters used in this biogas formation process are parameters that help in applying simulations to form biogas. Tofu liquid waste has a high nutrient and organic content consisting of water, carbohydrates, protein, and fat. The percentage content of tofu liquid waste can be seen in Table 2.

Table 3. Tofu Liquid Waste Levels

Number	Tofu Liquid Waste Levels	
	Parameters	Levels (%)
1	Water	90,72
2	Carbohydrate	6,28
3	Protein	1,8
4	Fat	1,2

2.2. Simulation of Superpro Designer Producing Biogas

2.2.1 Superpro the Flow of Making Tofu Liquid Waste Biogas with the Superpro Software

The potential of tofu liquid waste to become biogas is determined by an anaerobic fermentation method facilitated by SuperPro Designer Software. The procedure is shown in Figure 2 [8].

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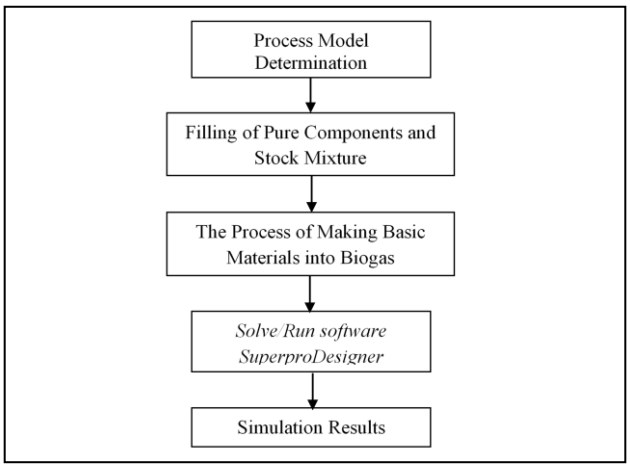

Figure 2. Biogas Production Series from Tofu Liquid Waste with Superpro Software

2.2.2 Determination of the Process Model

In the process of forming biogas with Superpro Software, there are several steps used in the process model, which is a process that is done after determining the value of the pure component. In simulating the software, it uses a Batch process with a duration of according to the Superpro Software recommendation of 336 days. Because of this method, the processing time can be changed while the primary process is in progress. The use of cycles in the anaerobic fermentation process. The unit procedure used is fermentation using Anaerobic Digestion.

2.2.3 Filling of Pure Components and Stock Mixture

Components consist called Pure Components are compounds that are reacted during simulation, while Stock Mixture is a compound in the raw material that will be processed into biogas.

2.2.4 Process of Manufacturing the Basic Materials Into Biogas

In this procedure, the preparation and processing of raw materials in the Anaerobic Digester are carried out. This procedure will produce methane and CO2 through chemical processes helped by bacteria, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Biogas processing from wastewater requires an Anaerobic Digester component, which is a closed process that lacks free oxygen to produce biogas gas. The output of this process is tofu liquid waste. The end product is biogas, which consists of methane gas and carbon dioxide.

2.2.5 Validation of Simulation Results

The validation that was done in this study was to compare with research [7] that has the topic of study to calculate the potential biogas that can be produced, the duration of fermentation, and the construction of the reactor.

Table 4. Levels of Tofu Liquid Waste

Number	**Validation of Simulation Results**		
	Parameters	**Researchs** [7]	**Validation**
1	Raw Material	Tofu Liquid Waste	Tofu Liquid Waste
2	Composition	Water 90,72%, Carbohydrate 6,28%, Protein 1,8%, and Fat 1,2%	Water 90,72%, Carbohydrate 6,28%, Protein 1,8%, and fat 1,2%
3	Inputs value	90 Liter/days	90 Liter/day
4	Biogas Levels	80,57% methane, 19,42%carbon dioxide	80,57% methane, 19,42%carbon dioxide
5	Volumetric Flow	31,7193 m^3	31,7193 m^3

The validation of the simulation results showed that in the research [7] volume of tofu liquid waste was 90 liters and 500 liters. The Superpro simulation results in this study produce biogas which has a composition of 80.57% methane and 19.42% carbon dioxide. This simulation produces biogas that has

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a composition of 80.57% methane and 19.42% carbon dioxide. From the results of the biogas composition parameters, it can be seen that there are no inaccuracies in the values, which means that this research is valid because it does not have an error value of more than 10%.

2.3. Calculation of Electric Potential

Determine the working duration of the generator per day, we can use (1) [4].

$$\text{Operation Time} = \frac{\text{Volumetric Flow} \times \text{Mass Comp Gas Methan}}{\text{Fuel Consumption}} \quad (1)$$

Where operating time is the duration of generator set work that can be obtained, volumetric flow is the volume flow rate of methane gas obtained from simulation, fuel consumption is the amount of fuel consumption with 100% load.

Calculation of potential electrical energy can use (2) [4], as follows:

$$\text{Total electrical energy} = \text{operating time} \times \text{generator power} \quad (2)$$

Total electrical energy is the total potential electrical energy generated from tofu liquid waste, electrical power is the generator specification power, and operating time is the time in operating the generator set.

3. RESULTS AND DISCUSSION

In this section, the authors explain the results of the research as well as provide a comprehensive explanation of the discussion.

3.1. Biogas Potential from Tofu Liquid Waste

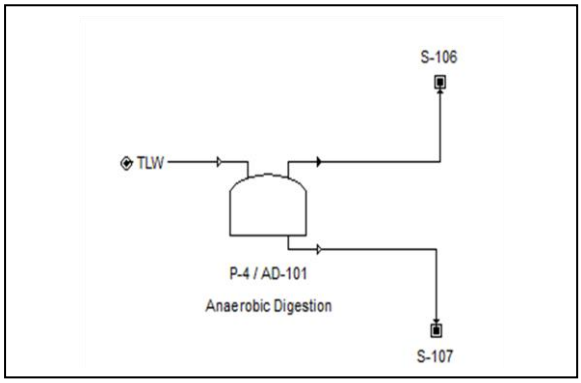

Figure 3. Single Line Diagram Anaerobic Fermentation Process

The first process of tofu liquid waste of 500 liters from the BK Tofu Industry in Payakumbuh City is included in the Anaerobic Digestion section. In Anaerobic Digestion, the formation of methane gas happens. The final results of the simulation are shown in the output.

Table 5. Levels of Tofu Liquid Waste

Number	Levels of Tofu Liquid Waste	
	Parameters	**Result**
1	Tofu Liquid Waste Volume	500 L/day
2	Volumetric flow	176218,54 L/day
3	Biogas levels	Methane 80,57% and CO^2 19,42%

The results of the simulation using Superpro software with the input of tofu liquid waste with a daily volume produced biogas with a Volumetric Flow of 176218.54 Liters or 176.21 m3 in a day with levels of 80.57% Methane Gas and 19.42% Carbon dioxide.

3.2. Potential of Electrical Energy from Biogas

In calculating the potential of electrical energy, we must choose the capacity of the generator set. The generator used for this PLTBG analysis is a Jet Power generator set. Based on the electrical energy

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capability of the BK Tofu Industry in Payakumbuh city and the amount of potential biogas formed, the details of the generator set used are shown in Table 4.

Table 6. Tofu Liquid Waste Generator Specifications

Number	Generator Specifications	
	Parameters	**Result**
1	Manufacture	Jet Power
2	Model No	NG-17
3	Output Power	12 kW
4	Speed	1500/1800rpm
5	Frequency	50Hz/60Hz
6	Currency	40A-1000A
7	Phase	1 Phase/3 phase
8	Fuel Consumption	12,1 m^3/h
9	Manufacture	Jet Power

After knowing the specifications of the generator set that will be utilized as a generator, the next step is to calculate the electrical potential of tofu liquid waste using (1) and Equation (2).

$$Operating\ time = \frac{176{,}21\ \ m^3 \times 80{,}57\%}{12.1\ m^3/hours}$$

$$Operating\ time\ = \frac{141{,}97\ m^3}{12.1\ m^3/hour}$$

$$Operating\ time\ =\ 11{,}73\ hour$$

In 500 liters of tofu liquid waste mass, it can produce about 141.97 m^3 of methane gas and the operating time of the biogas generator is about 11,73 hours

$$Total\ Electrical\ energy =\ 11{,}73\ hours \times 12.000\ watt = 140{,}76\ kWh$$

Table 7. Electrical Energy Comparison

Number	Electrical Energy Comparison		
	Parameters	**Researchs** [7]	**Validation**
1	Raw material	Tofu Liquid Waste	Tofu Liquid Waste
2	Inputs value	90 Liter/days	500 Liter/day
4	Operating time	2,11 hour	11,73 hour
5	Total Energy	25,32 kWh	140,76 kWh

Previous research has that 90 liters/day of tofu liquid waste can produce total electrical energy of 25.32 kWh while from this study,500 liters/day of tofu liquid waste produces electrical energy of 140.76 kWh and can turn on the generator for 11.73 hours using a 12,000 Watts biogas generator. BK Tofu Industry operates from 06.00 WIB to 18.00 WIB, so that the potential electrical energy generated from tofu liquid waste can be utilized as fuel for PLTBG to the maximum during the operational time of BK Tofu Industry in Payakumbuh City.

4. CONCLUSION

Based on the results obtained, it is concluded that with the amount of 500 liters of tofu liquid waste can be processed into biogas by anaerobic fermentation method with Superpro Designer simulation, the results of biogas output with methane gas content of 82.257% and carbon dioxide of 19.42% and volumetric flow of 176218.54 liters per day or 176.21 m^3, with a total gas produced of 141.97 m3. From the potential of methane gas, it can operate the biogas generator for 11,73 hours with a total energy of 140.76 kWh.

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