Co Digestion of Tofu Industry Liquid Waste with Cow Manure to become Biogas in a Fixed Dome Biodigester

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Abstract one source of material that has high potential to be proceed become biogas is tofu liquid waste.The composition of tofu liquid waste mostly consist of dissolved and insoluble solid particles amounting to 0,1%. Solid particles of organic substances (± 70%) and inorganic substances (± 30%). Organic substances consist of protein (± 65%), carbohydrates (± 25%), fat (± 25%). This research focus on processing liquid waste from the tofu industry into biogas by codigestion using cow dung in a fixe dome type biodigester by finding the optimum fermentation time to produce biogas. From the research results, with the characteristic of Tofu waste with COD of 11.105 mg/l and TSS 1938 mg/l, it was found that the optimum time for codigestion of tofu liquid waste with cow dung was 20 days, with a CH_4 content obtained from biogas of 50.32%, CO_2 content of 11.78% and H_2S of 256 ppm..

Keywords: Tofu, Biogas, Fermentation

1. Introduction

Since 2014 the Indonesian Government through Government Regulation (PP) no. 79/2014 concerning National Energy Policy (KEN) tray to increase the use of non-fossil energy in the form of new and renewable energy (EBT). The target for renewable energy utilization in 2025 is to increase to 23%, while the utilization of energy from petroleum decreases to 25%. Thus, the use of fuels originating from fossils or petroleum and coal must gradually decrease in quantity in order to maintain environmental sustainability and overcome the problem of reserves in the earth which continue to be depleted [1] One form of cheap and environmentally friendly alternative energy to reduce dependence on fossil fuels is biogas. Biogas is a gas produced by the

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activity of anaerobic microorganisms from organic materials through an anaerobic process in a biodigester.

Electricity generation from biogas has become a major trend in many countries such as Germany, China, and India. Traditional conversion of biogas to generate electricity through a generator is predominantly the most active technology; however, electricity can also be generated through biogas through a fuel cell. The installed capacity of biogas energy worldwide reached around 20.1 gigawatts in 2020. With the introduction of new. technologies and innovation in the development of fuel cells, the installed capacity is expected to be continuously growing [2]. The benefits for the goverman are helps reducing organic waste to landfill, fuels security, diversts incineration, less nitrat pollution and cleaner environment [3].

Anaerobic digestion can be conducted at 3 different temperature ranges: (a) psychrophilic (10–15 ◦C), (b) mesophilic (28–45 ◦C), and (c) thermophilic (>60 ◦C). Mesophilic AD is the most popular due to low energy requirements, the production of stable solids, and good biogas production. For the same amount of organic pollutant removal, lower temperature kinetically slows down the hydrolysis process thus requiring longer hydraulic retention times (HRT) and solids retention times (SRT) compared to digestion at mesophilic temperatures (i.e., 35 ◦C) [4].

The main components of biogas consist of methane gas (CH4), carbon dioxide (CO2), Nitrogen (N2), Hydrogen (H2) and Sulfur (H2S). Biogas is usually made from livestock waste suchas livestock manure, agricultural waste such as straw, garbage and industrial wastewater such as liquid tofu waste, liquid waste from the palm oil industry. The composition of biogas varies, depending on the source of the materials used in the fermentation process. Biogas usually contains 50% -70% CH4, 25% - 50% CO2, 1% - 5% H2, 0.3% - 3% N2 and H2S [5].

One source of biomass material that has high potential to be used as raw material for biogas is tofu waste. Tofu industry waste is produced from the tofu process and washing of soybean raw materials. The composition of tofu liquid waste mostly consists of water (99.9%) and the remainder consists of dissolved and insoluble solid particles amounting to 0.1%. Solid particles of organic substances (± 70%) and inorganic substances (± 30%). Organic substances consist of protein (± 65%), carbohydrates (± 25%), fat (± 25%) [3]. Most of the tofu liquid waste is directly discharged into the environment without prior processing.

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% . This research will focus on processing liquid waste from the tofu industry into biogas by codigestion using cow dung in a fixe dome type biodigester by finding the optimum fermentation time to produce biogas with a high methane gas content.

The four stages involved in anaerobic digestion are hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

1. Hydrolysis

Hydrolysis is a process in which complex polymers are converted into simpler molecules. Without hydrolysis microorganisms will not access the macromolecules of the waste material. Hydrolytic microorganisms secrete hydrolytic enzymes that convert biopolymers into simple and soluble ones [7]. In order to be easily broken down, complex organic compounds in solid form must be cut into pieces first to facilitate transport across the bacterial cell membrane. The results of hydrolytic reactions are simple molecules with short chains including glucose, amino acids, fatty acids, ethanol, carbon dioxide and energy for bacteria that carry out fermentation. At this stage the optimal pH is 6 – 7 [7].

2. Acidogenesis

The process of decomposition of chemicals such as carbohydrates by enzymes, bacteria, yeast, or mold in the absence of oxygen. The results obtained from this easily soluble hydrolysis process are then metabolized by the activity of hydrolytic and non-hydrolytic bacteria. The main results obtained from the acidogenesis process in mixed cultures are acetate, propionate, butyrate, hydrogen (H2) and CO2. Furthermore, by-products in the form of formia, lactate, valerate, methanol, ethanol, butandiol or acetone are produced by fermentation bacteria. Because these volatile fatty acids (VFA) are the main products produced by fermentative bacteria, they are generally characterized as acidogenesis bacteria.

3. Acetogenesis

This stage is the stage of formation of Acetate by acetogen. The acetogens catalyze the formation of acetic acid, carbon dioxide and hydrogen from the products produced in the acidogenesis stage [8]. In the acetogenesis stage, most of the acid fermentation products must be oxidized under anaerobic conditions to acetic acid, CO2, and hydrogen which will become substrates for methanogenic bacteria. Acetogenesis also includes the production of acetate from hydrogen and carbon dioxide by acetogens and homoacetogens. Sometimes the processes of acidogenesis and acetogenesis are combined as one step only [8].

4. Methanogenesis

At this stage, methane gas (CH4) is formed from acetate compounds, or from hydrogen and CO2 gas by methanogenic bacteria (methanogens). Methanogenic bacteria are obligate anaerobic bacteria whose growth is slower than the bacteria in stages one and two. These bacteria depend heavily on stages one and two to produce nutrients in the appropriate form. One of the functions of methanogenic bacteria is to reduce hydrogen to a minimum in the medium by using hydrogen to reduce CO2 to an inert final product (a gas that cannot react chemically with other substances), namely CH4. The methanogenesis process occurs at an optimum pH close to neutral (6.8 – 7.4) and if the optimum pH drops to 6.4 or lower, the formation of methane gas from hydrogen and CO2 will be inhibited [6]

2. Materials And Methods

2.1 Materials

The materials used in this research were tofu industry liquid waste, cow dung, water, and biogas probiotics.

2.2 Tools

The equipment used in this research is:
1. A set of Fixed Dome type Biodigester equipment
2. Gas Analyzer
3. Sample bag
4. pH meter
5. Bucket
6. Slurry sample bottle

2.3 Methods

2.3.1. Biogas production procedure

1. Tofu industry liquid waste is mixed with cow dung in a ratio of 1:3 then stirred until homogeneous
2. A small amount of waste mixed with cow dung and tofu liquid waste is taken to be analyzed for COD, pH, TSS and Total Nitrogen.
3. The mixture of tofu waste and cow dung is put into the biodigester
4. Adding Probiotics to the biodigester
5. The anaerobic process will occur in the fixed dome digester and produce biogas which will be stored in storage bags/balloons.
6. Biogas composition, biogas pressure, digester temperature and biogas slurry are observed every 5 days in an effort to obtain optimum fermentation time and control optimum operating conditions.
7. Biogas samples are taken using a biogas sample bag and taken to the laboratory to analyze the biogas content using a gas analyzer.

8. Biogas slurry samples are taken using a sample bottle with samples taken from inside the fixed dome biodigester.

Fig 1. Tofu Liquid Wastwe and Cow Manure

Fig 2. Fixed Dome Biodigester

The operating conditions of the anaerobic digestion process are observed to obtain optimum fermentation time and to control the operating conditions to remain optimum, with the observed parameters namely pH and pressure which aims to produce high methane gas [7]. The resulting biogas is analyzed to determine the CO2 and CH4 content. The research flow for obtaining biogas from cow dung can be seen in Fig. 3.

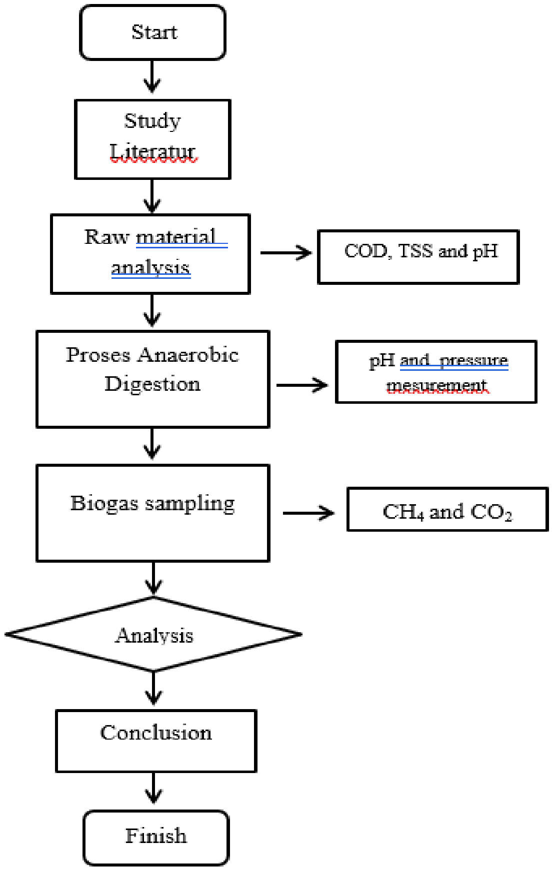

Fig 3. Research Flow

3. Result And Discussion

3.1. Analysis of Raw Materials

The mixture of tofu waste and cow dung was analyzed to determine the organic and solid content in terms of COD and TSS parameters. The results obtained were the organic COD content of 11,105 mg/l and TSS of 1938 mg/l.

3.2 Biogas Composition

The composition of the gas contained in the biogas produced depends on the organic raw materials and operational conditions or parameters set during the anaerobic degradation process in the biodigester. Figure 5 shows the initial content of biogas produced from the fermentation process in the biodigester, which shows that the content of CO2 gas and H2S gas in the biogas is still quite high. Biogas samples taken from the biodigester are carried out at intervals of 5 days from the first day the raw material is put into the biodigester (calculated as day 0), until the next day, respectively, days 5, 10, 15, 20, 25 and 30.

Table 1. Biogas Composition

Day	Composition (%)		
	CH_4	CO_2	H_2S
5	8,24	39,77	763
10	21,32	28,60	786
15	38,45	15,32	388
20	47,47	10,12	256
25	50,32	11,78	238
30	42,98	14,32	221

3.2 Data of operating conditions in the biodigester during fermentation

To ensure that the anaerobic fermentation process is optimal and well maintained, here are several daily operational conditions that need to be observed during the tofu waste fermentation process in the biodigester, including pH and biodigester pressure. These daily parameters are taken every day consistently at 8 o'clock in the morning to obtain valid, representative and consistent data regarding the actual conditions that occur every day which are presented in Table 2

Table 2. Operating conditions in the biodigester during fermentation

Day	Parameter	
	Pressure (Psi)	pH
1	0	6,5
2	0,1	6,5
4	0,2	6,0
6	1,1	5,3
8	2,8	6,0
10	4,7	6,2
12	6,5	6,5
14	8,1	6,8
16	9,1	7,2
18	9,2	7,3
20	9,5	7,2
22	9,4	7,4
24	9,3	7,3

26	9,0	7,4
28	8,7	7,4
30	7,7	7,5

3.3 The effect of fermentation time on biogas Composition

Analysis of the gas composition in biogas was carried out using the Multi Gas Detector at the Sriwijaya State Polytechnic Oil and Gas Processing Laboratory. Each sample was taken as much as 4 liters into 2 plastic sample bags with a volume of 2 liters.

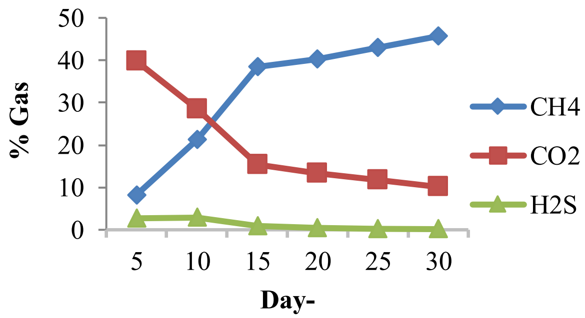

Fig 4. Biogas composition

From **Fig** 4, it can be observed that the increase in CH4 gas production in the biodigester experienced a fairly linear upward trend starting from day 5 at 8.24%. As the stage of the methanogenesis process begins to occur in the biodigester, the CH4 gas composition value also increases on the 10th day by 21.32% and then the sample on the 15th day reaches 38.45%. Entering the 20th day, CH4 gas production in the biodigester experienced a very rapid increase where the CH4 gas composition reached the highest figure, namely 50%. This increase in the percentage composition of CH4 gas was also accompanied by an increase in the total volumetric amount of biogas produced so that starting on day 20, researchers had to bleed off pressure to the biogas storage bag to keep the pressure in the biodigester below 10 psi.

However, the results of sample analysis on day 25 showed that the percentage of CH4 gas content tended to decrease, namely 47.67% when compared to the results of analysis on day 20 and was also accompanied by a decrease in the volumetric production of biogas in the biodigester. Furthermore, the decline occurred again in the results of the sample analysis on day 30 with a percentage figure of 42.98%. Likewise, in total volume there is no longer any increase in biogas production in the biodigester. Inversely proportional to the increase in CH_4 gas composition as the fermentation process in the biodigester progresses, where the percentage of CO_2 gas appears to be decreasing. The biogas formed in the biodigester is then further purified through an absorber column with Mono Ethanol Amin (MEA) as an absobent solution.

3.4 Operating conditions of pH and pressure in a fixed dome biodigester

The pH value is one of the main operational factors that greatly influences anaerobic digestion. Although most micro-organisms prefer a neutral pH range. In the biogas production process, there are microorganisms that require different optimal pH growth. The most favorable pH range for obtaining maximum biogas production from anaerobic digestion is 6.8 – 7.2 [8].

Every increase or decrease in pH value will bring changes to the biological system. Bacteria that form CH4 can be active at a pH of 7 to 9, therefore it is necessary to adjust the pH so that biogas can be produced optimally [9]. Methanogenic bacteria are very susceptible to changes in pH. In the Anaerobic Digestion process, methanogenesis microorganisms are very sensitive to pH variations and prefer a pH of around 7.0 [10]. The anaerobic digestion process should take place in the pH range 6 – 8 with an optimal pH of approximately 7 [11]. The optimal pH value is one of the main reasons to separate some reactors into two phases as acidogenic phase and methanogenesis phase [12]

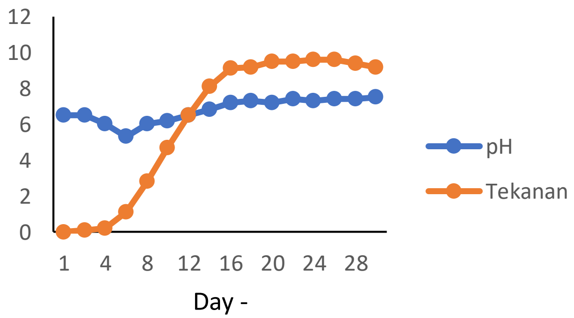

Fig 5. Operating conditions pH and pressure in the biodigester.

The degree of acidity (pH) of organic material in the biodigester is monitored every day and shows a fairly stable condition in the range of pH 6 to pH 7.5 except on days 5 to 7 where the pH had decreased to an acidic pH of 5. This This is possible due to the process of asedogenesis in the biodigester where organic compounds that have been broken down by bacteria begin to be converted into organic acid compounds. However, this does not take long as the process of decomposing organic acid compounds begins to be converted into CH_4,

Biogas formation affects the pressure in the biodigester. If the biogas produced is low, then the pressure in the biodigester is also low [13]. Operating conditions that indicate the formation of biogas in the biodigester can be seen from the pressure changes that occur, in the first 5 days of fermentation the pressure increase is relatively low. The increase in pressure in the biodigester increases gradually and is quite a large increase per day until on day 20 where the biodigester pressure reaches 9 psi. The increase in biogas volume in the biodigester is in line with increasing pressure. However, due to the limited operational pressure design of the biodigester, which has a maximum pressure limit of 10 psi, starting on day 20, the excess pressure is channeled to the gas reservoir.

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Conclusion

1. The optimum fermentation time in the co-digestion process of tofu industrial waste with cow dung to produce biogas with a high CH4 content (50.32%) is on the 20th day of fermentation time.

2. The pH parameters in the fixed dome type biodigester during fermentation process are stable, where the pH obtained is in the range of 6 to 7.5, which is still in the good range for the biogas fermentation process, while the pressure in the biodogester increases linearly until is 9.6 psi and then decrease inline the death phase of metanogenic bacteria.

Authors' Contributions

All authors contributed to the conduct of the research and publication. The head of this research is Leila Kalsum who is in charge of designing the research, Rusdianasari and Aida Syarif and Yordan Hasan contribute to data analysis and publication of research, and all other members actively contribute to conducting research.

References

1. Peraturan Pemerintah (PP) No. 79/2014 tentang Kebijakan Energi Nasional (KEN).
2. Research and Markets. Global Biogas Market (2022 to 2027) Growth, Trends, COVID-19 Impact and Forecasts. (2022).
3. Redman, Graham. A Detailed Economic Assesment of Anaerobic Digestion Technology and its Suitability to UK Farming and Waste System. The Andersons Centre. Leicester. Project NO. NNFCC. 10-010. (2010).
4. B. Shrestha, R. Hernandez, D.L.B. Fortela, W. Sharp, A. Chistoserdov, D. Gang, E. Revellame, W. Holmes, M.E. Zappi, A review of pretreatment methods to enhance solids reduction during anaerobic digestion of municipal wastewater sludges and the resulting digester performance: implications to

future urban biorefineries, Appl. Sci. 0 (2020) 1–28, https://doi.org/10.3390/app10249141

5. Triwikantoro, P. Pengaruh Tetes Tebu dan Limbah Cair Tahu pada Produksi Biogas. Fisika Dan Aplikasinya,, 8(2), 4–7. (2012).
6. Maragkaki, A. E., Fountoulakis, M., Kyriakou, A., Lasaridi, K., & Manios, T. Boosting Biogas Production from Sewage Sludge by Adding Small Amount of Agro-Industrial By Products and Food Waste Residues. Waste Management, 71, 605–611 (2018).
7. Soeprijanto, Suprapto, P, D. H., Puspita, i. F., Pudjiastuti, L., Setiawan, B., . . . Anzip, A. Pembuatan Biogas Dari Kotoran Sapi Menggunakan Biodigester Di Desa Jumput Kabupaten Bojonegoro. Jurnal Pengabdian kepada Masyarakat – LPPM ITS. (2017).
8. L. Kalsum, A. Zikri, W. E. Islamiyata, and F. Hibatullah, "Kotoran Sapi Dengan Variasi Jumlah Mikroba Design Building and Testing Biogas Production Equipment From Cow Dung With Various Microbial Variations," J. Kinet., vol. 9, no. 02, pp. 31–35, 2018.
9. Ward AJ, Hobbs PJ, Holliman PJ, Jones DL. Optimisation of the anaerobic digestion of agricultural resources. Bioresour Technol ;99:7928–40 (2008).
10. Pambudi, S., Kirom, M.R., dan Suhendi, A. Pengaruh Kadar Keasaman (pH) Terhadap Produksi Biogas dengan Menggunakan Campuran Kotoran Hewan Dan Substrat Kentang Busuk Pada Reaktor Anaerob. Proceeding of Engineering: Vol.5(3), pp: 5770-5776. (2018).
11. Benlin Dai JX, He Yulong, Xiong Peng, Wang Xinfeng, Deng Yuanfang, Wang Yixian, Yin Zhiming. Acid inhibition during anaerobic digestion of biodegradable kitchen waste. J Renew Sustain Energy ;7:9. 2015
12. Dwivannie, V., Sasmita, A., dan Pratiwi, E. (2019). Karakteristik pH dan Suhu dalam Proses Pembuatan Biogas dari Substrat Limbah Rumah Makan, Limbah Cair Tahu dan Kotoran Sapi. JOM FTEKNIK Vol. 6, pp: 1-6.
13. Arslan C, Sattar A, Changying J, Nasir A, Ali Mari I, Zia Bakht M. Impact of pH management interval on biohydrogen production from organic fraction of municipal solid wastes by mesophilic thermophilic anaerobic codigestion. BioMed Res Int ;2015:9. (2015).