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The Use of Liquid Waste of Tofu Industry for Biogas Production Using an Anaerobic Digester

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Abstract

The liquid waste of tofu industry is a component which is disposed of into the environment can cause foul odour, disease, water pollution. The liquid waste of the tofu industry contains high organic ingredients, in the form of protein, carbohydrates, and fat. Protein compounds have the largest amount. Therefore, the waste can be processed as alternative biogas energy. This aims of the study were to determine how to process tofu industrial waste water using an anaerobic digester to produce biogas. Biogas production includes three stages. Phase I was to prepare a set of a biogas digester. Stage II was mixing tofu liquid waste and cow dung with a weight ratio of 1:1 and entering it into the digester then analyzing the raw material in the form of COD. Stage III was a continuous fermentation process in a 60-day digester where the variables used were HRT 30 and 20 days of operation. Analysis of raw material for tofu waste in the form of COD was 7,546 mg O_2/l. The results showed that an average volume of biogas produced was 1,815 ml/day for HRT of 30 days, followed by the biogas production of 2,750 ml/day for HRT of 20 days, respectively.

***Keywords**: cow dung; biogas; anaerobic digester; tofu liquid waste.*

Introduction

Biogas as an alternative energy source has several advantages over fossil fuels. It is environmentally friendly and can be updated. In addition, biogas has an energy content that is not less than the energy content derived from fossil fuels. Therefore, biogas is very suitable to replace kerosene, LPG, and other fossil fuels (Triyatno, 2008). There are several sources of energy from biogas, including livestock manure, rice straw, water hyacinth, tofu industrial waste, jatropha cake, and various other sources (Masriadi, 2010). The liquid waste of the tofu industry contains high organic ingredients, especially proteins and amino acids. The presence of these organic compounds causes liquid waste of tofu industry to contain high BOD, COD and TSS (Husein, 2003). Many factories know that household scale in Indonesia does not have a liquid waste treatment process. The unwillingness of tofu factory owners to process their wastewater is due to the complexity and inefficiency of the waste treatment process, plus it does not produce added value. In fact, tofu wastewater contains high organic compounds that have the potential to produce biogas through an anaerobic process (Soeprijanto, 2019). Based on the background described, it can be concluded that the problems to be discussed are the influence of HRT and OLR on biogas production using a plug flow reactor. In this study, the problem is limited to the scope of the material used is tofu liquid waste originating from wastewater. Biogas is formed when organic matter decomposes by the activity of microorganisms in an oxygen-free environment, called anaerobic digestion. In the biogas process, various microorganisms play an active role through complex tissue processes and interact with each other to produce decomposition of complex organic compounds such as carbohydrates, fats and proteins into the final products of methane and carbon dioxide (Soeprijanto et al., 2010). This natural process is widely used in a biogas plant, using organic materials such as activated sludge from wastewater treatment, animal waste, agricultural residues and food waste placed or flowed into a truly airtight or digester chamber. Anaerobic digestion is a microbiological process in a digester where the flow of organic material fed by a degradation process by the activity of microorganisms under anaerobic conditions to decompose organic matter into biogas. Various groups of population of microorganisms involved in the anaerobic biodegradation process to produce two main products, namely energy-rich biogas and nutrient-rich digestate as the final product (Lastella et al., 2002; Lata et al., 2002). A series of metabolic reactions such as hydrolysis, acidogenesis, acetogenesis and metanogenesis are involved in the anaerobic decomposition process (Park et al., 2005; Charles et al., 2009). The raw material fed into anaerobic digestion is very likely to have a varied content of carbon and nitrogen, so it has a large effect on the performance of several bioreactors rather than the non-ideal ratio.

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The relationship between the amount of carbon and nitrogen in organic materials is shown by the ratio of carbon (C)/ nitrogen (N). The waste composition also determines the relative amount of organic carbon and nitrogen present in the waste substrate (C/N ratio). If the waste substrate with too much C/N ratio increases or decreases will affect biogas production. Microorganisms generally use the C/N ratio in anaerobic digesters which are considered optimum in the range of 25-30. It was stated that the optimum C/N ratio in anaerobic digesters was reached between 16-25 (Deublein and Steinhauser, 2011; Kayhanian and Hardy, 1995). In the digester with continuous mixing, the reactor contents have a relatively even residence time. In the anaerobic digestion process, HRT must be carefully determined because each microorganism requires specific time to consume the appropriate substrate and synthesize the product. If the process can not be maintained at optimum HRT, metabolic activity of unfavourable microorganisms and unwanted products will be produced.

The purpose of the study was to determine the value of hydraulic retention time (HRT) to produce biogas.

Materials and Methods

Bioreactor used was made of glass with a volume of 20 liters and was equipped with plastic pipes to accommodate the formed biogas which is shown in Figure 1. Preparation of liquid waste materials was obtained from the Tofu Factory in Surabaya, which has a characteristic high COD value of approximately 8,000 mg/l and has a low pH. The microorganisms used in this experiment derived from cow dung were obtained from slaughterhouse in Surabaya. A starter was made by mixing cow dung mixed with water with a ratio of 1: 1. Fresh cow manure with a certain weight was mixed with water in a ratio of 1: 2, then the mixture was fed into digester and left for several days. Afterward, the tofu waste was fed into the digester and incubated for 24 hours. After several days the volume of gas produced was measured using water displacement carried out in a volumetric glassware.

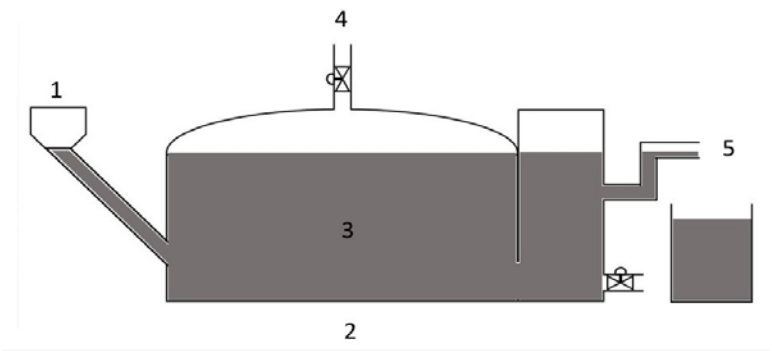

Figure 1. Schematic diagram of anaerobic digester. *Note*: 1 = influent of substrate; 2 = anaerobic digester; 3 = Slurry; 4 = effluent biogas; 5 = effluent of digestate.

Analysis of Results during the fermentation process, sample analysis was carried out on input and output. COD analysis was using the standard method (APHA, AWWA, and WEF, 1995). Measurements of pH, temperature, bioreactor pressure, and biogas production are carried out every day. At the end of the operation an analysis of the composition of biogas was carried out.

Results and Discussion

Most of the liquid waste produced by the tofu manufacturing industry is thick liquid which is separated from the tofu called whey (*air dadih*). In the tofu liquid waste still contains a lot of carbohydrates, proteins, and fats which are able to be used as biogas. Table 1 shows the analysis of mixture of cow dung and tofu liquid waste that was obtained for COD of 7,546 mg O_2/l, TOC of 4,190 mg/l and TON of 149.60 mg/l NH_3-N (Table 1).

Table 1. Results of analysis of mixture of cow manure and tofu liquid waste.

Parameter	Analysis
COD	7,546 mg/l O_2
TOC	4,190 mg/l C
TON	149.6 mg/l NH_3-N
C/N	28
pH	4-8

Figure 2 shows the average biogas production that the volume of gas produced for 14 days the average gas production was 2,304 ml/day. However, the results show that there was a fluctuating increase and decrease in the

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volume of gas for each variable, this is because the anaerobic process is very dependent on the activity of microorganisms that are very susceptible to fluctuations. The results of the experiment showed that at HRT of 20 days biogas production within 3 days produced an average volume of 1,137 ml/day. Then the observation was continued until the 5th day, there was an increase in biogas production to obtain a volume of 3,500 ml/day. Biogas production was observed until from the 5th day to the 15th day of biogas production had reached a stable with an average volume of 2,750 ml/day. This stable production is called to be a steady state condition. At 30 days HRT, the experiment was observed in up to 9 days, the average biogas production was 1,100 ml/day and this production was almost stable. Then from 9th day to 15th there was an increase in biogas production on average reaching 1,815 ml/ day. To optimize and accelerate biogas production addition of starter are needed, in this study biogas on day 1-3 has been formed biogas because previously it has used cow manure starter. The addition of starter in the biogas formation process can increase biogas production. Cow manure used for starter because it contains bio-decomposer bacteria that can support biogas production. The bacteria found in cow manure are cellulolytic bacteria which can increase biogas production by 8.4-44%.

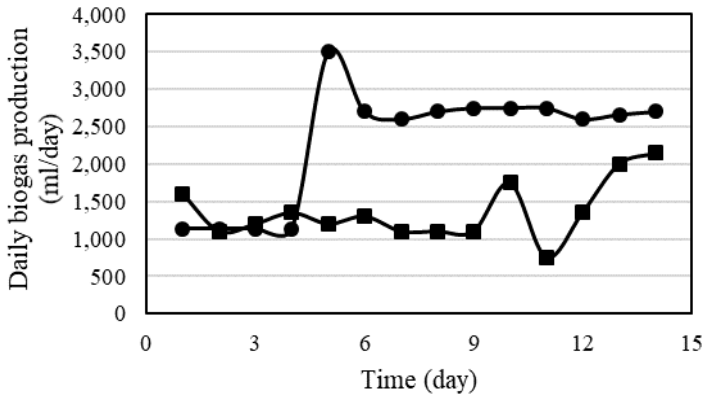

Figure 2. Effect of hydraulic retention time (HRT) on daily biogas production. *Note* : ● = HRT of 20 day; ■ = HRT of 30 day.

Effect of hydraulic retention time on cumulative biogas production is shown in Figure 3. The results show that at HRT of 20 days, cumulative production biogas was obtained to 32,260 ml, however, at HRT of 30 days cumulative biogas production was 19,050 ml.

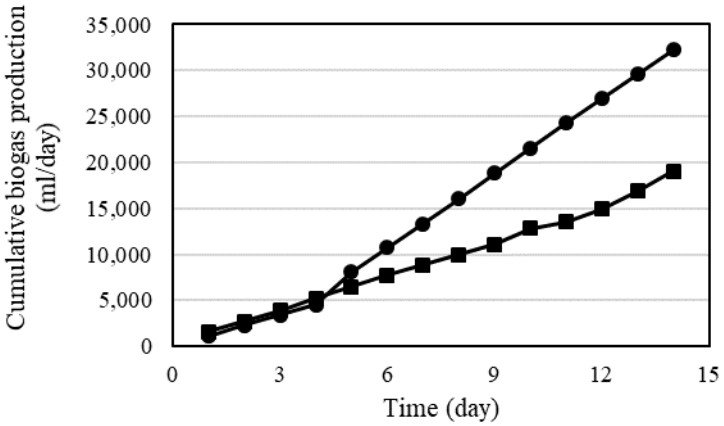

Figure 3. Effect of hydraulic retention time (HRT) on cumulative biogas production. *Note* : ● = HRT of 20 day; ■ = HRT of 30 day.

Figure 4 shows The effect of hydraulic retention time on gas production. The results show that gas production at HRT of 20 days produced CH_4 (39.37%), CO_2 (9.99%), H_2S (0.43%), NH_3 (0.20%) , while at HRT of 30 days gas production was CH_4 (35.64%), CO_2 (11,60%), H_2S (0.29%), NH_3 (0.20%).

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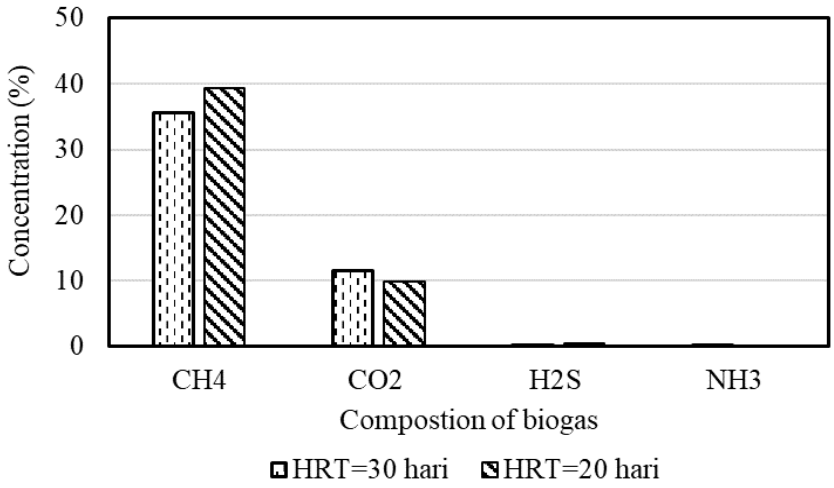

Figure 4. Effect of hydraulic retention time (HRT) on gas production.

Conclusion

Tofu liquid waste has a potential to produce biogas. An average biogas production was 1,815 ml/day for HRT of 30 days, and the average daily biogas production was 2,750 ml/day for HRT 20 days.Biogas production at HRT of 20 was CH_4 (39.37%), CO_2 (9.99%), H_2S (0.43%), and NH_3 (0.20%), and at HRT of 30 was CH_4 (35.64%), CO_2 (11,60%), H_2S (0.29%), and NH_3 (0.20%), respectively.

Acknowledgment

The authors would like to thank the Department of Industrial Chemical Engineering supports a Laboratory Facility.

List of Notation

BOD = biochemical oxidation demand [mg/l]
COD =chemical oxidation demand [mg/l]
HRT = hydraulic retention time [day, hour]
P = pressure [atm]
TOC = total organic carbon [mg/l]
TON = total organic carbon [mg/l]
T = temperature[^oC]

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Lembar Tanya Jawab

Moderator : Aspiyanto (Lembaga Ilmu Pengetahuan Indonesia, Serpong)
Notulen : Indriana Lestari (UPN "Veteran" Yogyakarta)

1. Penanya : Aspiyanto (LIPI Kimia, Serpong)
   Pertanyaan : Kotoran sapi seperti apakah yang digunakan dan indikator apa yang menunjukkan terbentuknya biogas, serta apakah penelitan ini sudah diaplikasikan secara langsung?
   Jawaban : Kotoran sapi yang digunakan adalah kotoran sapi segar. Indikator terbentuknya biogas adalah dengan menggelembungnya plastik yang dipasang di pipa pengeluaran produk. Biogas dari limbah cair tahu ini belum diaplikasikan secara langsung untuk kebutuhan bahan bakar, namun sudah dilakukan uji nyala api.

2. Penanya : Hotden Manurung (Universitas Gadjah Mada)
   Pertanyaan : Mengapa pada grafik HRT selama 20 dan 30 hari volume biogas yang dihasilkan naik-turun dan mengapa data yang disajikan hanya 15 hari, serta penelitian ini dilakukan berapa kali percobaan/pengulangan?
   Jawaban : Grafik efek HRT terhadap produk biogas hanya ditampilkan selama 15 hari, karena waktu optimal dan kondisi yang paling stabil diperoleh pada hari ke 9 – 15. Ketidakstabilan grafik selama proses *anaerob digestion* dikarenakan sifat dari mikroorganisme tersebut, dan penelitian ini hanya dilakukan 1 kali percobaan dikarenakan sistemnya kontinu.

3. Penanya : Aspiyanto (LIPI Kimia, Serpong)
   Pertanyaan : Pada saat fermentasi, bagaimana cara mengontrol semua parameter tetap akurat agar mikroba tetap stabil, sehingga kondisi naik turun tersebut dapat diminimalisir?
   Jawaban : Dalam prosesnya, selalu dilakukan pengukuran terhadap parameter suhu, pH limbah cair tahu, juga rasio C/N, sehingga biogas yang dihasilkan dapat optimal.

4. Penanya : Renung Reningtyas (UPN "Veteran" Yogyakarta)
   Pertanyaan : Terkait dengan aktivitas bakteri, di dalam proses fermentasi muncul bau tidak sedap, zat apa yang menyebabkan bau tak sedap tersebut?
   Jawaban : Timbul bau tidak sedap disebabkan karena terbentuknya gas amoniak dan H_2S.