Biogas production of tomato sauce wastewater by batch anaerobic digestion

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Biogas Production of Tomato Sauce Wastewater by Batch Anaerobic Digestion

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Abstract. The wastewater of tomato sauce production is a degradable and contains high organic compounds. Treatment for high content organic compounds is effectively treated through anaerobic treatment. High organic content is also a potential to produce biogas. The ultimate point of this research is to evaluate the influence of mass of activated sludge and the concentration of organic compounds (COD) to the production of biogas. The research is conducted in batch process in 2 L reactor, MLSS concentration was 12,000 mg/L, room temperature, atmospheric pressure, and pH of 7-7.5. Research variables were the volume of active sludge (40%-80% of the reactor), the concentration of synthetic wastewater (5,000 – 17,000 mg/L) and the response was the volume of biogas. The obtained result indicated that the highest biogas production achieved when volume of activated sludge applied of 80%, the higher the activated sludge the higher the content of microbes, hence it was also required high organic compound. While the effect of COD's wastewater concentration on biogas production, the higher the COD concentration will significantly increase the biogas production.

Keywords: tomato sauce, anaerobic, activated sludge, organic compound, and biogas.

INTRODUCTION

Wastewater of tomato sauce industries is produced during the production process. The characteristics of wastewater tomato sauce contains high COD concentration (> 16,000 mg/L) [1], suspended solids, dissolved organic compounds, microorganisms and inorganic salts. When, there is no treatment, high organic content will absorb oxygen in the aquatic and deteriorate the aquatic environment [2] and this wastewater is classified as food waste with high degradable compound [3,4,5]. In a world with depleting energy due to the limited resources, the amount of food waste generated from this industries everyday requires to move towards sustainable development. This wastewater, rich in organic acids, constitutes an ideal source for bioenergy recovery [6].

Anaerobic digestion, a biological process to convert of organic matter into methane, carbon dioxide, inorganic nutrients and humus-like matter, is the most promising method for FW treatment [7]. Compared to the aerobic method, the use of anaerobic processes for treatment of wastewater provides greater economic and environmental benefits and advantages [8]. Anaerobic digestion technology is a famous method for waste utilization. This tend to develop the various configurations of the reactor type have been developed thus far. The most simple and prominent reactor design is the single stage process and it has been widely used in various applications. However, its disadvantage of low efficiency has been highlighted [9].

In recent research of anaerobic digestion systems, organic matter/compound is converted into biogas, a mixture of gaseous compounds, mainly methane (CH_4) and carbon dioxide (CO_2), through acid fermentation and volatile fatty acids (VFAs) degradation, and through the activity of two groups of microorganisms: acid and methane-forming bacterial biomass [10]. In a reactor single system or one-stage anaerobic digestion, two type of microorganisms are kept together in a balance situation, which is delicate, due to both groups differ in terms of physiology widely, nutritional requirements, growth kinetics, and sensitivity towards environmental conditions [11].

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In the reactor of single system, previous research indicated that the pH prevailing in single reactor anaerobic digestion systems (pH between 7 and 8) did not provide optimal growth conditions for type of acidifying hydrolytic bacteria, inefficient hydrolysis/fermentation rates (especially for slowly degradable lignocellulosic substrates) and, diminishing biogas production [12]. Nevertheless, single reactor anaerobic digestion is a well-established system for the treatment of organic wastewater, characterized by a simple set-up and relatively limited cost of investment and operation, and applied to the most of the full-scale digestion plants in Europe (90% of the installed anaerobic digestion capacity) are designed and operated as one-stage systems [13]. A major information with single reactor anaerobic digestion is that the produced biogas is frequently reported to display a poor quality in terms of its calorific value [14,15].

The objective of this research is to evaluate the wastewater of tomato sauce in producing biogas due to rich of organic matter that easily to convert to biogas. The single reactor system applied to the research with consideration of the limiting land availability. The reactor was batch reactor and the biogas production will be observed on the various concentration and MLSS of activated sludge.

MATERIAL AND METHOD

Wastewater Preparation

In this research, the model wastewater is a synthetic wastewater made from product of tomato sauce due to difficulty to obtain the real wastewater from the tomato sauce plant. The real wastewater may be difficult to maintain the similar concentration but by using the product of tomato sauce product as synthetic wastewater the concentration can be kept constant at the certain concentration. Certain weight of the tomato sauce product dissolved to the distilled water and check the COD concentration, based on this concentration, the COD concentration for research can be calculated the requirement of the tomato product to dissolve in the water.

Acclimatization of Activated Sludge

Activated sludge was obtained from the anaerobic tank of wastewater plant. The wastewater plant was Centralized Wastewater Treatment Plant of Tofu and Tempe in Lamper Tengah Semarang [16]. Activated sludge was taken from the middle of the anaerobic tank by water sampler and collected to the tank to separate sludge and water, drain the water and obtain concentrated sludge. The sludge was carried out to the laboratory to acclimate. Acclimatization was conducted for 1-2 month by addition of sucrose 5 g/L. After acclimatization, the sludge was set up for MLSS of 12,000 mg/L for enrolling the research.

Experimental set up

2 L volume of polyethylene bottles were used for anaerobic digester (Figure 1). The top of the bottles was plug with rubber plug and equipped with a pipe hole for biogas measurement. The anaerobic digesters operated at the batch system and room temperature, and initial pH of 7.0-7.5. The measurement of biogas produced by using liquid displacement method [17]. Figure 1 showed that each digester was connected to a gas collector and the volume gas produced can be obtained due to the scale of glass cylindrical. Each gas collector immersed in the water of cylindrical glass to ensure complete sealing of the system.

Experimental design

Anaerobic digestions of experimental laboratory using 2-liter volumes were operated in batch system. The design of experimental was ratio of activated sludge and wastewater. The first was to observe the biogas production at the COD of wastewater around 5,000 mg/L and ratio volume of activated sludge and wastewater of 40 – 80 %. This useful to obtain the optimum ratio of activated sludge and wastewater. Secondly, based on the optimum ratio of sludge and wastewater, the experiments were conducted to the highest biogas production with several of COD wastewater concentration (10,000 – 17,000 mg/L). Nutrients for microorganism were based on the COD concentration, addition of nutrients for anaerobic digestion followed the ratio of COD : N : P = 300 : 5 :1 [16]. pH adjustment for the system was used NaOH or HCl solution of 2 N drop by drop, both NaOH and HCl were technical grade.

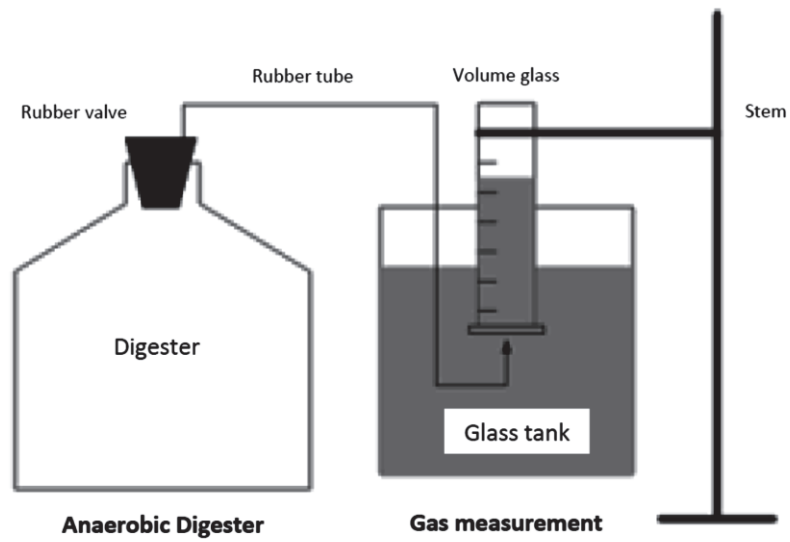

Figure 1. Experimental set up for batch-anaerobic digestion

EXPERIMENTAL PROCEDURES

Fermentation of anaerobic done in 15 days (retention time) for the time of the first variable to obtain optimum condition of activated sludge. This is because the wastewater is classified as high degradable compound, hence, with duration of 15 days was considered able to achieve maximum biogas production. While, for second variables, to obtain maximum biogas production with optimum activated sludge and various COD wastewater concentration, the researches were conducted in 30 days of retention time. In this research, each digester was manually mixed for one minute per day. Biogas produced was measured every three days by reading the scale of glass volume.

RESULT AND DISCUSSION

Figure 2 shows the biogas production cumulative curve and the evolution over time of the biogas content in the gas produced. The operating pH was not controlled during the digestion, the selection of pH values of 7,0-7,5 based on the fact that at the pH of 7.3–7.8 were found to lie within the recommended range for methanogenesis (6.5–8) [18] for the entire duration of the experiments.

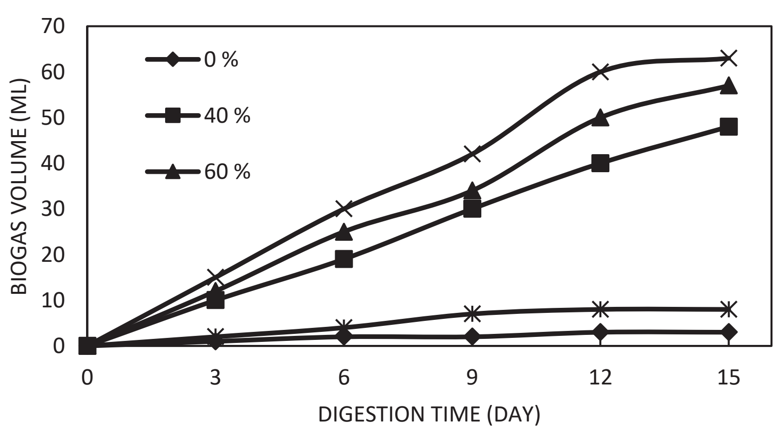

Figure 2. Biogas production for various percentage of activated sludge with COD wastewater of 5,000 mg/L.

The time of digestion until 15 days while other authors [5,19,20], only 50 hours under similar batch operation condition. This condition assumed that the formation of biogas through four steps of anaerobic digestion was taken place completely. The control of the research is the 100 % wastewater concentration and 100 % of activated sludge.

Data obtain from the experiments indicated that both control parameters were not significantly in the biogas production. The biogas product of the activated sludge was higher than of 100 % of wastewater because the 100 % of activated sludge still has organic carbon as a resource of microorganism which can be converted into biogas. While for 100 % of wastewater there was no media or microorganism to convert into simple compound or biogas.

Biogas production obtained as view in Figure 2 has correlation with the mass of activated sludge. Increasing the activated sludge resulted the higher biogas production. Degradation of wastewater was occurred in the early time of observation, there was no flat curve which indicated the acclimatization process of the activated sludge to degrade organic matter. Range of the MLSS for treatment of wastewater is 40-70 % high, the higher of the sludge would be easy to wash out. Increasing MLSS from 40 % to 80 % resulted the higher biogas production. At 80 % sludge indicated that stationary condition would almost be achieved by the last two data at 80 % while for 40 and 60 % the graph tend to elevate and did not reach the stationary condition. It means that at the 80 % the main part organic matter has been degraded. Based on this data, the next MLSS portion for optimization was 80 %. At 80 % of sludge shows that the equilibrium at this condition has been achieved between the wastewater and MLSS. Food waste with mainly the composition in terms of carbohydrates, proteins, and lipids, this product of biogas less than other authors because system one-stage produced biogas is frequently reported to display a poor quality in terms of its calorific value [14,15]. While Browne and Murphy [20] observed of 358 NL CH4/kg VS in batch test on food waste, El-Mashad and Zhang [21] attained of 353 NL CH4/kg VS from food waste.

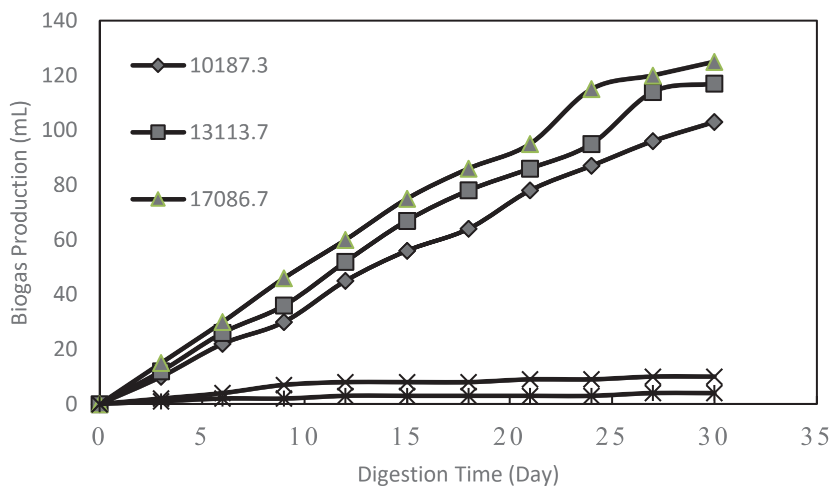

Figure 3. Biogas production for various COD wastewater concentration at percentage of activated sludge of 80 %.

Figure 3 resulted from the data of experimental, the control of 100 % sludge and 100 % of wastewater was similarly to the result of the Figure 2, low product of biogas obtained due to no wastewater as a source of carbon for microorganism and no sludge as a media to degrade the wastewater [22]. This indicated that to produce biogas, the wastewater and sludge must be contacted to maintain the life of microorganism and to produce biogas. At the sludge of 80 % volume of the reactor and with variables of COD wastewater concentration of 10,000 to 17,000 mg/L, the system indicated that anaerobic digestion occurred since in the early stage, there is no lag phase for microorganism growth that indicated the bacteria required a condition to adapt the wastewater, and it was also indication that the synthetic wastewater applied for this research is highly degradable [23].

For 30 days digestion showed that with the wastewater concentration of 10,000 to 17,000 mg/L, the graph has not been achieved stationary yet, the graph is still elevating. Budiyono et al. [24] suggested that the digestion time for anaerobic digestion done in 60 days, hence, the data can be treated as a trendline of biogas production or also modelling the biogas. This graph also showed that the system is still able to receive wastewater with higher COD concentration of 17,000 mg/L. Increasing the COD concentration of 10,000 – 13,000 – 17,000 mg/L resulted the biogas production increase with the different of elevation proportionally. Based on the biogas production of tomato sauce wastewater, it is more advantageous that to produce biogas before treated this wastewater anaerobically.

CONCLUSION

At the condition of MLSS of 12,000 mg/L and ratio of sludge to COD wastewater of 40 to 80 % volume can be conluded :

1. 1. At the ratio of 80 % volume of sludge, the COD wastewater of 5,000 mg/L, is a condition that all organic matter has been degraded completely.
2. 2. At the sludge of 80 %, with the COD concentration of 17,000 mg/L until 30 days, there is no stationary condition achieved.
3. 3. The high MLSS (80 %) gives advantageous to produce biogas and also to reduce the COD content of wastwater.

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REFERENCES

1. Cassini AS, I.C. Tessaro, L.D.F. Marczak, C Pertile, 2010 Journal of Cleaner Production 18: 260-265
2. Wang K., Jun Yin, Dongsheng Shen, and Li Na, 2014 Bioresource Technology, Vol. 161 (395-401)
3. Zuo, Z., Wu, S., Zhang, W., Dong, R., 2014, Bioresource Technology 162 (2014) 266–272
4. Zhang, L., Y.W. Lee, D. Jahng, 2011 Bioresour. Technol. 102:5048–5059, doi:http://dx.doi.org/10.1016/j.biortech.2011.01.082.21349706.
5. Zhang, P., Che-Jen Lin, James Liu, Pruek Pongprueksa, Peter Hart, Simon A. Evers, 2014, Renewable Energy 68 : 304-313
6. Ahamed, A., Chen, C.L., Rajagopal, R., Wua, D., Mao, Y., Ho, I.J.R., Lim, J.W., Wang, J.Y. 2015. Bioresource Technology, 182 : 239–244.
7. Pirsaheb, M., M. Rostamifar, A.M. Mansouri, A.A.L. Zinatizadeh, K. Sharafi. 2015 Journal of the Taiwan Institute of Chemical Engineers, 47 : 137–148.
8. Mohan, S., Bindhu, B.K., 2008 J. Environ. Eng. Sci. 7 (2), 91–103.
9. Ke, S., Shi, Z., Fang, H.H.P., 2005 Int. J. Environ. Pollut. 23 (1), 65–80.
10. Zhang, Q., Hu, J., Lee, D.J., 2016 Renew. Energy 98, 108–119. http://dx.doi.org/10.1016/j.renene.2016.02.029.
11. Demirel, B., Yenigün, O., 2002 J. Chem. Technol. Biotechnol. 77, 743–755. http://dx.doi.org/10.1002/jctb.630.
12. Giovannini, G., Donoso-Bravo, A., Jeison, D., Chamy, R., Ruíz-Filippi, G., Vande Wouver, A., 2016 Int. J. Hydrogen Energy, 1–10. http://dx.doi.org/10.1016/j.ijhydene.2016.07.012.
13. Rapport, J.L., Zhang, R., Williams, R.B., Jenkins, B.M., 2012 Int. J. Environ. Waste Manage. 9, 100. http://dx.doi.org/10.1504/IJEWM.2012.044163.
14. Zhang, D., Zhu, M., Zhou, W., Yani, S., Zhang, Z., Wu, J., Zhang, D., Zhu, M., Zhou, W., Yani, S., Zhang, Z., Wu, J., 2015 Handbook of Clean Energy Systems. John Wiley & Sons Ltd, Chichester, UK, pp. 1–17. http://dx.doi.org/10.1002/9781118991978.hces003.
15. Sunyoto, N.M.S., Zhu, M., Zhang, Z., Zhang, D., 2016 Bioresour. Technol. 219, 29–36. http://dx.doi.org/10.1016/j.biortech.2016.07.089.
16. Sumantri, I., Purwanto, and Budiyono., 2015 AIP Conference Proceedings 1699, 050017.
17. Syaichurrozi, I., Budiyono, B. & Sumardiono, S. 2013 Bioresource Technology, 149:390-397.
18. Mtz.-Viturtia, A., Mata-Alvarez, J., Cecchi, F., 1995 Resour. Conserv. Recycl. 13, 257–267. http://dx.doi.org/10.1016/0921-3449(94)00048-A.
19. De Gioannis, G., Muntoni, A., Polettini, A., Pomi, R,., Spiga, D, 2017 Waste Management 68 (2017) 595–602

20. Browne, J.D., Murphy, J.D., 2013 Appl. Energy 104, 170–177. http://dx.doi.org/10.1016/j.apenergy.2012.11.017.
21. El-Mashad, H.M., Zhang, R., 2010 Bioresour. Technol. 101, 4021–4028. http://dx.doi.org/10.1016/j.biortech.2010.01.027.
22. Dhamodaran, K., Ajay, S.K., 2014 J.Env Chem Eng.Sci. vol.2, pp.1821-1830
23. Niu, Q., Qiao, W., Qiang, H., Hojo, T., Li, Y.Y., *Bioresour. Technol.* **137**, 358–367 (2013).
24. Budiyono, Widiasa, I.N., Johari, S., Sunarso, *Int. J. Chem. Biol. Eng*. **3(1)**, 39–44 (2010)