Gas production in anaerobic dark-fermentation processes from agriculture solid waste

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Abstract. Approximately, Bandung produces agricultural solid waste of 1549 ton/day. This wastes consist of wet-organic matter and can be used for bio-gas production. The research aimed to apply the available agricultural solid waste for bio-hydrogen. Biogas production was done by a serial of batches anaerobic fermentation using mix-culture bacteria as the active microorganism. Fermentation was carried out inside a 30 L bioreactor at room temperature. The analyzed parameters were of pH, total gas, temperature, and COD. Result showed that from 3 kg/day of organic wastes, various total gases of O2, CH4, H2, CO2, and C8H16O2 was produced.

1. Introduction

Domestic solid waste is produced by people activities and serves as problem if there is no available space and technology for further handling and treatments. Many cities in the world have to face the problem to handle and treat their domestic waste in line with the increase of population. A proper technology is needed to manage and to treat the domestic waste, but unluckily the lack of funding for a proper infrastructure and management make this all more difficult.

Problems of waste can be generated as a result of population increases every year, the infrastructure is reduced, the development of the region urban, human resources are insufficient, the management system of waste management has not been good, limited land for waste disposal, lack of environmental education in the community, particularly the issue of waste and lack of understanding of the importance of protecting the environment and others [1].

Data in the Ministry of Environment (MOE) in 2010 states, the average volume of garbage in Indonesia reached 200,000 tons per day. Urban areas accounted for most trash. This is due to many factors, including population growth and urbanization. If the waste problem is not immediately addressed then in 2020 the volume of waste in Indonesia will increased to be five-fold or 1 million ton pile of garbage a day. In developed countries of whom people more aware for environment and supported by modern technology, solid waste is managed properly.

General garbage can be divided into organic and inorganic waste. The organic waste can rapidly decompose, such as food scraps, vegetable and fruits, and some part can be degraded slower like dried leaves, twigs and so forth. Inorganic wastes such as rubber, paper, cans, plastic, food wrappers, and glass are difficult to unravel or not easily decompose naturally. The dispose of waste will increase continuously. In order to reduce pollution, waste management is indispensable. Alteration of organic waste for energy resources sounds very interesting and beneficial.

Using anaerobic process, domestic solid waste produces biogas which is useful as energy source for cooking, heating or electricity. More hydrogen gas as alternative energy sources can be produced by anaerobic modification. Biogas derived from wet vegetable and fruits waste has been studied [2,3]. Hydrogen production by dark hydrogen fermentation is increasing [4]. Bio-hydrogen production has been done using biomass as sources for fermentation from sweet potatoes starch residues [5], molasses [6], tofu solid waste [7], sweet buckwheat [8], sweet melon [9], wheat straw [10], food wastes [11,12,13,14], starch [15], and waste and wastewater [16,17,18]. It was reported that mixed culture microorganisms is more valuable rather than single or pure culture for bio-hydrogen production. A controlled environment condition such as pH and temperature is strictly required [19] as well as hydraulic retention time (HRT) to reduce H2 – consuming bacteria [20,21,22]. The current study aimed to use agricultural organic waste and mixed culture bacteria of which naturally available in waste as well as invulnerable condition for high rate bio-hydrogen production.
2. Experimental

2.1. Material
The material used for media solution was purchased by Merck, such as yeast extract, buffer solution, Chemolithotropic Growth H-3 (DSM Catalogue), and trace element SL-6. The mixed culture microorganism was available in the laboratory and re-activated.

2.2. Method

2.2.1. Biomass waste
Biomass waste was collected from traditional fresh market garbage in Caringin, Bandung. Organic waste was crushed and blended by mechanical shredder to be smaller size as the feeding sludge. Biomass sludge was used for substrate in anerobic digestion bio-reactor. Feeding of organic agricultural sludge to bioreactor was of 3 kg per 10 days intermittently during 70 observation days.

2.2.2. Bioreactor
Bioreactor capacity was 30 L consisted of feeder and digester of 0.5 HP and electric Pump (40 L/min capacity). This pump serves to feed substrate into bio-reactor properly as well as to circulate substrate and to optimize the process. Bioreactors operated intermittently.

2.2.3. Mixed culture bacteria and growth media
As much as 100 ml of bacterial suspension from stock culture of mixed bacteria was inoculated in Erlemeyer containing of 1 L sterilized growth media. Growth media consisted of K2HPO4 750; KH2PO4 = 850; (NH4)2SO4 = 40; MgSO4.7H2O = 200; CaCl2.2H2O = 0.75; Co (NO3)2.6H2O = 290; Fe (NH4)2SO4.6H2O = 10; MnCl2.4H2O = 2.1; Na2MoO4.2H2O = 0.75; H3BO3 = 2.8; Cu (NO3)2.3H2O = 0.04; Na2EDTA.2H2O = 2.0; Nicotinic acid = 0.025; and Yeast Extract = 0.003 mg.L-1. Trace element SL-6 = 5 ml. Total usage of inoculum in bioreactor was 10% (v/v). In order to optimize the production of biohydrogen, temperature was maintained (25-30°C, pH 5.6-6.5). Addition of NaOH 3N was carried out to increase pH whereas the addition of HCL 3N was required to decrease pH.

2.2.4. Sample analysis
As much as 100ml per day of sample recovered from bioreactor outlet was required for analysis. Parameter analysis in this study was as of:
- **pH and Temperature**: pH of sample was measured by using pH-meter (LT Lutron pH-207) whereas temperature was measured by using Hg thermometer. Bioreactor was operated at room or ambient temperature about 25-28°C without setting. pH valued was adjusted to 5.6-6.5.
- COD was measured based on the standard methods for water and wastewater (APHA, 2005) with a UV-VIS Spectrophotometer (Shimadzu GC14-A, Japan). The measured sample was on the filtrate COD.

2.2.5. Gas analysis
Gas composition and its analysis were carried out using gas analyzer of Cubic gasboarrd - 3100 P infra red syngas RRC.

3. Result and discussion
During the experiment, the feeding solid concentration was constant at 2.4%. Figure 2 shows the fluctuation of dry matter in the reactor. Average total solid concentration in reactor increased slowly from 2 to 3% in the I-IV batch (10 days for each batch), but it increased to 4.5% in batch VI and then decreased to 3.5%. It showed accumulations of organic solid material in reactor during experiment.

![Figure 2. Total solid concentration in the reactor during observation days.](image)

The expectation in anaerobic hydrolysis process is the liquefaction of organic solid material and production of hydrogen gas. Liquefaction of organic material to liquid could be observed in the concentration of filtrate or dissolved COD (Figure 3). Dissolved COD was increased during observation days from initial concentration of 62 to 114 g/L in the first batch. The concentration was fluctuated in the second batch, but then it tended to increase up to 200 g/L. After second batch the trend of COD fluctuation was like a bacterial growth curve, especially in the fourth, fifth to sixth batches.

![Figure 3. Concentration of filtrated COD during observation days.](image)

Figure 4 shows the total solid and dissolved COD concentration. It is estimated that the first 30 days (3 batches) was the start-up process. In this period the anaerobic bacteria adapted to the feeding. After the third batch hydrolysis process became stable. The curve in each batch showed
microbial activities from the log phase, a short stationary phase, and death phase. These estimations were supported by the result of hydrogen production per batch.

Figure 4. H$_2$ accumulation produced per batch during observation days.

Figure 5 shows concentration of hydrogen gas in each batch. In the first three batches, H$_2$ concentration was lower than 2% then increased in the next batches with the curve form looked like bacterial growth. H$_2$ concentration increased up to 14%. Gas production could be used as indicator for anaerobic microbial activities in the reactor. As the H$_2$ concentration was tended to increase during experiment days, it was measured in the batch V, VI and VII the methane production was increased to 4-6 L at the end of each batch. The methane content in the gas could indicate the activities of methanogenic bacteria.

Figure 5. H$_2$ concentration during observation days.

It is important to adjust pH of 5.6 – 6.5 to produce effective conditions for microorganisms to produce hydrogen [5,17,19].

4. Conclusion
In current study, hydrogen production is not expected since the research was carried out in a few months and was of as early level. This conditions were in the process of acclimatization of which bacteria was adapting inside bioreactor. After lag phase period, the serial of batches hydrogen production increased after 30 days. After fourth batch, hydrogen was increased significantly.

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6. References

[1] Widiatmoko, Aji 2011 Scientific papers of Partnership, BAPPENAS.
[2] Sirodjuddin, Ardan. 2011 Pemanfaatan Sampah. Suistaining Partnership, (IRSDP) BAPPENAS.
[3] PD. Kebersihan Kota Bandung 2015. Condition of trash Bandung. Final report JICA 2010
[4] Z. Rasidi., Tabassum Mumtaz, Nor’Aini A., M. Ali Hasan 2012 Int. J. Hydr. Energy. 37 p 17724-17730
[5] Fajar A. Pamungkas and Rudiana Agustini 2014 UNESA J. Chemistry 3, No 1.
[6] Nanqi Rena, Jianzheng Lia, Baikun Lib, YongWanga, Shirui Liua. 2006 Int. J. Hydr. Energy. 31. 2147 – 2157
[7] Amir Husin, Sarto, Siti Syamsiah, dan Imam Prasetyo 2014. J. Rekayasa Proses. 8(2).
[8] Eddy Tri Widyastuti 2011 Thesis. Sekolah Pasca Sarjana. Institut Pertanian Bogor.
[9] Nurkholis, Sarto, Muslikhin Hidayat 2016 J. Inovasi Teknik Kimia, 1(2), 78-83
[10] Prasad Kaparaju , Maria Serrano, Anne Belinda Thomsen, Prawit Kongjan, Irini Angelidaki 2009 J. Bioresource Technol. 100. 2562–2568.
[11] H.M.Y Nazlina, A.R. Nor Aini, F.Ismail, M.Z.M Yusof and M.A. Hasan 2009 Asian. J. Biotechnol. 1(2); 42-50.
[12] Sun-Kee Han, Hang-Sik Shin 2004 J. Hydrogen Energy 29. 569 – 577
[13] Hang-Sik Shina;Jong-Ho Younb, Sang-Hyoun Kim 2004 Int. J. Hydr. Energy. 29. 1355-1363.
[14] Steven W. Van Ginkela, Sang-Eun Oha, Bruce E. Logan 2005 Int. J. Hydr. Energy. 30 1535-1542
[15] Tong Zhang, Hong Liu, Herbert H.P. Fang. 2003. J. Environ. Management. 69, 149-156
[16] Ilgi Karapinar Kapdan, Fikret Kargi 2006 Enz. and Microbial. Technol. 38 569–582.
[17] S. Venkata Mohan, Y. Vijaya Bhaskar, P. Murali Krishna, N. Chandrasekhar Rao, V. Lalit Babu, P.N. Sarma 2007 Int. J. Hydr. Energy 32 2286-2295
[18] Shihwu Sung, Dennis A. Bazylinski, Lutgarde Raskin 2003 Hydrogen, Fuel Cells, and Infrastructure Technologies. FY Progress Report
[19] Arief Wijaya, 2009 Proceeding of National Conference of Indonesia Chemical Engineering, Bandung. Pp. 19-20.
[20] D. Levin, R. Sparling, N. Cicek, R. Islam, 2005 Proceedings International Hydrogen Energy Congress and Exhibition IHEC: Istanbul, Turkey, 13-15 July 2005
[21] Yao-Ting Fan, Ya-Hui Zhang, Shu-Fang Zhang, Hong-Wei Hou, Bao-Zeng Ren. 2006 J. Bioresource Technol. 97 500–505.
[22] Mao-Lin Zanga, Yao-Ting Fana, Yan Xinga, Chun-Mei Pana, Gao-Sheng Zanga, Jiunn-Jyi Lay 2007 J. Biomass and Bioenergy. 31 250–254.