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Estimation of energy and organic fertilizer generation from small scale tapioca industrial waste

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Abstract. The main of tapioca industrial wastes are cassava fiber, cassava skin, and wastewater. To increase the revenue of tapioca industry, cassava fiber was also extracted to produce energy and the effluent of biogas plant was utilized as organic fertilizer. The aims of this research were to estimate energy generation from tapioca wastewater and cassava fiber and also to estimate Nitrogen and Phosphorous potential from the effluent of biogas plant. This research was conducted in a tapioca factory which was equipped with biogas plant, in Lampung Province, Indonesia. Concentration of COD (Chemicals Oxygen Demand), Total Nitrogen (TN) and total Phosphorous (TP) were measured in the inlet and outlet of biogas plant. Enhancement of biogas production from cassava fiber was also estimated. Flow rate of wastewater and cassava fiber production were also measured. Wastewater generation is 2.75 m3/ton of cassava with COD 9,647.5 mg/l. Electricity production was estimated about

29.96 kWh and 30.44 kWh per ton of cassava from the wastewater and cassava fiber, respectively. The observed tapioca factory could be fulfilling energy needs for drying tapioca process if they utilized wastewater and cassava fiber. The effluent of biogas plant also still has potential to produce about 1.15 and 0.05 kg of TN and TP per ton of cassava, respectively. 1. Introduction Lampung Province was well known as the biggest producer of Cassava (Manihot esculenta Crantz.) in Indonesia. Cassava production in Lampung Province at 2015 was about 7,387,084 ton [1]. Cassava tuber is raw material of tapioca, bioethanol, food, and other industries. Dealing with tapioca processing, mainly cassava was processed to become tapioca and some derivative products. Currently, almost all tapioca factory in Lampung Province have been utilized their wastewater for generating biogas energy. The biogas energy was used for generate electricity and/or for drying the tapioca starch. The 1small scale tapioca factory usually only use the biogas energy for drying tapioca starch and sometimes the energy is not enough to fulfilling their energy demand. They need additional resources, such as cassava fiber to get more biogas energy. Solid biomass that is generated from tapioca processing in form of skin, tips, and onggok (Cassava fiber) are used for cattle feed. There is no significantly effort yet to utilize this biomass for other 2International Conference on Green Agro-industry and Bioeconomy IOP Conf. 1Series: Earth and Environmental Science 230 (2019) 012084 IOP Publishing doi:10.1088/1755-1315/230/1/012084 2 important purposes like energy source. The potential of implementation low carbon and zero discharge could be generated from tapioca wastewater. Renewable energy was generated from tapioca wastewater through anaerobic digestion by converting organic matters to methane gas. Tapioca factory wastewater has very high amount and concentration of organic matter [2]. 3The methane potential of tapioca industry has investigated using laboratory scale equipment, measured this potential for effluent mixed with cow dung and urea [3]. The methane potential from anaerobic sludge obtained from an anaerobic pond of a tapioca starch factory was measured using a specific methanogenic activity test [4]. Biogas production rate in anaerobic ponds of tapioca starch factories was investigated [5]. Conversion technology to produce biogas from tapioca wastewater was develop and implemented in some tapioca industry, but utilization of cassava fiber together with tapioca industrial wastewater for producing more biogas was not investigated completely yet. We need some development on how to increased soluble material from cassava fiber which is easily to convert to biogas by anaerobic digestion. The effluent of biogas plant needs additional treatment to fulfilling the national effluent standard. Anaerobic digestion of tapioca wastewater under biogas plant usually only reducing COD about 90%, it is not enough to fulfilling the national effluent standard [6]. Under anaerobic digestion mainly only carbon based organic matters was decomposed become methane and carbon dioxide. The effluent of biogas plant is still containing nitrogen, phosphorous, and some others minerals which is could be used as a liquid organic fertilizer and at the same time will prevent eutrophication [7]. The risk of utilization of wastewater for land application was investigated [8] but benefit potential of the biogas plant effluent in tapioca industry was not investigated yet. The objectives of this study were to estimated energy generated from the utilization of tapioca wastewater and cassava fiber. The possibility of the utilization biogas plant effluent as liquid fertilizer was also investigated. 2. Method Study was conducted in a small scale tapioca factory, PD. Semangat Jaya, village of Sri Rejeki, Sub District Negri Katon, District of Pesawaran, Lampung Province, Indonesia. Real production capacity, wastewater flow rate, and cassava fiber production were measured for several days' operation of the tapioca factory. The schematic diagram of sampling location was described in Figure 1. Flow meters were installed at inlet wastewater streams (Q) to measure the wastewater flow rate. Gas sample was also collected at outlet pipe line (G) of biogas plant to measure biogas composition. Secondary data from other tapioca industry which is has more accurate instrument to measure biogas production was also utilized to estimate potential biogas production. Wastewater sampling and laboratory analysis were conducted to measure pH, COD (Chemical Oxygen Demand), TN (Total Nytrogen), TP (total Phosporous) in some stream of wastewater treatment plant. Samples were collected at least 3 hours after tapioca factory start operation. Parameters, frequently, sampling location, and measurement methods in this monitoring system were described in Table 1. The schematic diagram of sampling location was described in Figure 1. Table 1. Parameters, frequency, sampling location, and method in monitoring system of tapioca wastewater. Parameter Frequency Sampling location Method pH 4 times Cin and Cout On-site Wastewater flow rate 6 times Cin COD 6 times Cin and Cout Analysis at laboratory TN 4 times Cin and Cout TP 4 times Cin and Cout 2International Conference on Green Agro-industry and Bioeconomy IOP Conf. Series: Earth and Environmental Science 230 (2019) 012084 IOP Publishing doi:10.1088/1755-1315/230/1/012084 3 Figure 1. Schematic diagram of sampling location. Pre-treatment technology was also developed to increase soluble material content of cassava fiber. Aspergillus niger was used as decomposer of cassava fiber to become more soluble material. Soluble COD was evaluated under different fermentation time and concentration of cassava fiber. 3. Result and Discussion 3.1. 1Energy generation from tapioca wastewater and cassava fiber The actual production capacity of the observed tapioca factory was about 27.150 ton of cassava per day and produced 74.55 m3 of wastewater. The wastewater was treated in biogas reactor to reduce the environmental load and produce biogas, simultaniously. The average of CODin and CODout are 9,647.5 mg/L of and 781.7 mg/L, respectively (Table 2). Table 2. Quality and 1flow rate of wastewater from observed tapioca factory. Observation number Processed cassava (ton/day) Wastewater generated (m3/day) CODin (mg/L) CODout (mg/L) 1 27.73 78.36 10,595 510 2 22.79 66.47 7,980 975 3 30.71 71.80 11,870 705 4 16.80 55.98 10,070 700 5 32.00 93.34 6,610 910 6 32.93 81.32 10,760 890 Average 27.16 74.55 9,647.5 781.7 Based on the measurement result, the average of wastewater production was 12.75 m3/ton of cassava. This value was quite low compare with other factories. The factory was implemented separation of wastewater from cassava washing and from extraction; the wastewater is from extraction only. COD concentration of wastewater is about 9,647.5 mg/l. This value was relatively low due to before enter to biogas reactor; the wastewater was entered in two steps of sedimentation pond. The sediment was collected before entering biogas reactor. The wastewater production rate and COD 10International Conference on concentration of the wastewater will used for estimated methane gas generated from tapioca wastewater. Methane gas generated from the wastewater was estimated using equation 1: (1) Where: CH4ww = methane gas generated from the tapioca wastewater (m3/day) CODin = COD concentration in the inlet of biogas reactor (mg/l) CODout = COD concentration in the outlet of biogas reactor (mg/l) Q = flow rate of wastewater (m3/day) 0.35 = potential of methane generated (m3/kg COD removal) [9] Using the equation we can estimate the potential of methane generated per day in the observed tapioca factory. Based on the potential of methane generated we can estimate energy generated from the wastewater. Table 3 described the potential of methane production and power generated from tapioca wastewater. Heating value of methane was used for calculate the energy generation from the wastewater using the following equation: (2) Where: P = Power generation (MW) LHv = Low Heating Value of methane (=35.8 MJ/Nm3) [10; 11] 0.35 = Conversion efficiency from biogas to electricity [11] Table 3. The potential of methane production, energy and power generated from tapioca wastewater. Observation number Cassava processed (ton/day) Methane Potential (Nm3/day) Heat Potential (MJ/day) Heat Potential (MJ/ton cassava) Power Potential (kW) Electricity Potential (kWh/ton cassava) 1 27.73 276.59 9,901.97 357.08 40.11 34.72 2 22.79 162.97 5,834.25 256.00 23.63 24.89 3 30.71 280.58 10,044.64 327.08 40.69 31.80 4 16.8 183.59 6,572.39 391.21 26.62 38.03 5 32.00 186.21 6,666.44 208.33 27.01 20.25 6 32.93 284.37 10,180.60 309.16 41.24 30.06 Average 27.16 229.05 8,200.05 308.14 33.22 29.96 Energy potential from the wastewater is relatively low and not enough for fulfilling the energy needs during drying process. Based on amount of water should be evaporated during drying tapioca is about 0.2 ton water/ton of cassava, the energy need for drying is about 450 MJ/ton of cassava. One of the other resources that have possibility to produce energy is cassava fiber.

Cassava fiber has potential to produce biogas through anaerobic digestion but need additional process to increase the soluble COD (SCOD). SCOD is easily biodegradable materials which are easy to convert to biogas thought anaerobic digestion. Aspergilus niger was used to digest insoluble organic matters become soluble organic matters. The effluent of biogas reactor was used to dilute cassava fiber and has succeeded to improve pH of cassava fiber solution. Soluble material also increases during 5 days fermentation with Aspergillus niger. Figure 2 described the increased of SCOD concentration after inoculation of 0.1% [2]International Conference on Green Agro-industry and Bioeconomy IOP Conf. [1]Series: Earth and Environmental Science 230 (2019) 012084 IOP Publishing doi:10.1088/1755-1315/230/1/012084 5 (v/v) of Aspergilus niger at different concentration of cassava fiber and fermentation time. Methane production potential from cassava fiber was could be estimated using equation 3 as follow:

(3) Where: CH_{4cf} = methane gas generated from the cassava fiber (m^3/day) SCOD = Soluble COD concentration (mg/l) R = SCOD removal during anaerobic digestion (95%) Cf = Cassava fiber production (ton/day) D = Dilution rate of cassava fiber Figure 2. SCOD concentration during fermentation with Aspergillus niger. Based on SCOD concentration in Figure 2, methane production potential from cassava fiber was estimated. Table 4 describes methane production potential from of cassava fiber after fermentation 120 hours. Using equation 2, power generation potential from cassava fiber also could be estimated. Table 5 describe energy and power generation from cassava fiber in tapioca factory. Methane production potential from 7.5% of cassava fiber solution was higher than that 10%, 5%, and 2.5% of cassava fiber solutions. To high concentration of cassava fiber hampered decomposition rate during fermentation. Further estimation was based on methane production potential from 7.5% of cassava fiber. Table 4. Methane production potential [1]from cassava fiber after 120 hours fermentation. Observation number Cassava processed (ton/day) Cassava fiber production*) (ton/day) Methane production (Nm^3) Cassava fiber 7.5% Cassava fiber 10% 1 27.73 11.80 241.71 223.86 2 22.79 9.70 198.65

183.98 3 30.71 13.07 267.69 247.92 4 16.8 7.15 146.44 135.62 5 32.00 13.62 278.93 258.33 6 32.93 14.01 287.04 265.84 Average 27.16 11.56 236.74 219.26 Note: *) Average yield of wet cassava fiber is 42.56% (based on other measurement). 2International Conference on Green Agro-industry and Bioeconomy IOP Conf. 1Series: Earth and Environmental Science 230 (2019) 012084 IOP Publishing doi:10.1088/1755-1315/230/1/012084 6 Table 5. Energy and power generation from cassava fiber in tapioca factory. Observation number Cassava processed (ton/day) Methane Potential (Nm3/day) Heat Potential (MJ/day) Heat Potential (MJ/ton cassava) Power Potential (kW) Electricity Potential (kWh/ton cassava) 1 27.73 241.71 8,653.29 312.06 35.05 30.34 2 22.79 198.65 7,111.73 28.81 3 30.71 267.69 9,583.21 38.82 4 16.8 146.44 5,242.52 21.24 5 32.00 278.93 9,985.76 40.45 6 32.93 287.04 10,275.97 41.63 Average 27.16 236.74 8,475.41 34.33 These results revealing that 1small scale tapioca factory could be increased the energy and power more than double by utilization wastewater and cassava fiber. The energy generated from wastewater and cassava fiber has potential to fulfilling energy consumption in tapioca drying process. 3.2. Estimation of Organic Fertilizer from Tapioca Wastewater Monitoring of nitrogen and phosphorous concentration in the wastewater was done to evaluate the impact to eutrophication and their potential to utilize as liquid fertilizer. Table 6 describe total nitrogen (TN) and total phosphorous (TP) concentration in inlet and outlet of biogas reactor. It also indicated that TN and TP relatively not change during anaerobic digestion in biogas reactor. Anaerobic digestion decomposed macro-molecule of nitrogen and phosphorous compounds to become simple molecule, such as NH4+ and PO4. These molecules were still measured as TN and TP. Table 6. Total nitrogen, total phosphor and pH in tapioca wastewater. Observation number Sampling Location pH TN (mg/L) TP (mg/L) 1 Inlet Biogas reactor 3.85 328.3 22.7 Outlet Biogas reactor 6.49 402.4 17.2 2 Inlet Biogas reactor 3.85 317.2 23.7 Outlet Biogas reactor 6.49 415.3 18.2 3 Inlet Biogas reactor 4.3 336.12 24.14 Outlet Biogas reactor 6.54 434.2 18.9 4 Inlet Biogas reactor 4.12 320.6 29.3 Outlet Biogas reactor 6.36 406.9 19.0 1The effluent of observed biogas reactor was utilized as liquid fertilizer. The average of TN and TP concentrations in the effluent of biogas reactor were 412.6 and 17.0 mg/L, respectively. Considered to the amount of wastewater produced is 2.75 m3/ton of cassava, the effluent biogas reactor has potential to produce about 1.13 kg of TN and 0.05 kg of TP per ton of cassava. High concentration of TN and TP in treated tapioca wastewater were potential to promote euthrophication, but in other side is very important for crops nutrients. [2]International Conference on Green Agro-industry and Bioeconomy IOP Conf. Series: Earth and Environmental Science 230 (2019) 012084 IOP Publishing doi:10.1088/1755-1315/230/1/012084 7 4. Conclusion About 2.75 m3 of wastewater with average COD concentration 9,648 mg/l was produced from each [1]ton of cassava in small scale tapioca factory. Using covered lagoon system about 92% of COD was removed. Utilization of tapioca wastewater and cassava fiber has potential to generate 29.96 and 30.34 kWh of electricity per ton of cassava, respectively. If they utilized wastewater and cassava fiber for generate energy, the observed tapioca factory could be fulfilling whole energy needs for drying tapioca process. The treated wastewater contained about 1.15 kg of Nitrogen and 0.05 kg of Phosphorous per ton of Cassava. Utilization of tapioca wastewater for renewable energy and liquid fertilizer increased the sustainability of small scale tapioca industry. References [1] Central Bureau of Statistics 2016 Areal and Production of Cassava 2015. https://www.bps.go.id/linkTableDinamis/view/id/880. [Accessed on 25 September 2017]. [2] Hasanudin U 2007 Biogas production from agro-industries wastewater. Workshop on “Commercialization [11]of Renewable Energy Recovery from Agroindustry Wastewater”, February 1st 2007, University of Lampung. Lampung Indonesia [3] Manilal V B, Narayanan C S, Balagopalan C 1990 [9]Anaerobic digestion of cassava starch factory effluent World J Microbiol. Biotechnol. 6 149-154. [4] Rajbhandari B K, Annachhatre A P 2004 [7]Anaerobic ponds treatment of starch wastewater: case study in Thailand Bioresour. Technol. 95 2 135-143. [5] Kamahara H, Hasanudin U, Atsuta Y, Widiyanto A, Tachibana R, Goto N, Daimon H, Fujie K 2010 Methane emission from anaerobic pond of tapioca starch extraction wastewater in Indonesia J. Ecotechnol. Res. 15 2 79-83. [6] Hasanudin U 2011 Model of Zero Waste System on Small Scale Tapioca Factory. Proceeding of Workshop on Environmental Protection and Regional Development.

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