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Zero Waste Concept in Fruit Waste Anaerobic Digester: Case Study of Biogas Plant Gamping, Yogyakarta

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ABSTRACT
Gamping biogas plant was built in 2011 to solve waste problem from GemahRipah fruit market which generate 4-10 tons waste/day. The digester was design for 4 ton/day and produce biogas and electricity. The electricity is used for lighting the shops and the road. For eightyears along the installation, biogas unit has been facilitated with transportation, crusher, anaerobic digester, generator, electricity and sensor unit. All the facilities are purposedto utilize the biogas. Another side product of sludge from digestate as by product is just discharged without any application. Here, we developed zero waste concept to utilize all products of anaerobic digester i.e. biogas to produce electricity and biogas sludge as fertilizer. The liquid fertilizer potentially supports the sustainability of the biogas unit from economic value of vegetable products or liquid fertilizer itself. Biogas produced from fruit waste contains 59% methane and 37% carbon dioxide (average from one year). The cumulative production for a half year monitoring is 650 Nm3 biogas and generate electricity up to 120 kWh. Biogas slurry effluent was fermented for two weeks and directly appliedas fertilizer. The analysis showed it contains C-Organik, N Total, P, K 0.39%, 0.34%, 0.07%, 1.91% respectively. Biogas slurry could support the growth of vegetative phase, while less support for generative phase.

Keywords: *Anaerobic Digester, Biogas, Liquid Organic Fertilizer, Sludge*

1. INTRODUCTION

Indonesia is struggling with the increasing number of wastes. In 2018, Indonesia generated 66 million tons of waste and it is predicted that amount will increase to 67 million tons in 2020 [1]. The waste comes from various sources, with a distribution of 48% of households, 9% of commercial areas, 19% of public facilities, and 24% from markets. The biggest fractionation is organic (60-80%). Most of the waste is still dumped in the landfill (68%), buried (9%), burned (5%), unmanaged (7%), and only small amount (6%) is utilized as energy or converted to another usable material [2]. As the second-largest generation source of waste, markets are needto be managed. Fortunately, waste produced by the market is accumulated in the one location and typically has similar types. Hence, it makes easier to handle. By calculating the number, managing the organic waste from the market can reduce approximately 12 million tons/year of waste. This number can pursue the government target for reducing the waste until 20% in 2020 [3].

One solution to solve organic waste from market is anaerobic digestion technology, which is already popular in developing countries [4]. Anaerobic digestion (AD) can convert waste and produce energy at the same time, hence for energy supply and sustainable energy security [5,6]. Nowadays, AD became more popular in Indonesia, the government through the Ministry of Energy and

Mineral Resources had built more than 17.000 biogas digester and most of them are for animal waste in the rural area. However, converting municipal waste to energy is still limited.

Gamping Biogas Plant is a pilot plant for converting fruit waste from fruit market to biogas then electricity [7, 8]. The Gamping Biogas Plant can process up to 4 tons of waste/day. The alteration of organic material to produce biogas involves the presence of water with ratio of 1:1. Hence, the amount of the digestate of Gamping Biogas Plant is 8 ton/day. The fermentation process in a digester will produce residual fermentation process 90% [9] or 30-60% [10] from the total input material. It means 7.2 tons will be as side products from the fermentation process. This amount is large enough to pollute the environment, because the slurry just discharges in the irrigation canals outside the plant. Regarding in that condition, developing the fermentation unit to fertilizer is one solution to make better environment. The AD technology has by-products of liquid and solid waste which can be used as fertilizer to replace chemical fertilizers in agriculture [11].

In this paper, we present a zero-waste concept in AD process of fruit waste in Gamping Fruit Market. Zero-waste is an alternative paradigm based on circular system thinking, where waste can convert to appropriate materials and continues product [12]. Based on this zero-waste concept, there is no waste flow must be discharged into the environment and it led zero waste system. Thus, all products from biogas installations will be utilized which is in this case for electricity and liquid fertilizer, as shown in Figure 1.

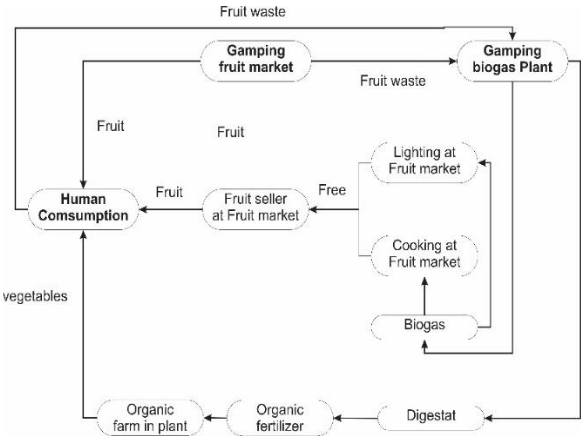


Figure 1 The Zero Waste System in Gamping Biogas Plant

2. METHODS

2.1. Operational of Biogas Unit

This article analyzes the biogas power plant which has a capacity of 4 tons/day. It operates at a pressure of 150 cmH2O, mesophilic conditions, pH between 6.2 - 6.5 and located at Gamping, Sleman, Yogyakarta Indonesia. This biogas plant can produce 162 Nm3/day of biogas, 5.7 ton/day digestate and generates electricity about 148.5 kWh/day for 4 tons of waste. Figure 2 explains how biogas is produced and equipment used on the Gamping Biogas Plant.

2.2. Production of biogas

The fruit waste is weighted by the operator on the weighting unit and the amount of waste is recorded. The fruit waste is crushed and mixed with water with ratio of 1:1. In the next step, slurry is pumped to anaerobic digestion system, and flow in two digesters working in parallel to produce biogas. The biogas flow toward an electrical generating system to generate electricity for the market needs. Digestate from the process flows out into digestate storage. The flow diagram is described below Figure 2.

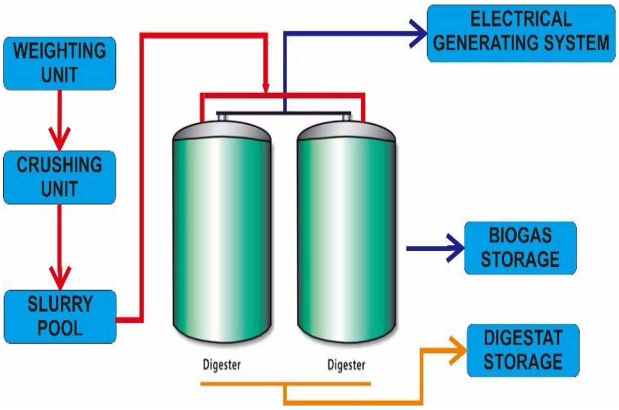
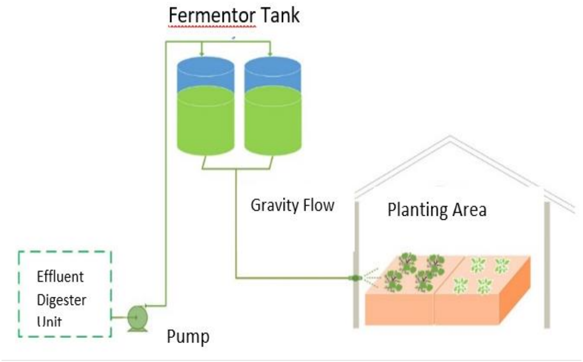


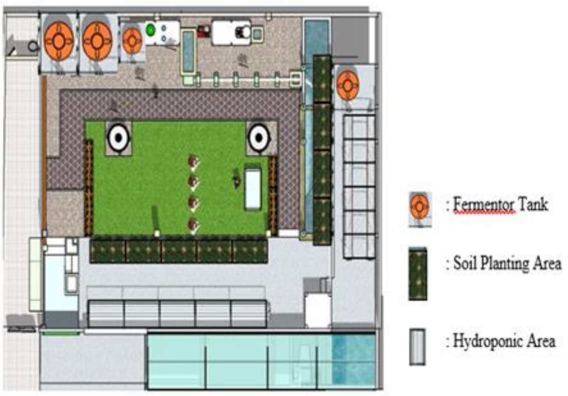
Figure 2 Flow Diagram of Gamping Biogas Plant

2.3. Preparation of Liquid Organic Fertilizer from Biogas Slurry

The schematic of the slurry and fermenter unit for manufacturing liquid organic fertilizer is shown in Figure 3(a). Effluent of biogas slurry is filtered and pumped to fermenting tanks made of HDPE tank (total capacity of twom3). The position of the tank is about 1 m (one) above the ground and is equipped with an iron structure. During fermentation process, liquid decomposer was added. The fermentation time was ± 14 days.



(a)



(b)

Figure 3 (a) Design of Organic Liquid Fermentation in Gamping Biogas Plant (b) Location Plot

The location of the liquid organic fertilizer unit in Gamping Biogas Plant is presented in Figure 3b. Due to the limitation area, some facilities were build adjusting the existing area without reducing the main function. The additional facilities are:

a. Fermentor Unit. Slurry will be fermented for 14 days before application. The further fermentation has a function to improve mineralization that can influence to the Electrical Conductivity of the material.

b. Soil Planting Area. The Soil Planting area is used to plant the horticulture vegetables with the total area is 16.5m2. Planting area is one way to optimize the utilization of organic liquid fertilizer.

c. Hydroponic Area. The hydroponic area was built in the line close to the wall. There are 9 m in length for 5 lines, so the total is 45 m2.

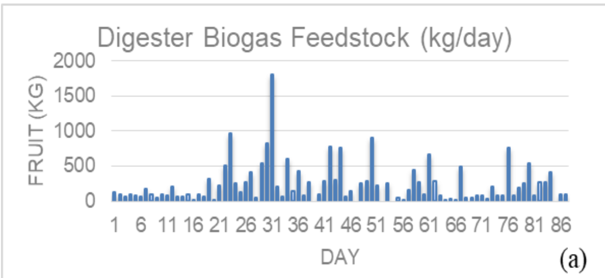
2.4 Application of Liquid Fertilizer

The liquid organic was applied in Pakchoy trough hydroponic and soil media. The liquid fertilizer was tested and compared to an organic fertilizer trough Pakchoy for hydroponic media and Paddy for soil media. The analysis for fresh weight for Pakchoy and rice grain total per pot for paddy. The fertilizerdose for Pakchoy were A3:1000 ppm, A4 : 1200 ppm, A5 : 1400 ppm, while for control we use A1 : water, A2 : aquadest, A6 : anorganic fertilizer. The Pakchoy research was treated for 3 replications. In soil media application, the dose of the fertilizer S1 : 60 mL/pot, S2 : 120 mL/pot, S3 : 180 mL/pot while S0- : without slurry, S0+ : anorganic fertilizer, Paddy had4 replications. Both of Pakchoy and paddy use randomized experiment design.

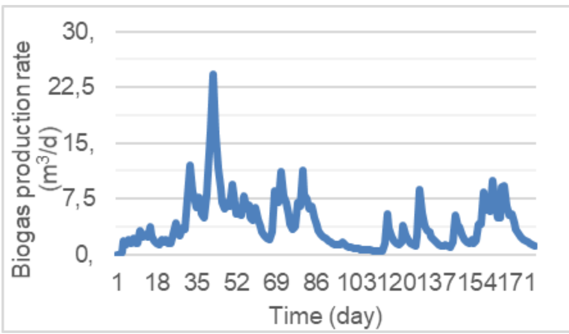
3. RESULT AND DISCUSSION

3.1. Data of product of biogas

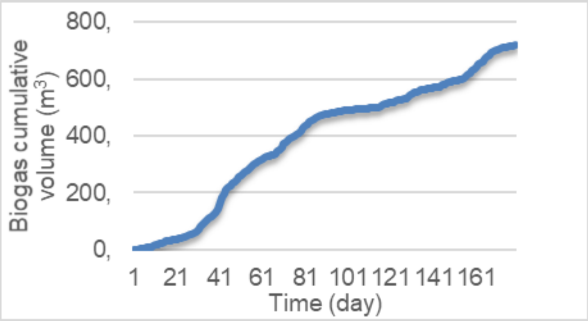
The feedstock in Gamping Biogas Plant is rotten fruits which are (mostly) tropical fruits such as melon, watermelon, dragon fruits, mango, and orange. The production of biogas was observed in existing daily operations, without special treatment. Figure 4b shows the production of biogas daily recorded using flow controller. There was fluctuation of biogas production due to unfixed amount of rotten fruits that fed to the digesters. The number was under maximum design of digester which has 4 ton/day. The low feedstock related with the existing waste condition during the research time (see Figure 4a). For approximately 6 months, the biogas plant produced cumulative volume of ± 650 Nm3biogas from 60 tons of fruit waste(see Figure 4c) . The highest daily production was 24 Nm3 and the average production was 2.05 Nm3. The electricity generation was 120 kWh and was utilized for 9 street lighting (450 watt) and 120 lighting lamp shops (1680 watt). Regarding the composition, methane content was ca. 59%.



(a)



(b)



(c)

Figure 4 (a) Biogas feedstock (b) Gas generation per day (c) 6 Months of cumulative volume of biogas

3.2. Product of liquid organic fertilizer from biogas slurry

Before being used as fertilizer, biogas slurry was characterized for the accuracy dosing to the plant. Different types of raw material and concentration lead to different nutrients in liquid fertilizer. The various waste was the big challenge to make liquid fertilizer standard, because it depends on the amount of waste per day that was generated from the market. The comparison of liquid organic fertilizer with SNI standard is shown in Table 1.

Table 1. Characteristic of Liquid Organic Fertilizer

Parameters	Liquid Organic*)	SNI**)
Water content (%)	90.15	-
C-Organic (%)	0.39	6
Nitrogen Total (%)	0.34	3-6
P2O5 (%)	0.07	3-6
K2O (%)	1.91	3-6
As (Arsen) (ppb)	0.6	Max 2.5
Hg (ppm)	0.0056	Max 0.25
Pb (Lead) (ppm)	<0.02	Max 12.5
Cd (Cadmium) (ppm)	<0.01	Max 0.5
Fe (Iron) (ppm)	8.42	5-50
Mn (Mangan) (ppm)	0.3	250-5000
Zn(Zinc) (ppm)	0.39	250-5000
pH	7.49	4-9
Salmonella sp. (cfu/ml)	81.3	Max 10^2

*) Analysis Data
**) Ministry of Agriculture rule :SK Mentan No.70/Permentan/SR.140/10/2011

Slurry from biodigester has pH value and Fe (iron) in the SNI range, as well as the requirements for maximum value for As, Hg, Pb, Cd and Salmonella sp. However, some nutrition contents were lower, those are C-Organic, N Total, P, K, Mn, and Zn of 0.39%, 0.34%, 0.07%, 1.91%, 0.3 ppm, and 0.39 ppm respectively. The Kalium content was highest among other nutrition content since the biogas feeding stock were fruits which are high in kalium. Based on analysis, the organic liquid fertilizer from slurry of Gamping Biogas Plant need fortification of some nutrition e.g. C, N, P, K, Mn, and Zn.

3.3. Application of biogas slurry in plant

Biogas slurry was applied as organic fertilizer in Pakcoy. The similar treatment was applied for water, distilled water, and anorganic fertilizer (ab mix). The replacement time of fertilizer application was part of treatment.

3.4. Fresh weight of pakcoy leaf

The weight value of fresh leaves of Pakcoy increases with the addition of organic fertilizer dose. Treatment with organic fertilizer could not have the same fresh weight with inorganic fertilizer (ab mix). Table 2 shows that the weight of Pakchoy using biogas slurry in 4days replacement (B1) has not significantlydifferent, from 97.9 g (inorganic)to 61.9 g (biogas slurry). This case was different for 8 days replacement (B2), where there was a big different value, from 164.47 (inorganic) to 43.22 (biogas slurry).

Table 2. Effect of different nutrient solution on fresh weight of leaf pakchoy (gram)

Doses	Time	
	B1	B2
A1	6.08 f	6.51 f
A2	5.04 f	3.83 f
A3	42.42 de	37.83 e
A4	53.33 cd	43.12 de
A5	61.98 c	43.22 de
A6	97.90 b	164.47 a

3.5. Rice grain weight per pot

The biogas slurry was appllied to paddy plant, with the dose treatment for 60 mL/pot, 120 mL/pot, 180 mL/pot (see results in Table 3). Biogas slurry was compared as well for anorganic (positive control) and water (negative control). The treatment was appllied for Inceptisol and Alfisol. In Alfisol, the dose of biogas slurry 80mL/pot was almost similar to the inorganic fertilizer (as positive control).

Table 3. Application of slurry in paddy plant

Type of Soil	Dose of the Slurry					
	Negative control	Positive Control	60 mL/pot	120 mL/pot	180 mL/pot	Average
Inceptisol	22.15	42.48	23.20	24.58	25.15	27.51b
Alfisol	41.43	47.28	40.63	41.50	44.68	43.10 a
Average	31.79	44.88 a	31.91b	33.04b	34.91b	-

4. CONCLUSION

Gamping Biogas Plant was design for 4 ton/day of fruit waste with biogas calculation is 162Nm3/day. Regarding observation for 87 times with total number of feedstock was 60 tons, the plant produces ± 650 Nm3cumulative biogas and generates 120 kWh electricity. Processing of making biogas requires water as the input material and produces the slurry as residue.For implementing the zero-waste concept, the installation of liquid organic fertilizer was built. The application shows that slurry can be used for nutrition to the plant, even though the nutrient content is lower than inorganic fertilizer. However, slurry has more advantages regarding the natural compound, which has a function as a natural pesticide.

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