The effect of loading rate to biogas production rate of the 500 liter anaerobic digester operated with continuous system

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Abstract. Conventional anaerobic digester such as fixed dome and floating drum are found having drawback in application in developing country. It was difficult in maintenance and operation. It was also difficult to relocate to the new site of waste processing. The portable anaerobic digester is prepared in this work as a solution. The capacity is about 500 liter so that suitable for home scale organic waste treatment. The material that is used for the digester was 304 stainless steel. The digester is completed wit agitator to optimize the biogas production. A slurry of cow dung (50% cow dung+ 50% water) is use to feed the digester. There are 2 variations of slurry loading rate that were investigated in this work, namely 5 liter slurry/day and 10 liter slurry/day. The biogas production rate is found about 51.7 liter biogas/day if loading with 5 liter slurry/ day. The biogas production rate is found increase significantly to become 82 liter biogas/day if loading with 10 liter slurry/day. The quality of biogas is found better with loading rate 5 liter slurry/day which has average CH4 content about 58.75% vol. comparing the one with loading rate 10liter slurry/day that have average CH4 content about 56.40% vol.

1 Introduction

In many countries biogas technology spread has foundered and/or up to 50% of plants are non-functional. This is linked to inadequate emphasis on maintenance and repair of existing facilities. Many new design of anaerobic digester are introduced with many feature to increase the performance. Attention to establish anaerobic digester in the developing country is increase rapidly [1]. General designs of biogas digester that is used in developing countries for digestion of livestock waste are classified as low-rate digesters, and lacking stirring capability [1].

The disadvantages of low-rate digesters biogas technology such as fixed dome and floating drum are : requires reliable feed source, high construction costs relative to income of users, laborious operation and maintenance, limited lifespan, requires reliable feed source, construction costly[2]. Certain researcher develop small size anaerobic digester but nor for the purpose of portable design [3].

Many of concrete fixed dome type of digester is found difficult to be repair. A static scum-breaking device in the form of nylon net has been incorporated in a fixed-dome biogas plant to control scum formation and to provide a limited amount of stirring [4]. A portable bio-digester should be fabricated with consideration of economic and ergonomic factors with maximum efficiency in production of methane gas [5].

For the case in Vietnam, there no best choice house hold biogas plant model for all the farmers. The existing models have their weaknesses and strengths. More studies are required to find optimal biogas models to the real situation . Such future biogas plant models should take 3 requirements: simple in construction, operation, and maintenance [6].

Many improvements already addressed for the fixed dome and floating drum [7] but portable design was not take in to account in the improvement. Little sized biogas plants solves the problem of the organic waste, reducing its transportation costs and producing green energy [3]. Effort to find best suit biogas digester is still on going, different technologies have been analyzed in order to identify the most suitable for small sized biogas plants [8].

In this work a small size (500 liter) anaerobic digester is introduced and can be operated as continuous system. The design is completed with manual agitator to optimize the result. Stainless steel is used as a material of anaerobic digester for corrosion resistance purpose. The effect of loading rate to the biogas production rate as wellas biogas composition will be investigated

2 Experimental

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The 500 liter portable anaerobic digester was set up at village of Baluk, sub-districts of Negara, districts of Jembrana, In Bali Island, Indonesia. The climate is tropical so that no external heating energy is needed to operate the anaerobic digester. Humidity level is around 85%. The operation temperature was recorded vary between 20-33^{o}C.

The anaerobic digester is made from stainless steel plate (thickness 1.22 mm) to ensure that the digester having high corrosion resistant. The biogas contain hydrogen sulfide (H_2S) [9, 10, 11] that is very corrosive to carbon steel or metals in general.

The anaerobic digester cylinder with diameter 76 cm and length 122 cm was obtained by rolling the stainless steel plate. The anaerobic digester cylinder was mounted horizontally for ergonomic design and easy loading [5]. The manufacture of the stainless steel anaerobic digester utilizes tungsten inert gas (TIG) welding technique.

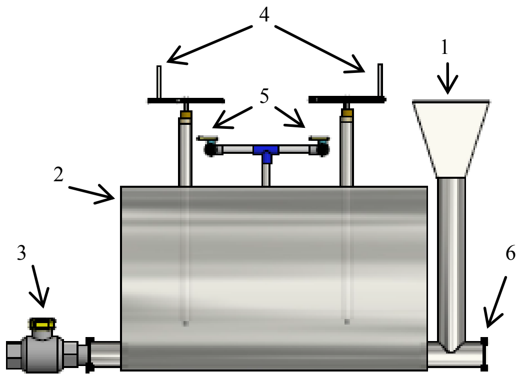

Fig. 1. The design of anaerobic digester. 1. Inlet slurry, 2. Anaerobic tank, 3.Slurry outlet, 4. Manual agitator handle,5. Outflow biogas, and 6. Manhole

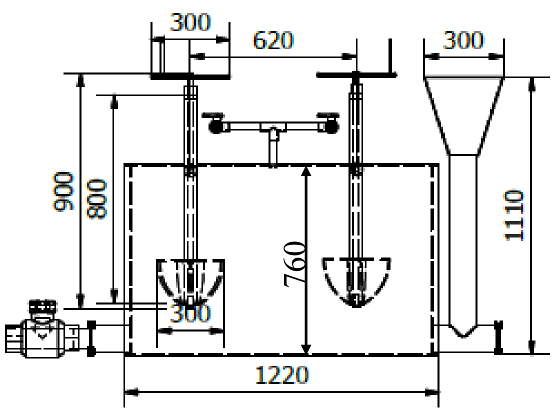

Fig. 2. Section design of 500 liter of anaerobic digester. The unit in millimeter (mm)

The drawing of anaerobic digester is presented in Figure 1, Figure 2, and Figure 3. The main part of the digester are inlet slurry, anaerobic tank, manual agitator handle, outflow biogas, slurry outlet, agitator blade. The manhole is also provided for easy cleaning during maintenance. The total weight of empty digester is about 60 Kg.

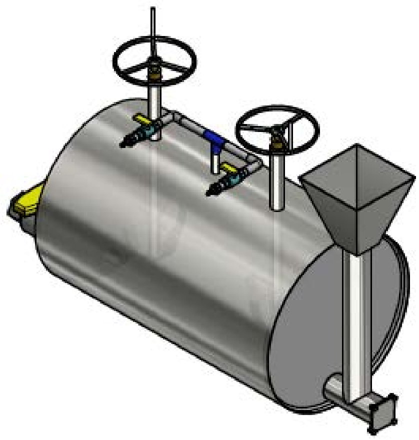

Fig. 3. Three dimension appearance of the anaerobic digester

At the beginning the anaerobic digester is operated as batch system by filling the tank fully with slurry of cow dung (50% cow dung+50% water). The stirring with agitator was conducted for about 10 minutes for 3 times a day (morning, noon, and evening). The anaerobic digestion then is let to produce biogas by batch system until no longer produce biogas again. In this stage the anaerobic digestion process finished byusing batch system.

The research then was continued with the investigation of the performance for continuous system. The first variable was conducted by releasing for about 5 liter slurry from the outlet and about the same amount (5 liter) of new slurry (50% cow dung+50% water) was added from the inlet. The stirring with agitator was conducted for about 10 minute for 3 times a day (morning, noon, and evening). The biogas produced in 30 day then was measured as well as biogas composition. The same process also was conducted for second variable that was by releasing for about 10 liter slurry from the outlet and about 10 liter new slurry (50% cow dung+50% water) was added from the inlet.

3 Results And Discussion

Base on the result from the experiment in this research, it is found that by loading rate 10 liter slurry/day the biogas production rate is higher (around 82.0 L/day) comparing with the one with loading rate 5 liter slurry/day (around 51.7 L/day) as can be seen in Figure 4 as well as Table 1. The biogas production rate from both loading rate are found linear in the range of 30 days (1 month) of biogas production. From this point it is clear that loading rate influent the biogas production rate in the continuous system of 500 liter anaerobic digestion. It is explained in previous publication that indeed loading rate influent the biogas production rate [12].

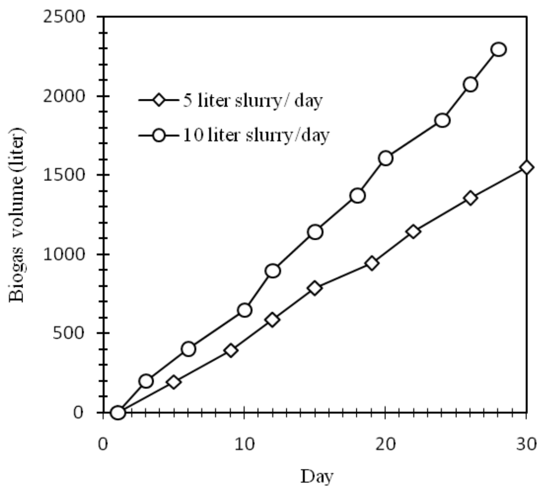

Fig. 4. The effect of loading rate of slurry to biogas production in the 500 liter of continuous anaerobic digestion

Table 1. The effect of loading rate to biogas production rate as well as biogas composition in 30 days (1 month) with continuous system operation.

Loading rate of slurry (liter of slurry/day)	Biogas production rate (liter of biogas/day)	Average biogas composition in 30 days		
		CH_4 (% vol.)	CO_2 (% vol)	H_2S (ppm)
5	51.7	58.75	35.75	42.75
10	82.0	56.40	33.30	106.50

The effect of loading rate to biogas composition can be seen in the Table 1. The result reveal that related with utilization of biogas as a fuel, loading rate 5 liter slurry/day resulting better quality of biogas with CH_4 around 58.75 % vol comparing loading rate 10 liter slurry/day that reach 56.40 % vol. which is a lower value. There are four stage of biological and chemical of anaerobic digestion namely: hydrolysis, acidogenesis, acetogenesis, and methanogenesis as a final stage [12, 13].

Biomass is made up of organic polymers. To access the energy potential of the material , in anaerobic digesters, the bacteria must first broken down these chain in to smaller constituent part such as amino acids, simple sugar, and fatty acids. To break the chain and dissolving the smaller molecules in to the solution is called hydrolysis. Hydrogen and acetate are produced in the hydrolysis and can be used by methanogens directly. volatile fatty acids (VFAs) with a chain length greater than that of acetate must first be catabolised into compounds that can be used by methanogens. The process of acidogenesis results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created, along with carbon dioxide, ammonia, and hydrogen sulfide, as well as other byproducts. Acetogenesis is the third stage of anaerobic digestion. Simple molecules through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as hydrogen and carbon dioxide. The biological process of methanogenesis is the terminal stage of anaerobic digestion. Methanogens use the intermediate products of the preceding stages and convert them into wate r, carbon dioxide and methane that make up the majority of the biogas [12, 13].

CO_2 is produced during stage acidogenesis, acetogenesis, as well as methanogenesis. H_2S is produced during stage of acidogenesis. Methane is produce during stage of methanogenesis [12]. Figure 5 is the result of investigation of CH_4 contents in the biogas in 30 days. It weres found that CH_4 contents in the biogas is about lower for loading rate 10 L/day until reach the 20^{th} day. After that the CH4 contents were found about the same

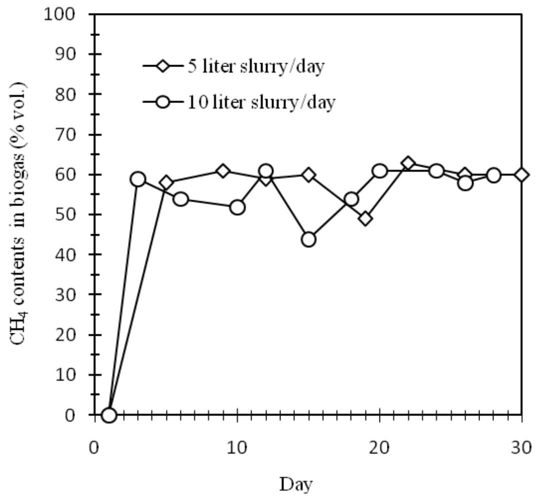

Fig. 5. Methane (CH_4) contents in the biogas in 30 days

The CO_2 contents in the biogas can be seen in Figure 6. Similar to CH4 contents in the biogas, The CO2 contents in the biogas also was found about lower for loading rate 10 L/day comparing with loading rate 5 L/day. After reach the 20^{th} day, the CO_2 contents were found similar.

The H_2S contents in the biogas is presented in Figure 7. The H_2S contents for loading rate 10 L/day was found very much higher comparing loading rate 5 L/day. The H2S contents was found very small for loading rate 5 L/day until reach the 20^{th} day, and after that H2S contents was found similar to loading rate 10 L/day. Seem that for capacity 500 slurry (50% cow dung+50% water) the crucial condition was at the first 20^{th} day. After the day of 2oth the biogas composition were found similar for bot loading rate of slurry

By increasing loading rate to 10 liter slurry/day without adding retention time, this will make the process will stay longer in the 3 first processes (hydrolysis, acidogenesis, acetogenesis) that make the content of CH_4 is lower and H_2S higher (106.50 ppm) than loading rate 5 liter slurry/day. At lower loading rate of 5L/day of slurry also resulting in very low H_2S content (47.50 ppm) which is a good condition. Hydrogen sulfide is produced during stage of acidogenic [12]. Biogas with low content of H_2S in very good as a fuel of the engine

[14] because will reduce the corrosion in the metal component of the engine.

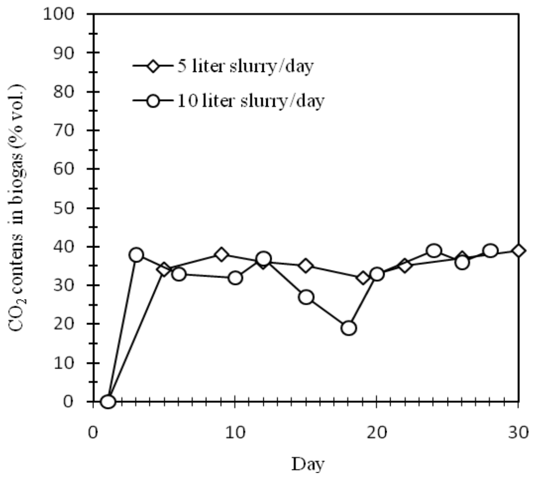

Fig. 6. Carbon dioxide (CO_2) contents in the biogas in 30 days

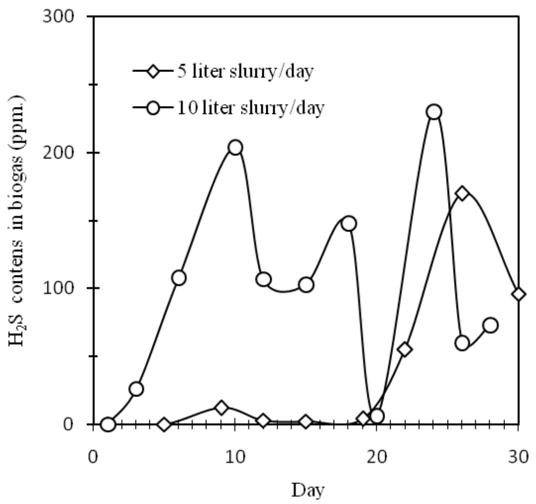

Fig. 7. Hydrogen sulfide (H_2S) contents in the biogas in 30 days

Training and education of householders, is needed in relation to the maintenance of digesters, feedstock suitability and the environmental and potential livelihood benefits of digestate [15]. The result in this work can be informed during training and education of biogas householder.

4 Conclusions

For the 500 liter anaerobic digester made by stainless steel operated in continuous system, the biogas production rate will be around 51.7 L/day if the loading rate of slurry is 5 L/day. The biogas production rate increase to reach 82.0 L/day if the loading rates of the slurry IS increased to 10 L/day. The slurry is made from cow dung (50% cow dung + 50% water).

The quality of biogas is better for loading rate of slurry at 5 L/day with average CH_4 content in 30 days around 58.75%vol. Increasing loading rate of slurry at 10 L/day yield lower average CH_4 content in 30 days to become around 56.40% vol.

The average H_2S content in the biogas is very low (47.50 ppm) for loading rate of slurry 5 L/day and become very much increase at higher loading rate of slurry at 10 L/day which is around 106.50 ppm.

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