Biogas Production from Water Hyacinth (Eichhornia Crassipes): The Effect of F/M Ratio

W D Nugraha[1], Syafrudin[1], L L Pradita[1], H H A Matin[1] and Budiyono[2]

1 Department of Environmental Engineering, Diponegoro University, 50275 Semarang, Indonesia
2 Department of Chemical Engineering, Diponegoro University, 50275 Semarang, Indonesia
E-mail: lathifahlp@gmail.com

Abstract. Distribution of water hyacinth (Eichhornia crassipes), generally considered as a water weed, that has been a problem which can harm the environment, irrigation system, and agriculture. However water hyacinth can be used in biogas production because it has large enough amount of hemicellulose contents. The purpose of this study was to know the effect of F/M ratio to biogas production from water hyacinth waste with Liquid Anaerobic Digestion (L-AD) method. A series of laboratory experiments using biodigester were performed in batch anaerobic operation at room temperature. F/M ratio that used in each reactor was 39.76, 20.03, 13.32, and 10.01. Degradation process was done in 60 days. The result showed that F/M ratio effects to the biogas production. The best performance of biogas production from this research will be obtained if F/M ratio is in the range of 10.01-20.03 (correspond to 25%-50% of rumen fluid) with water hyacinth as the main substrate.

1. Introduction

The current global energy supply is highly dependent on fossil sources (crude oil, lignite, hard coal, natural gas). These are fossilized remains of dead plants and animals, which have been exposed to heat and pressure in the Earth's crust over hundreds of millions of years. For this reason, fossil fuels are non-renewable resources which reserves are being depleted much faster than new ones are being formed [1].

The worldwide distribution of Eichhornia crassipes (E. crassipes) generally considered as an aquatic weed, has become a persistent and expensive aquatic problem damaging the environment, irrigation system and crops [2]. Water hyacinth is type of weed which grow very fast. The growth of water hyacinth can be 1.9% a day with 0.3-0.5 m in length [3]. According to Malik (2006), water hyacinth consist of 95% water and make it consist of hollow tissue, have a high energy, consist of materials that can be fermented and have big potential to produce biogas [3]. Water hyacinth can be used in biogas production because it has high hemicellulose content compare with other single organic components. Hemicellulose is complex polysaccarides which is polymer composite which if it hydrolized produce derivative mixture product that can be treated with anaerobic digestion methode to produce two simple mixture compounds which are methane and carbon dioxide that commonly called biogas [3] .

Anaerobic digestion (AD) has been extensively used to convert organic waste streams from various sources, such as agricultural, industrial, and municipal solid waste, to biogas. The AD process can operate in both liquid and solid states in terms of total solid (TS) content. In general, the TS content of

liquid AD (L-AD) systems ranges from 0.5 to 15%, while solid-state AD (SS-AD) systems usually operate at TS contents of higher than 15% [4].
Several studies of biogas production from lignocellulose biomass using water hyacinth and L-AD methods had been conducted. A research on biogas using waste of fisheries in the form of offal, filth, and gills as the main substrate had been done. Biogas production that has been resulted on F/M ratio 0.2 with total maximum methane 164.7 l / kg CODMn. Besides that, F/M ratio gave a significant effect to the retention time (HRT). Time retention that obtained from F/M ratio 0.2, 0.4, and 0.6 each were 36, 13, and 19 days [5].
Research also did on hydrogen production and methane from banana peel. The result was, the best perform from one fermentation phase was observed on F/M from 5.0. On this condition, methane yield, production level, and potential were 251.3 mL g-1 VS, 2.05 mL h-1, and 352.9 mL. The result of hydrogen and methane from 209.9 and 284.1 mL g-1 VS mL g-1 VS accomplished on F/M from 5.0 in the second step process [6].
Other research had been done about biohydrogen production and biomethane from water hyacinth. From that research resulted maximum hydrogen production was in water hyacinth on concentrate 40 g/ L resulted hydrogen 38.2 mmol H_2/L/d and maximum methane production was on concentrate 80 g/ L resulted methane 29.0 mol CH_4/L/d [4]. While other researcher did research about anaerobic digestion with water hyacinth, cabomba, and salvinia as the main substrate and water hyacinth and cabomba easily degraded, resulted 267 L biogas/ kg VS and 221 L biogas/ kg VS, with methane content 50%. While on salvinia resulted less degradation on 155 L biogas/ kg VS on methane quality 50% [7].
Research about adding rumen in biogas production also done about the effect of F/I ratio on biogas production from cow dung using rumen as the inoculum and the best result of biogas production was on F/I ratio between 17.64 to 35.27 (corresponding to 25-50% rumen fluid) [8]. That thing also supported by other researcher who said that rumen fluid that inserted into the reactor significantly effected to biogas production. The best biogas production was on rumen fluid and total solid on range 25-50% and 7.4 and 9.2%. Total solid between 7-9% and 50% rumen content will give the best result on biogas production. Therefore, this study focused on the effect of F/M ratio to biogas production from water hyacinth waste with liquid anaerobic digestion (L-AD) [9].

2. Materials and Methods

The main substrate that used in the research was water hyacinth with 15 cm in diameter. The biodigester that made from polyethylene bottle plugged with tightly rubber were 1500 ml in volume. The biodigester was equipped with valve for biogas measurement. The schematic diagram of experimental laboratory will be shown in Figure 1. Food to Microorganism ratio (F/M ratio) was varied from 39.76, 20.03, 13.32, and 10.01. Implementation of the research started with preparing water hyacinth substrate which was cut approximately 1-2 cm [10] and preparing rumen liquid, then conducting an examination of the total composition of solids and water content on each materials. After that calculating the variation of F/M ratio and preparing of anaerobic digestion batch reactor. Subsequently, the substrate was mixed with the inoculum. Samples that had been prepared could be inserted into the reactor, sealed in order to obtained anaerobic condition, and ready to operate. During the treatment process takes place, volume of biogas produced were observed in interval of two days. The observation was terminated after 60 days.

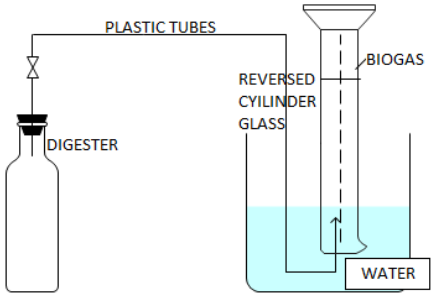

Figure 1. Schematic diagram of series laboratory batch assessment of L-AD.

3. Result and Discussion

3.1. The Effect of F/M Ratio to Biogas Production with L-AD

This research aims to know the effect of F/M ratio to biogas production from water hyacinth waste liquid anaerobic digestion (L-AD). In biogas production anaerobically, value of F/M shows comparison between the amount of substrate that contained in waste (medium) and the amount of microorganism used [5]. The variation of F/M ratio produced from the existence of rumen volume variation and total solid from each materials. The initial total solid of water hyacinth is 13.52. When it combined with different rumen volume in each reactor, total solid of water hyacinth that has been changed can be seen in Table 1.

Table 1. The Initial and Final Total Solid of Water Hyacinth.

	Initial TS (%)	**Rumen Volume (ml)**	**Final TS (%)**
F/M Ratio 39.76	13.52	50	10.82
F/M Ratio 20.03	13.52	100	9.06
F/M Ratio 13.32	13.52	150	7.73
F/M Ratio 10.01	13.52	200	6.76

If seen from total solid variation existence, from those four reactors that produced the most biogas yield was F/M ratio 10.01 with biogas yield 127.071 ml/ gr TS on total solid 6.76%. According to Brown, et al (2012), the content of higher total solid has minimal effect to the total solid efficiency and reduction of biogas production. Because on higher total solid content can cause inhibition to hydrolysis step that caused by limited mass transfer between microbe and material [11]. The product from hydrolysis step has been accumulated on substrate surface because of the limited mass transfer which finally obstruct hydrolytic enzyme absorption. The limited mass transfer make amount of hydrolysis product existence for acidogenic microbe is limited so can reduce the amount of product that has been produced in acidogenesis microbe to be converted into biogas on methanogenesis step [12] . The graphic can be seen on Figure. 2.

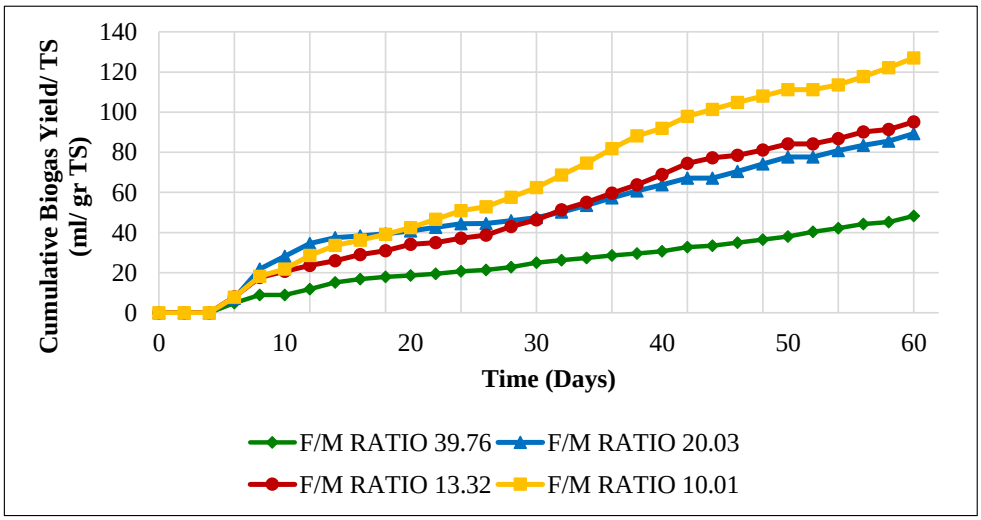

Figure 2. Cumulative Biogas Yield per gr TS.

After the research had been done, it showed that the existence of F/M ratio variation effected to biogas production. The research about the effect of F/M ratio to biogas production has been done by Sunarso, et al (2010) used manure as the main material. On that research, there were four F/M variation that has been used which were 17.64, 23.51, 35.27, and 70.54. And known that on variation 17.64-35.27 produced the most optimum biogas. Also on this research used four F/M variation which were 10.01, 13.32, 20.03, and 39.76 used water hyacinth as the main material. And it is known that on those F/M variation, the most optimum biogas production was 10.01. The optimum F/M variation on those two researches were different because there was a difference of material using, so it caused a different F/M variation.

3.2. Production Rate of Biogas from Water Hyacinth Waste with L-AD Method

The second aim from this research was to know the production rate of biogas. On Table 2 and Figure 3 show that the existence of F/M ratio variation gave effect to kinetic constants production of biogas. In a row, kinetic constants of biogas that has been formed with the treatment are biogas daily production (A), biogas production rate (U), and minimum time of biogas formation (λ). On F/M ratio 39.76 was 59.207 ml/ gr TS, 0.833 ml/ gr TS, 0.411 days. On F/M ratio 20.03 was 91.376 ml/ gr TS, 1.772 ml/ gr TS, and 0 day. Next on F/M ratio 13.32 was 121.483 ml/ gr TS, 1.878 ml/ gr TS, 3.321 days. And the last on F/M ratio 10.01 was 151.910 ml/ gr TS, 2.624 ml/ gr TS, 4.448 days.

Table 2. Kinetic Constants on The Effect of F/M Ratio to Biogas production Research

Constants	F/M Ratio			
	39.76	**20.03**	**13.32**	**10.01**
A, ml/(grTS)	59.207	91.376	121.483	151.910
U, ml/(grTS.day)	0.833	1.772	1.878	2.624
λ, days	0.411	0	3.321	4.448

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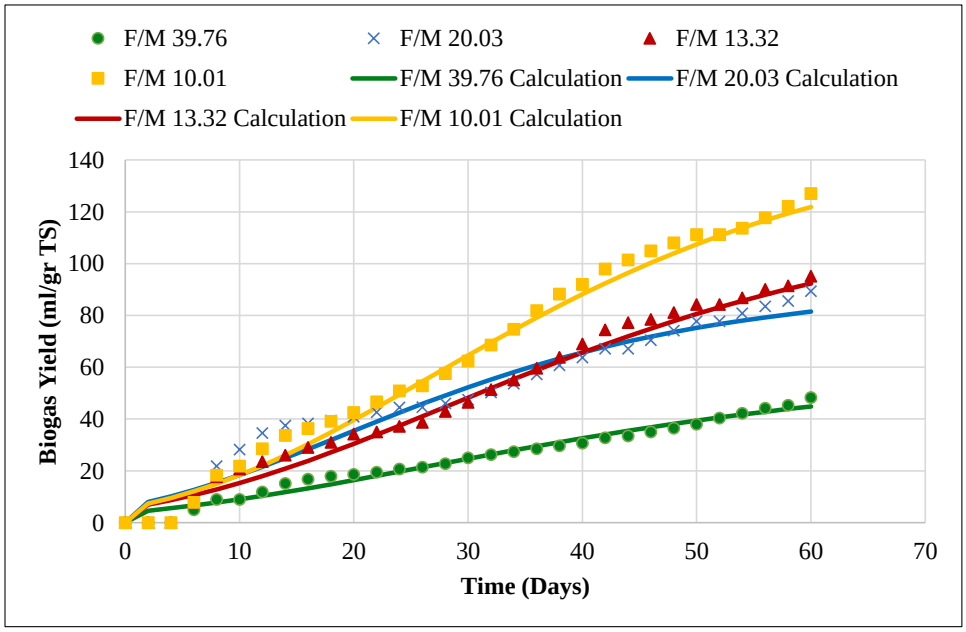

Figure 3. The Relationship between Experimental Data with The Calculation Result on The Effect of F/M Ratio to Biogas Production Research.

After doing model on F/M ratio 10.01, biogas yield on the 160th day was 151.548 ml/ gr TS. From that biogas yield, can aims for lightning, power, and also electricity from 1m^3 biogas conversion. After knowing the conversion every 1m^3 biogas, hence can be calculated for lightning, power, and electricity needs that can be produced from 151.548 ml/ gr TS of biogas yield. Knowing that if there is 1 ton

water hyacinth waste, hence biogas yield that can be produced is 151,548,000 ml or 151.548 $m^{3.}$ From that biogas yield can aims to produce electricity 712.276 kWh. The model biogas yield on the 160th days can be seen on Figure 4.

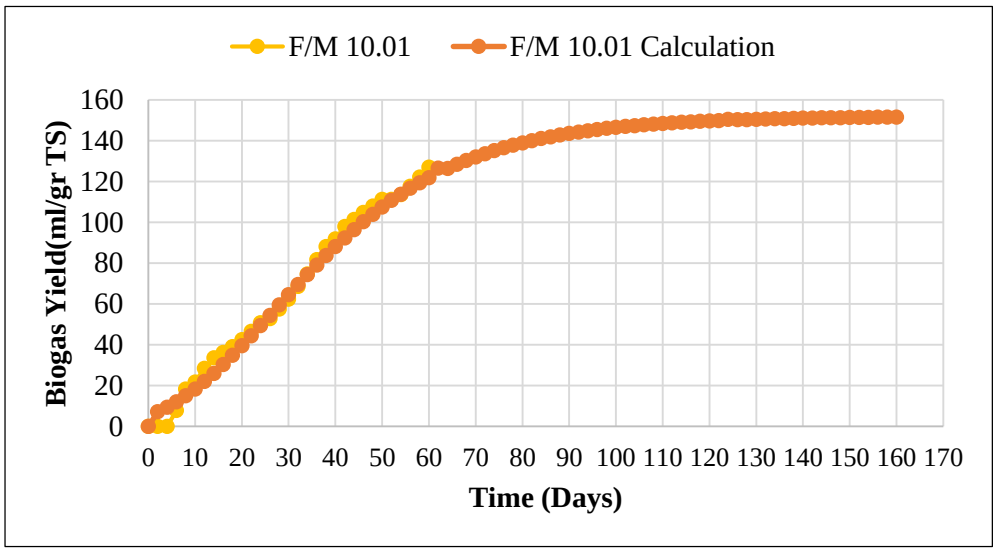

Figure 4. The Calculation Result on The Effect of F/M Ratio 10.01 on Biogas Production Research.

4. Conclusions

Water Hyacinth is one of the alternative from agricultural waste that can be used for biogas because a high hemicellulose content F/M ratio can take effect to biogas production. The smaller F/M ratio, the amount of biogas production will be higher. The highest biogas production was on F/M ratio 10.01 (content of 50% rumen). On this research, from the four F/M ratios that have been researched, the most optimum F/M ratio was on 10.01 with optimum total solid 6.76%.

The biggest biogas yield was on F/M ratio 10.01 in amount of 127.071 ml/ gr TS started on the fourth day. The daily biogas production (A) and production rate constants (U) respectively 151.910 ml/ gr TS and 2.624 ml/ gr TS.

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