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Production of Biogas from Water Hyacinth with Addition of Cow Dung as Inoculum Using a Plug Flow Anaerobic Reactor

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Abstract

Biogas as an alternative energy source has several advantages over fossil fuels. Water hyacinth is a type of weed that has the potential to produce biogas. The purpose of this study was to determine the effect of pre-treatment on water hyacinth with the addition of 0.5 N NaOH and without NaOH and determine the effect of ratio of water hyacinth and water at 1: 2 and 1: 3 to the biogas production in a Plug flow reactor. Water hyacinth was crushed and then pre-treated by heating it in 0.5 N NaOH solution at 100^{o}C. Biogas output from the reactor was accommodated in tubular plastic, and the volume of biogas was measured by water displacement using a volumetric glassware. The results showed that the average production of biogas at ratio of 1: 2 and 1: 3 was 9,983 ml and 7,172 ml, with a composition of CH_4 (45.024%), CO_2 (11.50%), H_2S (0.86%), NH_3 (0,3%) and CH_4 (35.25%), CO_2 (12.41%), H_2S (0.96%), NH_3 (0.34%), respectively. The average production of biogas in the pre-treatment by heating materials 100^{o}C without NaOH and heating 100^{o}C with NaOH 0.5 N was 11,853 ml and 9,110 ml with biogas composition produced was CH_4 (50.19%), CO_2 (12.36%), H_2S (0.64%), NH_3 (0.33%) and CH_4 (54.13%), CO_2 (12.36%), H_2S (0.91%), NH_3(0.43%), respectively. It concluded that the addition of NaOH for thermal treatment was able to increase the production of biogas and the methane content in the biogas produced.

Keywords: *biogas; cow dung; energy; fermentation; water hyacinth.*

Introduction

Fuel scarcity is an important problem in recent years. World energy needs will continue to increase in line with population growth and economic growth which is expected to grow by an average of 1.7% by 2030. Energy demand is growing rapidly, while oil supplies are reduced and unstable, on the other hand the use of fossil fuels contains dangerous toxic compounds. Energy scarcity does not only occur in Indonesia, but also in other countries, this indirectly affects the country's economy, especially for poor and developing countries, including Indonesia. So it is time to decide on dependence on fossil energy sources and switch to alternative energy sources made from renewable raw materials such as the use of biomass (organic material) for biogas production (Renilaili, 2015). Biogas is a gas produced from fermented products from organic/ biomass materials with the help of anaerobic bacteria, such as manure. Livestock is an abundant producer of biomass, including solid wastes and methane gas (CH_4), one of the causes of global warming and ozone destruction, at a rate of 1% per year and continues to increase. According to Anton (2011) the advantages in producing biogas include the energy produced is clean and renewable energy and the fuel produced is of high quality. Environmentally, the benefits obtained are being able to reduce air pollution (Renilaili, 2015). Water hyacinth (*Eichhornia crassipes*) is one type of aquatic plant that has a very high growth rate so that this plant is considered a weed, or a disturbing plant that can damage the aquatic environment. Although water hyacinth is considered a weed in the water, water hyacinth has a role in capturing heavy metal pollutants, rich in calcium and can be used as raw material for making biogas because water hyacinth contains 95% of water and makes it composed of hollow, high energy tissue from materials that can be fermented and potentially very large in producing biogas (Malik, 2006). Development of renewable energy from the Government according to Ferial (2016) has an ambitious target of adding up to 23% of renewable energy generation by 2023. So, as to support the movement of renewable energy use initiated by the government, the authors offer the development of energy in the form of biogas. Currently pilot plant on biogas based on water hyacinth has not been applied much. Based on research conducted by Astuti (2013), the highest biogas production with raw water hyacinth on a batch scale was 125.7 ml. Further research by Yonathan (2013), by examining the effect of pre-treatment on the pH variation of acid hydrolysis on biogas produced from raw water hyacinth using a batch reactor, the highest volume was 1,180 ml. Soeprijanto et al. (2017) also carried out further research on the production of biogas from water hyacinth using different reactors, namely plug flow bioreactor and without pre-treatment treatment on raw materials.

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From the results of his research, the highest volume of biogas produced was 1,230 ml. In a number of previous studies, it was found that production yields were still small and not optimal so that they could not be utilized for the industrial scale of biogas manufacturing plants.

The aim of the study was to study the effect of pre-treatment of NaOH 0.5 N on raw materials by heating 100^0C and without pre-treatment of NaOH to produce biogas produced in a Plug flow bioreactor, and study of the effect of the composition of the mixture of water hyacinth and water with a ratio of 1: 2 and 1: 3, respectively.

Materials and Methods

The experiment was carried out by pre-treatment and non pre-treatment. The first step by non pre-treatment: water water hyacinth was cut off and weighed as much as 2 kg, then the cut water hyacinth was crushed and mixed with water in a ratio of 1: 2 and 1:3 using a blender until it is homogeneous. The second step by pre-treatment using thermal + NaOH and thermal + NaOH: Water hyacinth was weighed as much as 2 kg. The cut water hyacinth was then mixed with water in a ratio of 1: 2 and blended until homogeneous. The blended water hyacinth was cooked with NaOH 0.5 N solution for 30 minutes at 100^0C. Finally, the cooked water hyacinth was then washed using tap water until the pH was neutral.

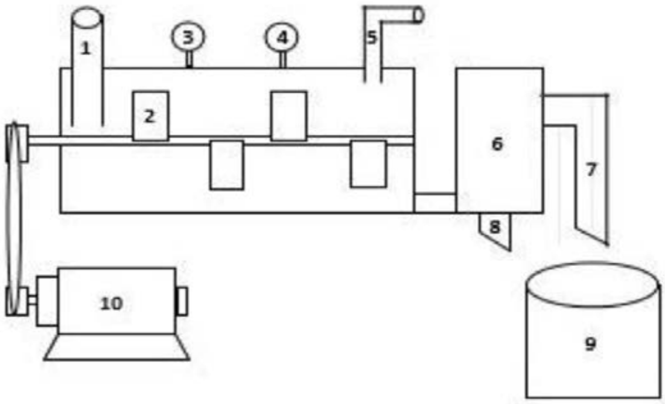

Figure 1. Schematic diagram of plug flow anaerobic digester. *Note*: 1 = feedstock influent; 2 = flat blade; 3 = pressure parameter; 4= temperature parameter; 5 = valve outlet gas; 6 = digestate collection; 7 = digestate effluent; 8 = disposal valve; 9 = digestate collection; 10 = motor.

Results and Discussion

Figure 1 shows that the volume of biogas produced for 30 days has fluctuated per day, both in the raw material dilution variables 1:2 and 1:3. This is because the anaerobic process is very dependent on the activity of microorganisms that are very susceptible to fluctuations. The results show that the use of water hyacinth and water at ratio of 1: 2, biogas production increased sharply up to on the 6^{th} day 20,700 ml and on the following day the volume of biogas was drastically decreased up to 7,150 ml on the 15^{th} day. the average volume of gas production per day was 9,983 ml. In this ratio the formation of biogas was stable during the 15^{th} day to the 30^{th} day.

Whereas the use ofwater hyacinth and water at ratio of 1:3, biogas production increased sharply up to 13,300 ml on the 4^{th} day then in the next two days it increased which was quite stable and then dropped dramatically on the 7^{th} day of 10,600 ml. In this process the biogas formation was stable at the 15^{th} to the 30^{th} day, this condition was said to have reached steady state conditions. The average volume of biogas production per day was 7,182 ml.

The high water content in the substrate will facilitate the decomposition process, and homogeneity also affects the work processes of microorganisms because the homogeneity of the system makes contact between microorganisms and substrates more intimate, so that the water content added in the biogas production process must be optimal to obtain optimal results. If the water content added in the right composition, the anaerobic digester condition is not too acidic which results in better growth of methanogenic bacteria so that more gas is produced (Wahyudi, 2017).

From this study indicate that the composition of the mixture between water hyacinth and water by 1: 2 is the most appropriate because it produces more gas volume and better gas quality than the composition of the mixture between water hyacinth and water by 1: 3. This is because methanogenic bacteria develop better in the biogas production process with a 1: 2 dilution variable compared to the 1: 3 ratio.

Based on the results of the study, it was found that the 1: 2 raw material dilution variable produced more volume of biogas and had a higher methane content when compared to the 1: 3 ratio. This indicates that the water content is indeed influential in the process of mixing raw materials for making biogas.

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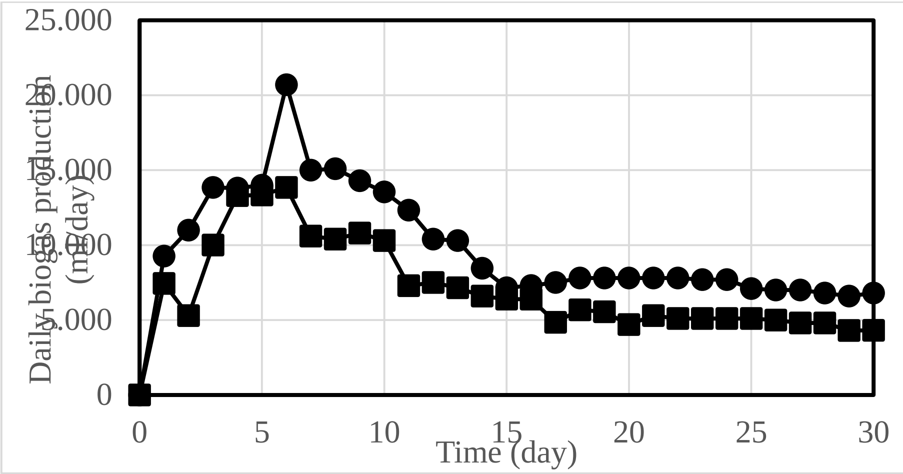

Figure 2. Effect of water hyacinth and water ratio on daily biogas production. *Note:* ●= ratio of water hyacinth and water (1:2); ■= ratio of water hyacinth and water (1:3).

Figure 2 shows the cumulative biogas production with ratio of raw water hyacinth and water as much as 1: 2 and 1: 3. It can be seen that the higher cumulative biogas production was found to be 299,500 ml with a mixture of water hyacinth and water of 1:2. Whereas the composition of the mixture of water hyacinth and water by 1: 3 the cumulative biogas production was 215,160 ml for approximately 30 days.

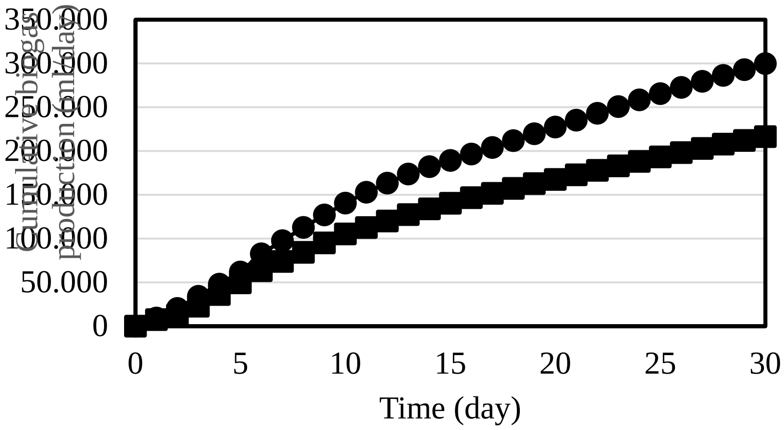

Figure 3. Effect of water hyacinth and water ratio on cumulative biogas production. *Note:* ●= ratio of water hyacinth and water (1:2); ■= ratio of water hyacinth and water (1:3).

It can be seen in Figure 3 that the biogas production during the experiments has fluctuated per day, both in the pretreatment of using NaOH and without NaOH. This is because the anaerobic process is very dependent on the activity of microorganisms that are very susceptible to fluctuations. In the pretreatment of the feedstock by adding NaOH 0.5 N and heating it at 100^0C for 30 minutes, the average volume of gas production per day was 11,853 ml, and the maximum volume achieved on the 3^{rd} day was obtained 24,200 ml and on the following day the volume of biogas dropped dramatically up to 9,300 ml on the 10^{th} days.

In this process the formation of biogas was stable during the 10^{th} day to the 14^{th} day. Whereas in the pretreatment by heating the feedstock at 100^0C for 30 minutes without the addition of NaOH, the average volume of gas

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production per day was obtained at 9,110 ml, and the maximum biogas production was obtained on the 4th day 14,200 ml. In this process the biogas formation stabilizes on the 9th day to the 30th day, the condition is said to have reached steady state conditions.

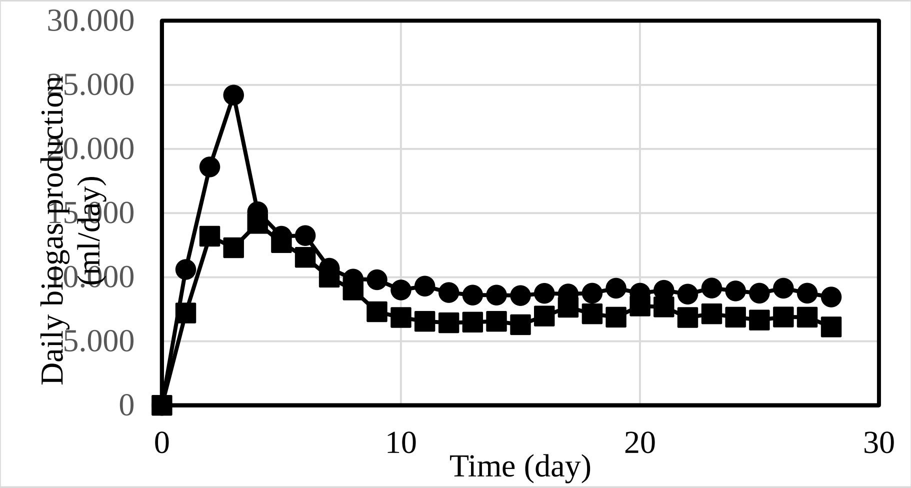

Figure 4. Effect of pre-treatment of water hyacinth on daily biogas production. *Note*: ●= heating Temperature of 100^{0}C + NaOH 0.5 N; ■= heating temperature of 100^{0}C without NaOH.

Figure 4 shows the effect of pre-treatment of water hyacinth treatment by heating of 100^{0}C + NaOH 0.5 N and heating 100^{0}C without NaOH on cumulative biogas production. The results show that the higher cumulative biogas production was 177,800 ml with a pretreatment of heating temperature of 100^{o}C and the addition of NaOH 0.5 N. Whereas in the pretreatment with a heating temperature of 100^{0}C only without the addition of NaOH, the cumulative biogas production was 136,650 ml. The addition of NaOH 0.5 N in the pretreatment process was able to increase the cumulative biogas production by 30.11%. Based on the results of this study indicate that the addition of NaOH in the pretreatment process can open the lignocellulose structure so that it can help the production of biogas in accordance with the literature proposed by Zheng, et al. (2014). Lignocellulosic breakdown also has the potential to increase the growth of microorganisms to produce better biogas, this is evidenced by the high levels of methane in the biogas that has been produced. In addition, this study also proves that with the addition of NaOH, the hydrolysis process becomes more optimal so that the formed biogas is also faster and more abundant.

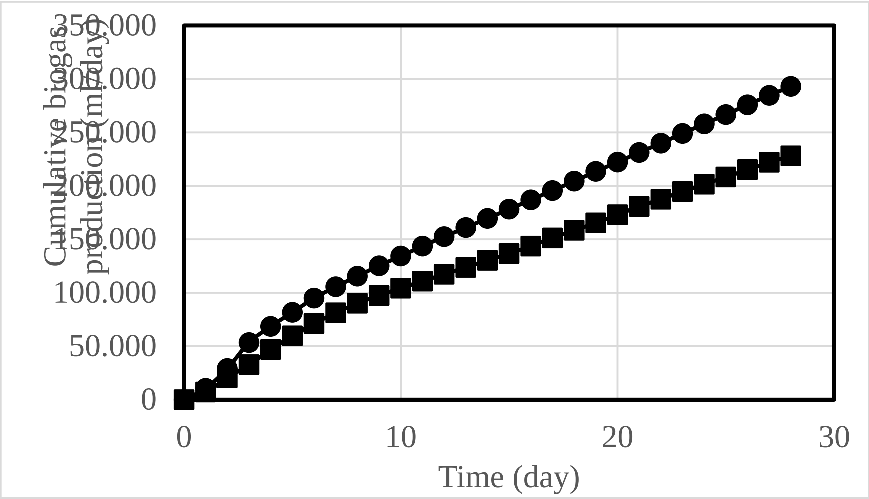

Figure 5. Effect of pre-treatment of water hyacinth on cumulative biogas production. *Note*: ●= heating Temperature of 100^{0}C + NaOH 0.5 N; ■= heating temperature of 100^{0}C without NaOH.

The results of methane (CH_4) content in biogas with a 1: 2 ratio of feedstock are greater than that of biogas with a 1: 3 ratio of feedstock. On the results of biogas with a pre-treatment of 1: 2, methane content was obtained at 45.02%. Whereas the biogas yield with 1: 3 ratio of feedstock obtained for methane content of 35.25%. Based on the results of the study, it was found that the feedstock with a ratio of 1: 2 produced more volumes of biogas and had

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higher methane content when compared to the 1: 3 ratio. This indicates that the water content is indeed influential in the process of mixing raw materials for making biogas.

The results by pre-treatment of heating 100^0C only without the addition of NaOH. On the results of biogas with a heating treatment temperature of 100^0C and the addition of NaOH, methane levels were obtained at 54.12%. While the results of biogas with a heating treatment of 100^0C only without the addition of NaOH obtained methane levels of 50.20%. The results of the analysis of biogas methane content in both of these variables indicate that the biogas products produced have met the literature proposed by Zieminski (2012), namely the standard methane content of 50-75%.

Conclusions

The addition of NaOH in the pre-treatment process can increase the volume of biogas produced. The average production of biogas in the pretreatment variation of raw materials by heating 100^0C without NaOH and heating 100^0C + NaOH 0.5 N was 11,853 ml and 9,110 ml. The biogas composition produced in the pre-treatment variable of the raw material by heating 100^oC without NaOH was CH_4 (50.20%), CO_2 (12.36%), H_2S (0.65%) and NH_3 (0.33%). Whereas in the pretreatment of feedstock with heating of 100^0C + NaOH 0.5 N was CH_4 (54.12%), CO_2 (12.35%), H_2S (0.91%) and NH3 (0.43%).

Acknowledgment

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Lists of Notation

P = pressure [atm]
T = temperature [^{o}C]
t = time [second, hour]
V = volume [ml]

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Lembar Tanya Jawab

Moderator : Sri Sukadarti (UPN "Veteran" Yogyakarta)
Notulen : Fauzan Irfandy (UPN "Veteran" Yogyakarta)

1. Penanya : Piyantina Rukmini (STKIP NU Indramayu)

Pertanyaan : a. Bahan baku yang digunakan dalam penelitian biogas adalah limbah. Selain limbah enceng gondok yang digunakan dalam penelitian ini, bahan baku yang dapat digunakan misalnya adalah sampah kota yang jumlahnya sangat melimpah. Apa alasan pemilihan limbah enceng gondok sebagai bahan baku?
b. Apa alasan penambahan NaOH dalam proses?

Jawaban : a. Pemilihan limbah enceng gondok dikarenakan jumlah limbah enceng gondok di lingkungan kampus ITS yang cukup melimpah. Limbah ini hanya dibuang dan belum dimanfaatkan. Selain itu, limbah enceng gondok juga lebih homogen sifat dan jenisnya dibandingkan dengan sampah kota.
b. NaOH digunakan untuk memecah lignin yang dapat menghambat proses.

2. Penanya : Sri Sukadarti (UPN "Veteran" Yogyakarta)

Pertanyaan : a. Analisa dilakukan terhadap hasil penelitian. Apakah pengukuran jumlah dilakukan terhadap gas yang dihasilkan dari setiap waktu?
b. Saran:
Pada penulisan hasil penelitian, perlu dilakukan penyajian hasil persentase dan jumlah gas metana (CH_4) setiap satuan waktu.

Jawaban : a. Pengukuran jumlah gas yang dihasilkan dilakukan pada setiap waktu sesuai grafik hasil penelitian, namun belum disajikan hasil persentase dan jumlah gas metana yang dihasilkan setiap satuan waktu.