Co-Digestion of Bagasse and Waterhyacinth for Biogas Production with Variation of C/N and Activated Sludge

A Hadiyarto*, D Soetrisnanto, I Rosyidin, A Fitriana
Chemical Engineering Department of Diponegoro University, Tembalang, Semarang

* Corresponding Author : agushadi55@che.undip.co.id

Abstract. One of the factors that influence biogas production is the C/N ratio of the substrates. In this study the bagasse as a carbon-rich substrate (C/N=58) is combined with nitrogen-rich substrate namely is water hyacinth (C/N=19) so that the C/N ratio is in the range of 20-30. The research was carried out by preparing a filtered substrate with a 200 mesh sieve. Microbes needed to decompose the substrate are cow rumen, activated sludge from rotten bagasse and rotten water hyacinth. At the stationary phase, the ratio F/M of 0.5 and C/N ratio of 20, 25, 30, the each of biogas yield produced (liter/kg COD removed) are 381, 351 and 339.

Keywords : biogas yield, co-digestion, C/N ratio, cow rumen, bagasse, water hyacinth

1. Introduction
Biogas is one of the renewable energy sources, derived from organic materials (can be expressed as COD), in the form of animal waste (livestock and poultry), domestic waste water (black water), or solid waste (vegetable waste, fish offal), plants (water hyacinth, rice straw). Biogas is a gas mixture produced from the fermentation process of organic matter, consisting of methane gas (CH₄) 55-70%, carbon dioxide (CO₂) 25-50%, water (H₂O) 1-5%, H₂S 0-5%, nitrogen (N₂) 0-5%, and ammonia (NH₃) 0-0.05% [1].

Decomposition of organic material into biogas is carried out anaerobically. This process is known as ananaerobic decomposition process (anaerobic biodigestion, or anaerobic fermentation). The decomposition process of biogas formation will go through four stages, namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis which are not visible organoleptically. The decomposition process carried out by microbes will pass through the adaptation phase, the growth phase, the stationary phase and the death phase. Generally, the largest rate of biogas production occurs in the stationary phase.

Organic material needed as a substrate (food) can be a single substrate (only one substrate) or combination (more than one substrate). Two factors that affect the productivity of biogas are the ratio of carbon to nitrogen in the substrate and the types of microbial added. The anaerobic digestion process besides produces biogas, it can also reduce the COD content of substrate and convert it to biogas [2].

To obtain the optimal C/N ratio, it is necessary to mix the substrate which has carbon content and with a substrate has nitrogen content. Some studies that combine of various substrates to regulate the C/N ratio have been done by Saputra et al [3].

This study combines water hyacinth with bagasse. Water hyacinth contains C/N ratio of 10.8 [4]. Otherwise bagasse are rich in carbon with a C/N ratio of 150 [5]. If decomposition is desired at a ratio of 20-30, it needs to be combined water hyacinth and bagasse. In order for decomposition to take properly, microbes are needed which are able to decompose the substrate with cellulose content. In this study, the
effectiveness of microbes from cattle rumen containing Methanosarcina, sp. It is reported that Methanosarcina sp. have high growth rates [6], activated sludge of rotten water hyacinth and activated sludge from rotten bagasse.

2. Material and Method

The studies needed are water hyacinth, bagasse, microbes (cattle rumen obtained from Semarang slaughterhouse, activated sludge from rotten water hyacinth and rotten baggase). Carbon contents were analyzed by Walkey and Black Titration methods [7], Nitrogen content was analyzed refers to [8] SNI 19-7030-2004, COD of combination substrates refers to [9] SNI 06-6989.15-2004. VSS analysis refers to [10] SNI 06-6989.27-2005. The volume of biogas is measured by "water displacement method".

Substrates, cow rumen, activated sludge from rotten water hyacinth and baggase were filtered using a 200 mesh filter in order to homogeny of particle size. The first study, was used of cow rumen, the VSS ratio of substrate to microbes (F/M) is set at 0.5, pH is neutral. Substrate which has known C and N content and calculated the volume requirements based on C/N ratio 20, 25 and 30, mixed until homogen. The substrate which has been mixed and arranged C/N is put into each of three biodigesters @ 4 liters. The second study, the combination substrate were added cow rumen, activated sludge of rotten water hyacinth rotten bagasse at C/N = 25 and F/M = 0.5 and pH neutral. The decomposition process was carried out for 67 days. The biogas volume anda COD substrates were measured every day.

3. Result and Discussion

3.1. The rate of biogas production as a function of time on variation of C/N

The biogas production over a period of 60 days is shown in Figure 1 below. Biogas production is not significance in variations of C/N ratio 20, 25 and 30. Up to day fifty, biogas production is relatively the same. After fifty to sixty, biogas production of the C/N ratio = 25 more than the ratio of 20 and 30. Biogas production until sixty (C/N=25 is 5,833 ml), (C/N=20 is 4,986 ml ) and (C/N=30 is 4,611 ml).

![Figure 1. Cumulative production of biogas as a function of time at C/N variations with cow rumen, F/M = 0.5 at neutral pH.](image-url)
The rate of biogas production in the variation of C/N, can be seen in Figure 2 as follows.

Figure 2. The rate of biogas production in the time function in C/N variations with rumen activated sludge F/M = 0.5, at neutral pH.

The pattern of biogas production is similar to the pattern of microbial growth. Up to fourth day, the rate of biogas production was little, because microbes were still in the phase of adaptation. After the 4th day to the 14th day the rate of biogas production increases rapidly. At that time, microbial growth may also be quite high. From 15th to day 45th, the rate of biogas production is relatively constant. At that time the stationary phase takes place. In this phase the rate of biogas production was highest. Starting from 46th to 67th, the rate of biogas decreases rapidly and at that time is the phase of microbial death.

The rate of biogas production until day 4th in the range of 2-5 ml/day; the rate of biogas production in the growth phase is in the range of 51-63 ml/day; the highest production rate takes place in the stationary phase with a range of 116-139 ml/day, then decreases dramatically in the death phase with the rate of biogas production in the range of 10-44 ml/day. At each phase, the bacteria convert of substrat to produce biogas. Microbes growing more and more in the growth phase and then slow down in the stationary phase. In this phase, microbial metabolism it was optimum conditions so that biogas production at this phase is relatively high. In the death phase the rate of biogas production tends to decrease because substrate were decreased.

| Day to | dV/dT Biogas (ml/day) |
|--------|-----------------------|
|        | C/N 20 | C/N 25 | C/N 30 |
| 1-4    | 5   | 4     | 2      |
| 5-14   | 63  | 51    | 57     |
| 15-45  | 129 | 139   | 116    |
| 46-67  | 16  | 44    | 10     |

The rate of biogas production until day 4th, in the range of 2-5 ml/day; the rate of biogas production in the growth phase is in the range of 51-63 ml/day; the highest production rate takes place in the stationary phase with a range of 116-139 ml/day, then decreases dramatically in the death phase with the rate of biogas production in the range of 10-44 ml/day. At each phase, the bacteria convert of substrat to produce biogas. Microbes growing more and more in the growth phase and then slow down in the stationary phase. In this phase, microbial metabolism it was optimum conditions so that biogas production at this phase is relatively high. In the death phase, the rate of biogas production tends to decrease because substrate were decreased.
3.2 The rate of biogas production as a function of time on variation of type of microbe
This study was carried out by varying the type of microbes (activated sludge) were used. The activated sludge from cow rumen, rotten water hyacinth and rotten bagasse. The results were shown in the following figure 3.

![Figure 3. Relationship of biogas produced as a function of time at variations of activated sludge (C/N 25 and F/M = 0.5, pH neutral).](image)

Table 2. The rate of biogas production with variations of activated sludge, (C/N = 25; F/M = 0.5; pH neutral)

| Day to | dV/dT Biogas | Rumen | Bagasse | Water Hyacinth |
|--------|--------------|-------|---------|---------------|
| 1-4    |              | 6     | 30      | 48            |
| 5-14   |              | 58    | 16      | 14            |
| 15-45  |              | 141   | 2       | 3             |
| 46-67  |              | 40    | 0       | 0             |

From Figure 3 and Table 2 it can be seen that the volume of biogas produced and the rate of biogas production by microbes from cow rumen more than by the microbes of rotten bagasse and rotten water hyacinth. It turns out that cow rumen contain much of acetogenic and methanogenic bacteria [11]. These microbes include cellulolytic microbial groups, amylolytic microbes, sugar digesting microbes, acid-using microbes, proteolytic microbes, ammonia-producing microbes, methane-producing microbes, lipolytic microbes, and vitamin-synthesizing microbes [12]. Meanwhile water hyacinth and bagasse substrate whose main component is cellulose. Until 67th days, by the cow rumen capable of producing biogas up to 5,833 ml, rotten bagasse only 435 ml and rotten water hyacinth only 460 ml. The rate of biogas produced at stationary phase can be seen as follow: the rate of biogas production with rumen is 141 ml/day, rotten bagasse 2 ml/day and rotten water hyacinth 3 ml/day.

3.3 Conversion of Substrate to Biogas based on COD
An increase in the volume of biogas produced is accompanied by a decrease in COD of combination substrates. This indicates the conversion of organic substrate into carbon dioxide and methane gas [3]. The addition of biogas volume to the reduction in COD levels decomposes for more details can be observed in Table 3.
Table 3. Biogas Yield, Liter of Biogas per Kg COD removed

| Day to  | C/N 20 | C/N 25 | C/N 30 | C/N 25 | C/N 25 |
|---------|--------|--------|--------|--------|--------|
|         | Rumen  | Rumen  | Rumen  | Bagasse| Water Hyacinth |
| 1–5     | 2      | 1      | 0,5    | 25     | 42     |
| 6–14    | 36     | 20     | 32     | 52     | 49     |
| 15–45   | 381    | 351    | 339    | 19     | 47     |
| 46–61   | 49     | 203    | 4      | 0      | 0      |

From Table 3 it can be seen that the highest biogas yield is 351, 339 and 381 liters of biogas per kg of COD removed, i.e. when using bacteria from cattle rumen. The decrease in COD is caused by the degradation of organic matter by microbes in the substrate to be converted into biogas. In the process of making bacterial biogas which acts to degrade organic compounds is anaerobic bacteria that does not need oxygen and many types of methane-forming bacteria are found that convert it to methane gas [13]. This type of bacteria will form biogas in its exponential phase so that in that phase COD content in a combination of bagasse and water hyacinth substrate will decrease.

4. Conclusion
Biogas production using a combination substrate of water hyacinth and bagasse in the C/N 25 ratio using cow rumen, at F/M= 0.5, decompose until 67th days resulted biogas volume of 5,833 ml. Biogas production with C/N ratio in the range of 20-30 is not significantly different. Cow rumen more effective than activated sludge from rotten bagasse and rotten water hyacinth. Conversion factor or biogas yield in the range of 339, 351 and 381 liter per kg COD removed.

References

[1] Deublein, D. & Steinhauser, A. 2008. Biogas from waste and renewable Resource. Germany: Wiley-VCH Verlag GmbH & Co. KGaA.
[2] Clemens, J.; M. Trimborn; P. Weiland; and B. Amon. 2006. Mitigation of greenhouse gas emissions by anaerobic digestion of cattle slurry. Agriculture Ecosystems & Environment 112 (2) : 171-177
[3] Trisno Saputra, Suhrjono Triatmojo, Ambar Pertiwiningrum.2010. Biogas Production from mixture of Dairy Manure and baggase with different C/N ratio roduksi Biogas. Bulletin Peternakan Vol.34 (2) 114-122
[4] Astuti, N, Soeprobowati, T.R, Budiyono. 2013. Potential of Water hyacinth (Eichhorniacrassipes (Mart.) Solms) Rawapening for Biogas, combination with Cattle Dung. Workshop on Rescue of Rawapening Lake Ecosystem KLH-UNDIP (Potensi Eceng Gondok (Eichhorniacrassipes (Mart.) Solms) Rawapening untuk Biogas dengan Variasi Campuran Kotoran Sapi. Workshop Penyelamatan Ekosistem Danau Rawapening. KLH dan UNDIP). Semarang.
[5] Pound, B., Done, F. and T.R. Preston. 1981. Biogas Production from Mixtures of Cattle Slurry and Pressed Sugar Cane Stalk, with and without Urea. Trop Anim Prod 6:1
[6] Jo De Vrieze, Tom Hennebel, Nico Boon, Willy Verstraete, 2012. Methanosarcina : The rediscovered methanogen for heavy duty biomethanation. Bioresources Technology 112 1-9
[7] Piper.C.S., 1955. Soil and Plant Analysis “A Laboratory Manual of Method for the Examination of Soils and the Determination of the Inorganic Constituents of Plants”. Interscience Publishers, Inc. New York
[8] BSNI, 2004. Nitrogen (Standard Methode : SNI 19-7030-2004. National Standardization Agency of Indonesia. Jakarta.
[9] BSNI, 2004. CODcr (Standard Methode : SNI 06-6989.15-2004). *National Standardization Agency of Indonesia*. Jakarta.

[10] BSNI, 2005. VSS (Standar Methode : SNI 06-6989.27-2005). *National Standardization Agency of Indonesia*. Jakarta.

[11] Ningsih Suciyati, Yuni Ahda, dan Dezi Handayani. 2014. The Influence of Addition Some of Rumen Liquid to biogas Production from Cow’s Manure. *Jurnal Biospecies* vol.7 No.2 . 34-42.

[12] Susilowati, E., 2009. The potential utilization test of cattle rumen fluid to increase the speed of biogas and methane production in biogas (Uji Potensi Pemanfaatan Cairan Rumen Sapi Untuk Meningkatkan Kecepatan Produksi Biogas Dan Konsentrasi Gas Metan Dalam Biogas). *Theses Magister Gadjah Mada University, C1(0585-H-2009).*

[13] Gerardi, M. H. 2003. The Microbiology of Anaerobic Digesters. *A John Wiley & Sons Inc. Publication*, Hoboken, New Jersey