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Biogas Production from Canteen Wastes Using a Vertical Anaerobic Digester

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Abstract

Food waste can cause various environmental problems, one of which is the depletion of the ozone layer because CH_4 compounds are produced. Therefore, resolving the problem of food waste can be utilized as alternative energy that can be renewed to replace petroleum, namely biogas. The purpose of this study was to find out the production biogas in an anaerobic digester with the use of canteen food and vegetable wastes in ITS Campus. The first step, digester was introduced cow manure as a starter and was diluted with water at a ratio of 1: 1 until the digester was fully filled and then was left for 3 days. Then a mixture of canteen waste with a volume of 1,200 ml per day was introduced to the digester to achieve Hydraulic Retention Time (HRT) of 21 for 30 days. The results showed that the largest daily biogas production was 2,026 ml/day using the mixture of rice-green mustard, followed by a mixture of rice and water spinach (1,728 ml/day) and rice-lumps (1,356 ml/day), respectively. The composition of biogas produced from rice-mustard greens: CH_4 (75.35%), CO_2 (12.17%), H_2S (0.72%) and NH_3 (0.58%). The composition produced from rice- spinach: CH_4 (43.90%), CO2 (21.65%), H_2S (0.72%), NH_3 (0.74%), while for rice- kale: CH_4 (54%); CO_2 (12.46%), H_2S (1.31%), NH_3 (0.36%).

Keywords: *Anaerobic digester; biogas, food waste; HRT; vegetable waste.*

Introduction

Energy has an important role and can not be released in human life. Moreover, at present, almost all human activities are very dependent on energy. Various supporting devices, such as lighting equipment, propulsion motors, household appliances, and industrial machinery can be used if there is energy. Basically, energy use such as solar energy, water energy, electricity, nuclear energy, oil and gas energy, and mineral and coal energy have indeed been done long ago.

The use of energy that can not be over-renewed can cause energy crisis problems. One symptom of the energy crisis that has occurred lately is the scarcity of fossil fuel oil, such as kerosene, gasoline, and diesel. Scarcity occurs because the level of fuel needs is very high and always increases every year. Meanwhile, oil is the raw material for making fuel which is limited in number and requires millions of years for its formation process.

Energy scarcity does not only occur in Indonesia but also in other countries. Because the human population continues to grow every year resulting in increased demand for energy. Because of its scarcity, the price of crude oil in the world continues to increase every year. This will indirectly affect the country's economy, especially for poor and developing countries, including Indonesia. In addition, various human activities in addition to producing products also produce both organic and inorganic waste. The waste produced comes from crop residues, food scraps, dirt, urban waste, and mud from water treatment wastes. These materials are often dumped into landfills, which can cause environmental problems, such as, releasing heavy metals and minerals, and evaporating methane, CO2, hydrogen sulphide, and others. The impact has now been felt by all people of the world as a result of pollution of the waste, one of which is global warming which is a phenomenon of rising earth temperature, which is feared to threaten all human activities. According to Nurmaini (2001), global warming and destruction of the ozone layer in the stratosphere earth were due to excessive accumulation of greenhouse gases. This gas will rub or react with the ozone layer, which causes ozone to break down. So, it is necessary to do a real action by treating the waste to prevent environmental damage. Biogas is an energy formation technology by utilizing waste, such as agricultural waste, livestock waste, and human waste. Besides being alternative energy, biogas, which can also reduce environmental problems, such as air and soil pollution.

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Biogas can be made from organic materials, such as vegetable waste, food waste, animal waste, and humans and all biodegradable organic waste. Biogas can not only be obtained in rural areas, but even urban communities can get it because there are many ingredients that can be used as raw material for biogas, one of which is food waste both from households and restaurants. Lots of food residue is disposed of and not utilized so that the waste piles up and decays. For this reason, it is necessary to use the remaining food as a raw material for making biogas. In biogas systems using raw materials for food waste containing sugar or flour ingredients, such as wheat flour, fruits, non-starch seeds, and others, has the potential to produce biogas quite large and fast, and also has enormous potential compared to biogas systems using animal waste. Thus, making biogas using food waste is quite interesting.

Several studies on anaerobic digestion of FVWs have been carried out by some authors (Tambone et al. (2010); Bouallagui et al., 2004a, 2004b; Garcia-Peña et al., 2011; Jiang et al., 2012; Khalid Azeem et al., 2011. However, a few studies have been obtained using FVWs as single substrate and, most of these experiments were performed in laboratory scale reactors. The experiments only performed on pilot and industrial scale up bireactors used fruit and vegetable wastes in co-digestion with other materials (Macias-Corral et al., 2008; Lastella et al., 2002; Sharma et al., 2000).

The purpose of this study was to determine the results of biogas production on the influence of the use of ITS canteen waste.

Materials and Methods

Materials. The materials used this experiment were as follows: residual waste of mustard greens (sawi hijau), residual waste of spinach (bayam), and residual waste of water kale (kangkung) obtained from ITS Canteen. Cow dung used as a starter was obtained from slaughterhouses in Surabaya. Acetone (Smart Lab, 99.5%), sulfuric acid (Sigma-Aldrich, 95-97%), sodium hydroxide (Merck, 99%), used in this experiment were analytical grade and were commercially available.

Pretreatment of material. As much as vegetable waste is cut into small pieces, then it was boiled for 30 minutes. The cooked raw material was mixed with rice at a ratio of 1: 1 then blended it to get a fine size.

Experimental Procedure. This experiment was carried out using a vertical anaerobic digester using bacteria obtained from cow dung in the process of biogas production. The cow manure was used as a source of bacteria weighed as much as 12.5 kg and was mixed with PDAM water with a ratio of 1: 1. This mixture was then fed into the anaerobic digester and left for 3 days for acclimatization.

Analysis of Biogas volume. Volume of biogas production was measured by water displacement.

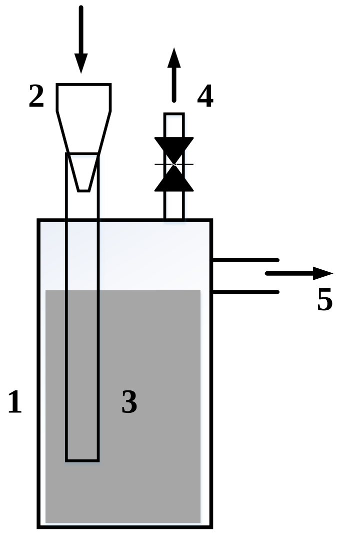

Figure 1. Schematic diagram of a vertical anaerobic digester for biogas production. *Note*: 1 = Vertical anaerobic digester; 2 = feedstock influent; 3 = digestate slurry; 4 = biogas flow; 5 = digestate effluent.

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Results and Discussion

Figure 2 shows that the volume of biogas production for 30 days has fluctuated in production per day. At the initial experiment on days 1 and 2, there was not biogas released at all. This is because bacteria are still in the growth phase. Where in this phase microorganisms are in the process of adaptation so that there is no increase in bacterial population, microorganisms tend to adapt namely changes in chemical composition and increase in size, so the process of decomposing organic matter into biogas is still small. The use of a mixed mustard and rice, the average volume of biogas production was 2,046 ml/day, and the maximum biogas production was achieved by 3,000 ml on the 3rd day. Then the next day the biogas production decreased up to 2,300 ml, and the formation of biogas stabilized on days 5 to 23 because it did not undergo a decline in biogas production. In the feed of rice-mustard greens, it started to stabilize in the formation of biogas on the 28-30 day at 2,200 ml/day. On day 1 there was not biogas released. But on the 2rd day the volume of biogas increased to 1,000 ml. For the feed of Rice-Spinach, the average volume obtained was 1365 ml. On the 21st day, a significant increase occurred. The volume on day 21 was 2,000 ml. It is also known that in the feed of Rice-Spinach the biogas formation has undergone stability during the 26th to the 30th day because it did not undergo a decrease in biogas production which was 1,500 ml/ day. The substrate of (rice-Kale) began to stabilize in the formation of biogas and did not undergo a decrease on the 16-30 day with the amount of gas produced at 1,800 l/ day. It is known that the highest daily volume is found in Rice-Sawi which is equal to 3000 ml and the lowest daily volume is in (Rice-Kangkung) of 700 ml. Rice-Sawi has a C/N value of 21.45. The optimum value of C/N ratio for the microorganism of the remover is 20-25. For this reason, the three combinations of raw materials can be used as substrate in the anaerobic fermentation process. Sources of C and N are needed for microbes that are anaerobic in process as a source of nutrition for the growth and development of these microbes. If the N content in subtract is small, the bacteria can not produce the enzymes needed to synthesize carbon-containing compounds. Meanwhile, if subtract contains too much N, bacterial growth will be hampered due to the presence of large amounts of ammonia. Although kale has a C/N ratio of 33.95, it produces only a small amount of gas. The C/N ratio that is too low will produce biogas with a low CH_4 content, high CO_2. The C/N ratio that is too high will produce biogas with a low CH_4 content, high CO_2. A balanced C/N ratio will produce biogas with high CH_4, moderate CO_2. While the lowest volume is found in Rice-Water spinach with a C/N value of 33.95.

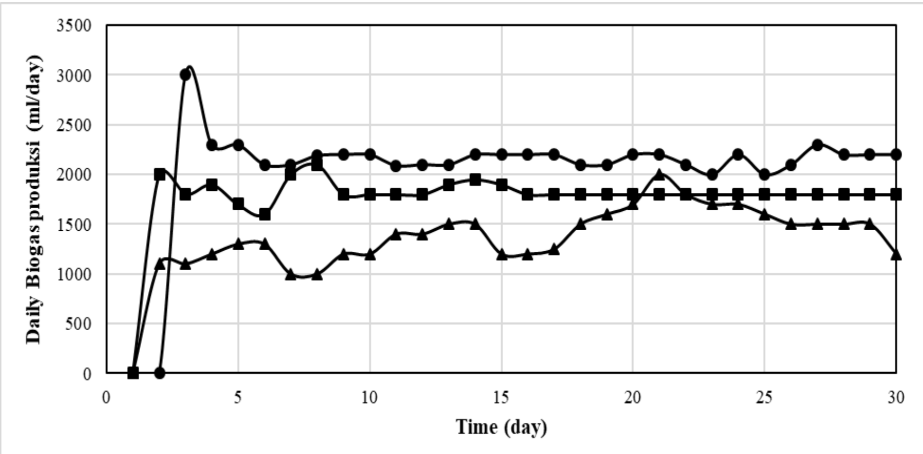

Figure 2. Effect of feedstocks on daily biogas production.
Note: ●= Rice-Mustard greens (sawi hijau), ■= Rice-Kale (kangkung), ▲= Rice-Spinach (bayam).

Figure 3 shows that the volume of biogas increased significantly every day. The highest volume of cumulative biogas production was a mixture of green Rice-Mustard which was equal to 61,380 ml, followed by spinach-Rice 40,950 ml and finally Spinach-Rice at 51,850 ml. This was because the ratio of C/N rice-mustard was the most optimum to be used as biogas which was 21.4 while Spinach-Sawi had a C/N ratio of 15.03 and for Rice-Spinach is 33.95. The optimum C/N ratio for the microorganism of the remover is 20-25. Therefore, the volume of mixture of Mustard - Rice produced more of the total volume of biogas than Sawi-Spinach or Kangkung- Sawi. The optimum C/N ratio for the microorganism of the remover is 20-25. Therefore the volume of mixture of Mustard-Rice produces more of the total volume of gas than Spinach-Sawi or Kangkung-Sawi. From the total volume produced by each variable, it can be seen that the average volume of biogas produced per day was 2,046 ml/day for Mustard-Rice, 1728 ml/day for Kale-Rice, and 1365 ml/day for Spinach-Rice, in this study for feedstock of Rice-Mustard greens according to SNI-7826-2012 where the volume of daily biogas production for small class reactors is between 700 - 4000 ml/day.

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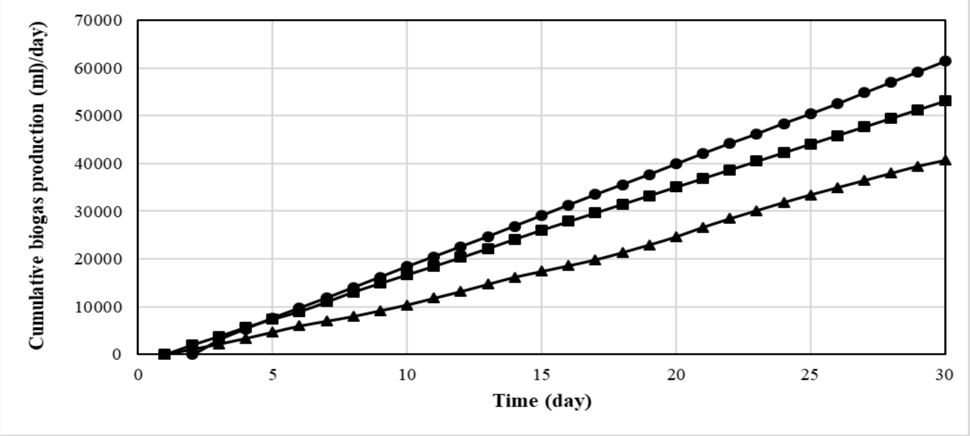
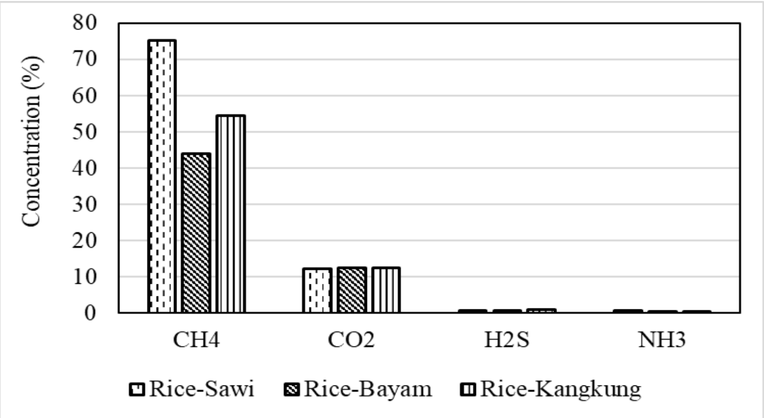


Gambar 3. Effect of feedstocks on cumulative biogas production.
Note: ●= Rice-Mustard greens (sawi hijau), ■= Rice-Kale (kangkung), ▲= Rice-Spinach (bayam).

Figure 4 shows that the percentage of gas composition produced from the three samples varies, the difference in gas composition contained is because the C/N ratio found in each variable also varies, 21.45; 15.03; 33.95 respectively. The results showed that the biogas produced from rice-mustard greens was CH_4 (75.35%), CO_2 (12.17%), H_2S (0.7214%) and NH_3 (0.580%); from rice-spinach was CH_4 (43.9%), CO2 (21.65%), H_2S (0.715%), NH_3 (0.74%); while for rice- kale was CH_4 (54%); CO_2 (12.457%), H_2S (1.31%), NH_3 (0.355%), respectively. The optimum C/N for decomposing microorganisms is 20-25, this is in accordance with the results of this study where the highest CH_4 compound was obtained from the mixture of rice and green mustard which has a C/N 21.45 ratio of 75.35%. Whereas the highest percent of CO_2 compound was found in the mixture of rice and spinach at 21.65%, for the highest percent of H_2S compounds, namely in the mixture of rice and kale at 1.31% and the highest percent of NH3 compounds in the mixture of rice and spinach of 0.74%. Therefore, the analysis of the composition of the gas in this study is in accordance with the literature which says that the ratio of C/N that is too low will produce biogas with a low CH_4 and high CO_2. The C/N ratio that is too high will produce biogas with a low CH_4 content, high CO_2.



Gambar 4. Effect of feedstocks on composition of biogas production.

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Conclusions

The largest daily biogas production was found to be 2,026 ml/day for the mixture of rice-green mustard. Then the second one was rice-water spinach (1,728 ml/day). While the lowest average biogas production was rice-spinach (1356 ml/ day). The largest cumulative biogas production for 30 days was found to be the use of a mixture of 61,380 ml of rice- green mustard, then the second one was a mixture of rice-water spinach (51,850 ml), and the lowest was a mixture of rice-spinach (40,950 ml). It concluded that the highest CH_4 was obtained from the mixture of rice and green mustard which has a C/N 21.45 ratio of 75.35%; the highest percent of CO_2 compound was found in the mixture of rice and spinach at 21.65%, the highest percent of H_2S compounds produced from the mixture of rice and kale was 1.31%; and the highest percent of NH3 in the mixture of rice and spinach of 0.74%.

Acknowledgment

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List of Notations

P = tekanan [atm]
T = suhu [^{o}C]
T = time [second, hour]
V = volume [ml]

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Lembar Tanya Jawab

Moderator : Aspiyanto (Lembaga Ilmu Pengetahuan Indonesia, Serpong)
Notulen : Indriana Lestari (UPN "Veteran" Yogyakarta)

1. Penanya : Ricky Herjunata (UPN "Veteran" Yogyakarta)
   Pertanyaan : Apa tujuan dari perebusan sayur dan bagaimana cara untuk membuat kondisi anaerob di *digesting tank*?
   Jawaban : *Pretreatmeant* bahan diawal berupa perebusan sayur bertujuan untuk menghaluskan sayur dan memudahkan proses perombakan, sedangkan cara untuk mengkondisikan *digesting tank* tetap anaerob adalah dengan mengisi penuh *digesting tank*, kemudian menginjeksi gas N_2 ke dalam *digesting tank*.

2. Penanya : Aurelius Airlangga Suryo Wicaksono (UPN "Veteran" Yogyakarta)
   Pertanyaan : Mengapa grafik perolehan biogas untuk setiap sayuran berbeda dan mengapa komposisi produk biogas yang dihasilkan juga berbeda?
   Jawaban : Adanya perbedaan hasil yang diperoleh dari proses perombakan sayuran yang berbeda, dikarenakan kandungan C/N tiap sayuran berbeda. Rasio C/N berpengaruh terhadap komposisi produk biogas. Rasio C/N yang tinggi akan mengakibatkan kandungan CO_2 dalam biogas juga tinggi, sehingga biogas yang dihasilkan akan sulit untuk dibakar. Dan apabila rasio C/N rendah, maka pada produk biogas akan dihasilkan amoniak dalam jumlah yang banyak, sehingga gas CH_4 yang terbentuk akan rendah. Kondisi ini juga menyebabkan biogas sulit untuk dibakar. Rasio C/N yang paling baik adalah antara 16-25. Komponen lain yang juga berpengaruh dari pembentukan biogas yaitu kandungan selulosa, hemiselulosa dan lignin yang akan didekomposisi pada tahapan proses hidrolisis hingga metanogenesis untuk membentuk metan.

3. Penanya : Nur Hidayati (Universitas Muhammadiyah Surakarta)
   Pertanyaan : Keterbaruan apa yang ada dari penelitian ini?
   Jawaban : Tujuan awal mengangkat limbah kantin sebagai bahan baku biogas dikarenakan limbah kantin di ITS belum banyak diolah menjadi bahan yang bermanfaat. Tujuan kedepannya, proses ini nantinya akan diaplikasikan ke kantin, sehingga limbah tersebut dapat bermanfaat untuk kantin, sedangkan *side product* yang dihasilkan dapat dimanfaatkan sebagai pupuk tanaman di sekitar Jurusan.

4. Penanya : Renung Reningtyas (UPN "Veteran" Yogyakarta)
   Pertanyaan : Di TPA kondisi sampah organik bercampur dengan sampah plastik dan belum terolah, adakah proyeksi dalam jangka waktu ke depan semua sampah TPA akan dijadikan biogas?
   Jawaban : Proses pembentukan biogas membutuhkan bahan baku organik. Jika sampah, sebagai bahan baku yang digunakan tercampur dengan sampah plastik, maka proses pembentukan biogas tidak terjadi, sehingga perlu proses lain, seperti pirolisis untuk merubah sampah plastik menjadi bahan bakar. Dalam hal kondisi TPA yang memiliki sampah dalam jumlah sangat banyak, solusi tercepat untuk mengatasinya adalah dengan cara insinerasi.