

Design and testing of mini-size biogas plant

Erwin Randjawali^{1,3} and Abdul Waris^{2,4}

¹Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesa 10 Bandung 40132, INDONESIA

²Nuclear Physics and Biophysics Research Division, Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesa 10 Bandung 40132, INDONESIA

³erwinrandjawali@gmail.com

⁴awaris@fi.itb.ac.id

Abstract. Biogas is a renewable source of energy which is developed to fulfill the energy needs of the society. Two important aspects of the biogas itself is biogas plant and starter. This research aims to design a mini-sized biogas plant which can be use effectively to produce the alternative energy, and also to examine the difference quality of biogas which is produced from slurry which was given starter and slurry which was not given starter. In this study, a mini-sized biogas plant has been designed, and tested for two different types of slurry. Ratio of cow dung : water : starter of the first slurry is 3 : 2 : 0.003 (The starter which was used in this study is Green Phoskko), and for the second type of slurry, ratio of cow dung : water is 3 : 2, but in this second type, the slurry was not given a starter. Cattle dung used in this study is stored in advance for one week, two weeks, and three weeks, before use. Result of this study showed that the first type of slurry produce biogas in a faster time than the second type of slurry. Also, the amount of gas obtained from the first slurry is more than the second type of slurry. It can be seen from the length of time which is takes to burn the gas produced from the first slurry much longer than the second type of slurry.

1. Introduction

Indonesia's population still rely on fuel as a primary energy source. This is evident from the fuel consumption data from 2000 to 2012 an increase in fuel consumption of 1.9% in each year [1]. However, with the rising of fuel prices, makes people difficult to obtain. This can be overcome by using alternative sources of energy, so that energy needs can remain fulfilled. One of the alternative energy that can be developed in Indonesia is biogas.

Biogas is a gas obtained from decomposition of organic material (called biomass) in the absence of oxygen (anaerobic). In general, biogas consists of methane (50-75%), carbon dioxide (25-50%), as well as small amounts of other gases such as nitrogen (0-10%), hydrogen (0-1%), hydrogen sulfide (0-3%), and oxygen (0-2%) [2]. Biogas is suitable to be applied in Indonesia because there are a lot of biomass that can be used as a source of biogas. The biomass can be derived from agricultural waste such as animal manure, and feed crops; biomass can also be obtained from household and urban waste



such as expired food that has been sorted out beforehand, waste derived from market activity; and it can also be derived from industrial waste such as waste from the food industry, and industrial separation of fat [3].

In general, the process of biogas formation is divided into three stages: hydrolysis, acidification, and methanogenesis. In the hydrolysis step, complex organic material decomposed into a smaller form [4]. Polymer molecules such as carbohydrates, protein, and fat molecules are not soluble in water because it consists of many small molecules are joined through a unique chemical bond. To be able to dissolve, then chemical bonds must be destroyed first through hydrolysis. Hydrolytic bacterial will produce enzymes that can be used to break the bond [5]. For example, the lipid is hydrolyzed using lipase into fatty acids, and glycerol; hydrolyzed proteins using protease enzymes into amino acids; and hydrolyzed polysaccharides using cellulase, cellobiase, xylanase, and amylase enzymes into monosaccharides [4].

Results obtained from the hydrolysis stage are then fermented in acidogenesis stage. Fermented are then consumed by the acetogenic bacteria, so then obtained acetic acid, carbon dioxide, and hydrogen [6]. Carbon dioxide and hydrogen can be directly converted to acetate or methane [5]. But other compounds that can not be converted directly must go through acetogenesis [4]. Acetate is the most important product because it used as a substrate for methanogenic bacteria [5]. And finally at the methanogenesis stage, methanogenic bacteria will consume acetate, hydrogen, and carbon dioxide to produce methane gas [6].

During the process of anaerobic decomposition takes place, there are several parameters that play an important role in it. Temperature can affect the physicochemical components of all the components in the digester, as well as affect the biological processes in it [7]. Anaerobic decomposition can take place in three temperature ranges: psychrophilic (4-25 °C), mesophilic (25-40 °C), and thermophilic (50-60 °C). However, mesophilic and thermophilic are normally used for anaerobic digestion [8]. In addition to temperature, pH in the digester is important to be controlled, because if the pH becomes too high or too low can be a barrier for biogas production process [9, 10]. The experimental results showed that the optimum pH for anaerobic decomposition in the range of 5.5 to 8.5 [11]. The quality of the organic material used also affects the production of biogas. It can be seen from the C/N ratio of the organic material. C/N ratio related to the nutrients needed by methanogens [12]. The very high or very low of C/N ratio can inhibit the production of biogas. If the C/N ratio is very high, the nitrogen will be rapidly consumed by methanogens as a source of protein, causing excess carbon that very much. However, if the C/N ratio is very low, the nitrogen will be released and accumulates into ammonia which can raise the pH of the material [9]. Similarly, the presence of heavy metal ions such as copper, nickel, and others in very high concentrations can serve as a barrier [9].

Biogas formation process must take place in a place that is free of oxygen, called a digester. The shape and size of the digester can vary, according to the needs and available materials to make the digester [2]. Biogas digester that is often used in Indonesia is a fixed dome digester, built underground by using materials such as cement, sand, stone, and others. To build the digester, of course, required no small cost. In addition, skilled personnel are needed to ascertain whether the digester has been constructed correctly. If an error occurs in the digester construction, such as a leak, it would be difficult to repair, because it is under ground. The leak certainly will cause the formation of biogas process can not take place as it should be [13].

One way to cope with the construction cost of the conventional digester by creating a mini biogas digester, but still effective for everyday purposes. The advantages of making this mini-sized biogas digester are relatively low manufacturing cost, and simplify users to make repairs if something goes wrong at the time of manufacture. With the mini-sized biogas digester can be a solution to energy shortages that exist in Indonesia.

2. Materials and method

Materials used to make this mini-sized biogas plant is a 19 liters gallon, and some other equipment such as socket, nipples, and PVC. The material should be sufficiently elastic, to avoid the occurrence of cracks or leaks during the manufacturing process. Once the digester is completed, it is an important step that must be done is to check whether there is a pinpoint leaks or other faults which may occur during the manufacturing process. Methanogenic bacteria inside the digester tank are very sensitive to oxygen, therefore it is important to do the checking.

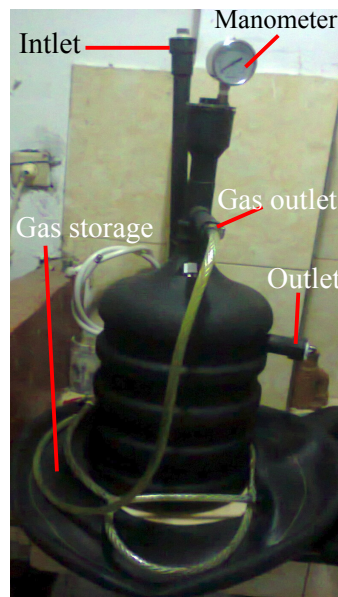


Figure 1. Prototype of mini-sized biogas plant.

In this experiment we tested the mini-sized biogas plant using slurry derived from the wet cow dung. For the wet cow dung, we did two different treatment (we made two different slurry). The first type of slurry uses a wet cow dung with an additional starter, and the second type of slurry uses of wet cow dung without additional starter. Wet cow dung which we used in these experiments was stored in varying time, i.e., one week, two weeks, and three weeks. The first slurry of wet cow dung made with a composition: 9 kg wet cow dung, 6 kg water, and 0,009 kg starter. In this experiment we use Green Phoskko as a starter for producing biogas. While the second slurry made with the composition: 9 kg wet cow dung and 6 kg water (without additional starters).

3. Result and discussion

The biogas plant in this experiment is made of materials which are easy to obtain. But it must be remembered that the plastic material used should not easy to crack, so there is no cracks nor leaks during the drilling holes process. While the metal materials used should be material that does not easily rust. Digester that has been created as shown in **Figure 1**.

This biogas plant has several major parts such as inlet, outlet, and gas storage. Inlet pipe serves as chamber for supplying slurry into the digester, while the outlet serves to remove digestate (waste obtained from the biogas production process) out of the digester. Gas that has been formed in the

digester will come out through the gas outlet and then stored into the gas storage. This biogas plant is also equipped with manometer to measure the pressure inside the digester.

The biogas plant is then tested using slurry derived from wet cow dung with varying storage time (as describe in the section above). Slurry which has been made are then inserted into the digester through inlet by using a dipper and funnel. When the slurry has been completed inserted, then the inlet, outlet, and the faucets should be closed. In this experiment we used pvc tape to ensure no leakage at the inlet and outlet. After that, we make observation on the biogas formation time.

From the experimental results obtained that there is a difference in the time of biogas formation between the slurry which was given an extra starter with slurry which was not given an extra starter.

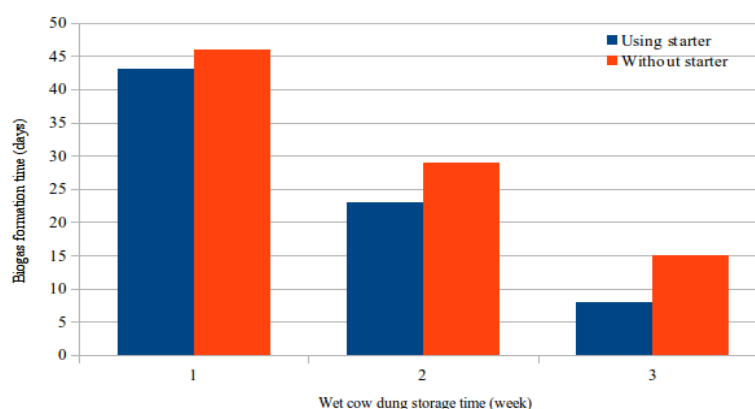


Figure 2. The time required for biogas formation.

From **Figure 2** can be concluded that the slurry which was given starter will be faster to produce biogas than the slurry which was not given a starter. This shows that with the provision of starter into the slurry, there will be an increase in the number of methanogenic bacteria. With the increasing number of bacteria makes the anaerobic decomposition process will go faster, so that biogas was formed more rapidly than the slurry which does not get an extra starter. In the slurry which was not given starter, it takes some time for the formation of bacteria, thus the time required for the anaerobic decomposition process becomes longer, so that biogas production is slower than the slurry that used starter. Therefore, it is advisable for people who will make a digester for domestic purposes, should use the starter at the time of initial entry into the digester slurry.

From the graph in **Figure 2** also seen that the longer the manure is stored in a closed container (before eventually mixed with water to be made into a slurry that will be incorporated into the digester), then the time it takes to do anaerobic decomposition process becomes shorter. This is because there has been a natural breeding of bacteria contained in the manure itself. Therefore, it can shorten the process of anaerobic decomposition. But in this study, the maximum storage cow dung is for three weeks. Therefore, could not be ascertained whether the formation of biogas will be faster or slower when the manure is allowed to stand in a time that is longer than three weeks.

Biogas which has been obtained from the two different types of slurry is then burned, and the data obtained by the length of time it takes to burn the biogas produced, as shown in **Figure 3**.

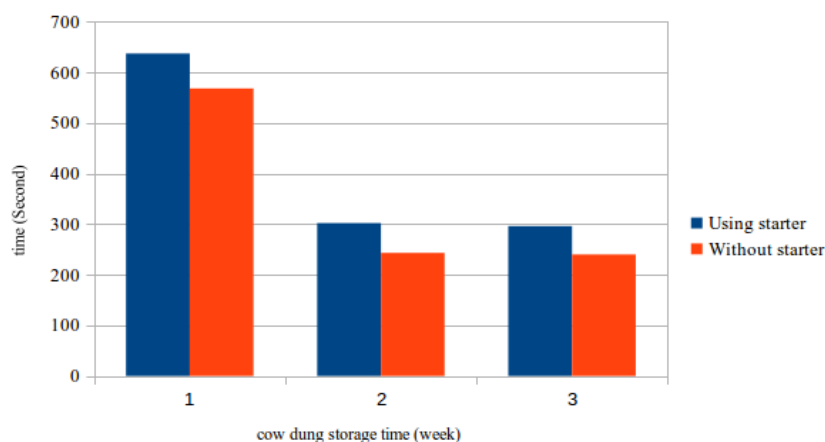


Figure 3. Biogas burning time.

Based on those graph also seen that there is a difference between the quantity of biogas slurry supplied starter with slurry that was not given a starter. From the graph can be concluded that the biogas generated by the anaerobic decomposition of a given starter slurry has higher numbers than the biogas generated by the anaerobic decomposition of slurry which was not given a starter. This is evident from the length of time the combustion of biogas slurry produced by a given starter longer than the biogas produced by the slurry that was not given a starter. This is because of the amount of bacteria that was generated by a given starter slurry. As a result, the anaerobic decomposition process could be more optimal, so that biogas obtained becomes more than the slurry which was not given a starter.

We calculate the efficiency of biogas which is derived from cow dung, by heating 1kg of water with temperature 23°C until it reach to 56°C , and assumed that the slurry composed entirely of glucose. So, the efficiency of the biogas is 0.14%.

4. Conclusion

From the results of these experiments we have developed a mini-sized biogas producers, and it can be concluded that slurry which was given an extra starter can produce biogas in a faster time than the slurry which did not get an extra starter. Also, slurry which was given starter produce biogas in an amount more than the slurry that was not given an extra starter. However, the data obtained is just a rough data, requiring further research using more time span.

References

- [1] BPPT 2014 *Outlook Energi Indonesia 2014: pengembangan energi untuk mendukung program subsidi BBM* (Jakarta: Pusat Teknologi Pengembangan Sumber Daya Energi, Badan Pengkajian dan Penerapan Teknologi) p 12
- [2] Ford S 2007 *Advances in Biogas* (UK: Pira International Ltd) p 1-2, 13
- [3] Gomez C D C 2013 *Biogas as an energy option: an overview on The Biogas Handbook (science, production and application)*, ed Arthur Wellinger, Jerry Murphy, dan David Bexter (Cambridge: Woodhead Publishing Limited) p 1
- [4] Seadi T A, Rutz D, Prassl H, Köttner M, Finsterwalder T, Volk S, and Janssen R 2008 *Biogas Handbook* (Denmark: University of Southern Denmark Esbjerg) p 21-23
- [5] Gerardi M H 2003 *The Microbiology of Anaerobic Digesters* (New Jersey: John Wiley & Sons, Inc) p 51-56

- [6] CIWMB 2008 *Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste* (California: California Integrated Waste Management Board) p 1-2
- [7] Kerroum D, Mossaab B and Hassen M A 2012 *Production of Biogas from Sludge Waste and Organic Fraction of Municipal Solid Waste on Biogas*, ed Sunil Kumar (Croatia: InTech) p 157
- [8] Schnürer A and Jarvis Å 2010 *Microbiological Handbook for Biogas Plants* (Swedish: Avfall Sverige) p 33
- [9] Abbasi T, Tauseef S M and Abbasi S A 2012 *Biogas Energy* (New York: Springer) p 5-7, 9
- [10] Monnet F 2003 *An Introduction to Anaerobic Digestion of Organic Wastes* (Remade Scotland) p 8
- [11] Verma S 2002 *Anaerobic Digestion of Biodegradable Organics in Municipal Solid Wastes* (Columbia University) p 7
- [12] Jørgensen P 2009 *Biogas-Green Energy (Process, design, energy supply, environment) 2nd Edition* (Aarhus University: Digisource Danmark A/S) p 12
- [13] Vögeli Y, Lohri C R, Gallardo A, Diener S and Zurbrügg C 2014 *Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies* (Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)) p 33-34