Biomethanization technology application on slaughterhouse in Indonesia

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Abstract. At small community slaughterhouses /TPH in Indonesia, waste is discharged into the environment. On the government side, waste from small slaughterhouses/RPH is channeled into facultative ponds, while solid waste from big slaughterhouses is disposed of in a landfill, while liquid waste is dumped into wastewater treatment using the activated sludge method. The research objective is to prove that biomethanization technology could be used to treat liquid waste in Indonesian slaughterhouses. The study used a 2x3x5 factorial randomized block design. The first factor was stirred substrate/rumen; P0 = not stirred, P1 = stirred 10 minutes and P2 = stirred 20 minutes. The second factor was addition of urine; U0 = no urine, U1 = 20% urine and U2 = 40% urine and there were five replications. The parameters were Biological Oxygen Demand (BOD), biogas production, temperature, pH and sludge Carbon/Nitrogen ratio (C/N ratio). The results showed a decrease in BOD by 72%, and 20 minutes of stirring treatment resulted in 170.26 liters of methane gas per kg of rumen. The average temperature of the research substrate was 26.43°C with a pH around 7, and sludge C/N was 9.01. The results of the study are worth considering for application on Indonesian slaughterhouses because they prove that with the biomethanization technology, besides eliminating waste, other benefits can also be obtained, such as renewable energy and sludge.

1. Introduction
The main activity in many slaughterhouses belonging to the community (TPH) or the government (RPH) is slaughtering livestock, and the main product is meat. In addition to meat, liquid waste – the contents of the rumen, blood and solid waste such as skin, horns, feathers, and bones are produced. Liquid waste from slaughhters contain highly concentrated pollutants which are significantly far below the quality standards [1]. This makes the liquid waste require treatment before being released into the environment (water bodies). Untreated liquid waste will deteriorate water quality by, among others, lowering oxygen and biochemical oxygen demand (BOD) and increasing nutrient levels. Pollutants that enter water bodies damage the aquatic habitat, which affects aquatic biota [2].

In TPH, one or two cattle are slaughtered every day as TPH is more accessible from cattle fattening locations. Until now, liquid waste in TPH is only channeled to a water body or facultative ponds in order to reduce waste load, including pathogenic bacteria [3]. Meanwhile, in RPH, wastewater treatment requires anaerobic and aerobic ponds. A high number of slaughtered cattle, for example, in Mabar RPH, Medan, with an average of 40 cows per day, causes the original waste to have a very high concentration of pollutants. Only anaerobic microorganisms can effectively decompose the initial waste. At this stage, without oxygen, the pathogenic bacteria dies. Furthermore, if the concentration of pollutants has begun to decrease, the oxygen level begins to rise in ponds and aerobic microorganisms will start working to break down the remaining pollutants. Anaerobic ponds are ideal if slaughterhouses have a sufficient area...
– BOD and suspended solids can be reduced by 80%. In European countries, where there are infectious diseases such as Bovine Spongiform Encephalopathy (BSE) and Foot and Mouth Disease, treatment for contamination is absolutely necessary [4].

In reality, the sewage treatment pool may also not work. This usually starts because the working power of activated sludge decreases. According to Green, this can happen, among others, due to excessive waste load, such as excessive blood volume and rumen contents, so it should be reduced because it causes microbes not to work optimally. The situation will get worse if the treatment of the pool is not done optimally. The sludge must be lifted out because if it is too thick, the pool volume will decrease, which in turn will cause a reduction in the volume for microorganisms to grow [5]. This often occurs in sewage treatment ponds in many RPH, such as in Mabar RPH, Medan, North Sumatra.

Nowadays, sewage treatment ponds are not environmentally friendly because anaerobic ponds emit methane gas. The ozone layer that protects our earth is damaged by methane gas, one of several greenhouse gases that cause global warming. The amount of methane gas on global warming has reached 18%. [6, 7]. Therefore, a new method is needed to treat slaughterhouses wastes so that no methane is emitted.

In slaughterhouse waste, the kinds of waste that become the source of contamination are the contents of rumen and blood. The contents of rumen are no longer appropriate when treated using the activated mud pond method. Another alternative is to process them with biomethanization, which can be applied both in TPH and RPH because it does not require a large place. The gas that is formed is a renewable energy that can be used for various purposes, and the output, the sludge, can be used as organic fertilizer [8].

2. Materials and method

2.1. Materials

The materials are the rumen content from slaughterhouses, urine and well water to dilute the contents of the rumen. This research was provided with tools such as 6 units of biodigesters, where digestion would be conducted anaerobically. Biodigester was designed to follow a continuous feeding type with a maximum capacity of 145 liters and an optimal filling of 120 liters. After designing, the biodigesters were constructed by a contracted company using fiberglass materials. After that, the equipment was placed at the Department of Animal Husbandry, Faculty of Agriculture, University of North Sumatra. As biodigester has a continuous feeding system, substrate is added every day [9]. In addition, there was a plastic gas container as a tool to measure gas production. Figure 1 is a prototype of the biodigester used in this study. Through the inlet, the substrate will enter the biodigester. Previously, the substrate was diluted with well water with a ratio between the substrate and well water of 1: 3. The substrate that has been processed in the biodigester is called sludge. After undergoing 30 days of hydraulic retention time [10], the sludge will come out to the outlet. Gas that has been formed will come out through the gas pipeline to the gas storage plastic. Research by Ferrer et al. used gas storage plastics to measure gas production[11].

2.2. Method

The study was conducted using a factorial randomized block design. Factor I was the stirring of substrate consisting of 3 levels, namely: P0: substrate was not stirred; P1: substrate was stirred for 10 minutes; P2: substrate was stirred for 20 minutes. Factor II was the addition of urine consisting of 3 levels, namely: U0: no urine; U1: 20% ; U2: 40% urine. There were five replications. In a biogas study, replications were carried out by measuring the recurring gas production for five days, once every day at the same hour after stirring [12].

Data is collected after the gas production condition is stable, that is 30 days. Data collection was also carried out to obtain data on BOD, temperature, pH and C/N of sludge [13]. From research by Veiga et al., measuring methanogenic activity at various depths of biodigester, it is known that the bottom of biodigester has the highest methanogenic activity and the highest biomass concentration[14]. This
means that stirring treatment is needed so that the methane gas is not blocked up to the gas storage section and the biomass concentration can be evenly distributed.

Figure 1. Biodigester prototype.

3. Result and Discussion

3.1. The BOD content from the biomethanization process

The study used rumen contents taken from the slaughterhouse containing 1737.45 mg/l of BOD. After hydraulic retention time for 30 days in the biodigester, BOD content decreased by an average of 72%. Biomethanization applications are mostly carried out in European countries in pig waste. On average, they degrade organic matter by 65-75% [9]. The decrease in BOD is related to the action of microorganisms in degrading the substrate.

Table 1. BOD content of the substrate with Hydraulic Retention Time (HRT) 30 days.

| Treatment | BOD content with HRT 30 days (mg/l) |
|-----------|-----------------------------------|
| P0U0      | 480                               |
| P2U2      | 425.32                            |
| P1U1      | 499.43                            |
| P1U0      | 394.98                            |
| P2U0      | 235.72                            |
| P0U2      | 625.83                            |
| P0U1      | 510.12                            |
| P1U2      | 672.51                            |
| P2U1      | 525.14                            |
| Average   | 474.34                            |

% Decreased BOD 72%

There were 3 stages of degradation in the biomethanization process: hydrolysis, acidification, and methanization [15]. The substrate contains cellulose, carbohydrates, lipids and protein. Complex bonds of the substrate were broken down by enzymes released by microorganisms into simpler bonds resulting in simple carbohydrates such as volatile fatty acids, ethanol and amino acids. In addition, it also produced water and CO₂. In the process of hydrolysis, there were bacteria that play an important role, among others, Ruminococcus albus, R. Flavefasiens, Bacteroides succinogenes, Butyrvibrio fibrosolvens, Clostridium lockheadii which digests cellulose [16]. Besides bacteria, there were also fungi that degrade fibers such as Neocallimastic frontalis and Sphaermonas communis. At the next
stage of degradation, namely acidification, organic acids such as acetate, H₂S, CO₂, and ammonia were formed. Next was the formation of methane through the process of methanization by secondary bacteria that utilize carbon from CO₂ [17].

BOD is an indicator of the presence of pollutants in water. Organic pollutants cause the need for oxygen by microorganisms to decompose the pollutant. Pollutants come from waste materials. The more waste materials in water are, the more oxygen is needed by microorganisms, which means less oxygen left in the water. As a result, there will be less biota left in the water, because biota requires oxygen for living. In this study, the BOD is obtained to be an average of 474.34 ppm, while the wastewater quality standard set by the government for class IV (heaviest) wastewater was 300 ppm. Substrates that have undergone biomethanization are called sludges. Although the sludge still has a BOD value above the quality standard, the sludge still has other features. In European countries, the sludge will not be discarded, but is used for soil amendment or improving soil conditions [18]. This is because sludge contains not only macro elements but also micro elements that are not present in chemical fertilizers [19]. Ginting and Mustamu found that every 250 ml of sludge was equal to 2.5g NPK. Sludge can be applied very well to substitute some of the fertilizer needs [20].

3.2. Methane gas production by stirring and addition of urine treatments
From table 2, it was known that stirring for 20 minutes resulting in the formation of methane gas which was the highest and significantly different from stirring for 10 minutes. Stirring for 10 minutes resulted in a formation of methane gas which was significantly different from without stirring. This means that stirring the substrate in the biodigester was very useful for triggering large gas production. The amount of gas produced with stirring is in accordance with the results of the study of Ward et al., stating that substrate stirring is necessary for efficient organic material transfer so that active microbial growth occurs [21].

| Treatments | Group | Total | Average |
|------------|-------|-------|---------|
| P0U0       | 1     | 117.49| 23.50A  |
| P2U2       | 2     | 119.01| 23.80A  |
| P1U1       | 3     | 117.50| 23.50A  |
| P1U0       | 4     | 45.87 | 91.17B  |
| P2U0       | 5     | 851.28| 170.26C |
| P0U2       | 6     | 99.00 | 19.80A  |
| P0U1       | 7     | 116.00| 23.20A  |
| P1U2       | 8     | 101.00| 20.20A  |
| P2U1       | 9     | 103.50| 20.70A  |

The need for stirring is in line with research conducted by [22], which states that the substrate must be mixed evenly. The piles of substrates cause microorganisms to be unable to work efficiently in digesting the substrate. Furthermore, Ward et al. stated that stirring would also cause the release of gas bubbles trapped in the middle of the substrate. Methane is a gas that has low pressure so that if there are some obstacles for methane to find a way out, the gas can not escape. In biodigesters filled with substrates that contain lots of fiber, a lot of foam will form, and thick foam can block the methane gas [21]. In this study, the used substrate content was from cow rumen originated from corn plants that were chopped with an average length of 7 cm. Foam formation is based on the type of cow diet sources. If the foam is not stirred, the foam can inhibit the methane gas from escaping.
Ward et al. said that stirring would prevent deposition of solid particles [21]. Deblain and Steinhauser added that the materials settling at the bottom of the biodigester must be removed by stirring so that trapped CO₂ can be removed. CO₂ plays a role in the formation of methane gas so that the release of CO₂ will affect the quality of the gas [17].

In this study, there are 2 treatments, stirring and adding urine. Stirring turned out to be beneficial for gas production as much as 20% urine and 40% reduced gas production. Livestock urine contains various nitrogen such as creatine, ammonia, uric acid, allantoin, amino acids and urea [23]. Besides, urine contains NaCl (salt). Sodium in high concentrations is an inhibitor for the development of microorganisms while inhibiting gas production. The results of laboratory tests on cattle urine showed that the Sodium content was 17 mmol/liter. If the urine concentration in the biodigester is 20%, then there is a sodium content of 15,640 mg/l, and if the urine concentration is 40%, then there is a sodium content of 31,280 mg/l, while the toxic level of sodium as an inhibiting agent is 3500 - 5500 mg/l [24].

3.3. Biodigester temperature by stirring and addition of urine treatments

From table 3, it can be seen that the treatments did not have a significantly different effect on temperature. According to Cantrell et al., there were three temperature ranges in the anaerobic digestion process, namely 1) the low/psychrophilic temperature range of <20°C; 2) range of 20-45°C or mesophilic; 3) 45-60°C or thermophilic. The temperature difference in the biomethanization process is more influenced by the ambient temperature than the digestion process itself [25].

In a study conducted in Costa Rica by Lansing et al., the average biodigester temperature is 26.2 ± 0.2°C, and the environmental temperature in Costa Rica was relatively similar to it in Medan. In this study, the average research temperature was 26.43°C where the ambient temperature at the time of data collection was 23-32°C [26]. Research conducted by Amaru in Bandung shows biodigester temperatures are in the range of 19-20°C [27]. Bandung is a city in Indonesia that is relatively cooler in temperature.

Table 3. Average temperature in the biodigester by stirring and addition of urine treatments (ºC).

| Treatments | Group | I    | II   | III  | IV   | V    | Total | Average |
|------------|-------|------|------|------|------|------|-------|---------|
| P0U0       |       | 25.6 | 26.2 | 26.4 | 27.2 | 26.4 | 131.80| 26.36   |
| P2U2       |       | 25.7 | 26.2 | 26.3 | 27.2 | 26.5 | 131.90| 26.38   |
| P1U1       |       | 25.6 | 26.5 | 26.5 | 27.3 | 26.5 | 132.40| 26.48   |
| P1U0       |       | 25.8 | 26.4 | 26.4 | 27.2 | 26.5 | 132.30| 26.46   |
| P2U0       |       | 25.3 | 26.5 | 26.7 | 27.4 | 26.5 | 132.40| 26.48   |
| P0U2       |       | 25.6 | 26.4 | 26.6 | 27.2 | 26.4 | 132.20| 26.44   |
| P0U1       |       | 25.7 | 26.3 | 26.6 | 27.2 | 26.4 | 132.20| 26.44   |
| P1U2       |       | 25.5 | 26.3 | 26.6 | 27.3 | 26.3 | 132.00| 26.40   |
| P2U1       |       | 25.6 | 26.4 | 26.5 | 27.3 | 26.4 | 132.20| 26.44   |

According to Amaru, gas production in the research he conducted was relatively lower because the temperature of the biodigester was below the optimal temperature level for microorganism activity, around 35°C [27]. As a result, the ability of microorganisms to decompose the substrate is reduced. Biodigester substrate derived from rumen contents contains many strains of microorganisms. Microorganism strains will naturally adjust to their environment. According to Kadarwati, strains that adapt to anaerobic and mesophilic conditions include: Methanobacterium omelianskii, Methanosarcina bacterium, Methanobacterium formicicum, Methanobacterium suboxydans and Methanobacterium sohngenii [28].
3.4. The pH of substrate by stirring and addition of urine treatments

Table 4. Average pH of the substrate by stirring and addition of urine treatments.

| Treatments | Group I | Group II | Group III | Group IV | Group V | Total | Average |
|------------|--------|---------|-----------|----------|---------|-------|---------|
| P0U0       | 7.2    | 7.2     | 7.3       | 7.4      | 7.4     | 36.5  | 7.30    |
| P2U2       | 7.5    | 7.3     | 7.3       | 7.2      | 7.2     | 36.6  | 7.32    |
| P1U1       | 7.4    | 7.4     | 7.3       | 7.2      | 7.2     | 36.6  | 7.32    |
| P1U0       | 7.2    | 7.3     | 7.3       | 7.3      | 7.4     | 36.5  | 7.30    |
| P2U0       | 7.4    | 7.4     | 7.3       | 7.2      | 7.2     | 36.5  | 7.30    |
| P0U2       | 7.4    | 7.2     | 7.3       | 7.3      | 7.3     | 36.5  | 7.30    |
| P0U1       | 7.4    | 7.4     | 7.3       | 7.2      | 7.2     | 36.6  | 7.32    |
| P1U2       | 7.2    | 7.2     | 7.3       | 7.4      | 7.5     | 36.6  | 7.32    |
| P2U1       | 7.4    | 7.4     | 7.3       | 7.3      | 7.2     | 36.6  | 7.32    |

Table 4 shows the average pH data with the highest average at P2U2 treatment with 7.32, while the lowest average is at P0U2 treatment with 7.30. From table 4, it is known that different treatments did not provide a significant difference in the pH of the substrate in the biodigester. The pH of the study was at an average of 7.3. Barnett stated that the pH of the substrate would be stable, which is around 7.2-8.2 if the entire set of substrate decomposition processes had been completed, which would take about 30 days under esophilic conditions [29].

3.5. Sludge C/N ratio by stirring and addition of urine treatments

C/N ratio of sludge is an indicator of the degradation level that occurs on biogas process. The rumen C/N in this study was 10.88, and after going through HRT for 30 days, the C/N ratio became 9.01. The C/N ratio decreased due to the degradation process. There was an overhaul of the rumen fiber content so that the C value decreased, accompanied by the formation of organic acids so that the N value increased. In this study, the C/N ratio was still below the standard formulated by the Minister of Agriculture Regulation No. 70, which states that the C/N for crop fertilizer must be between 15 to 20. Even though the C/N of the rumen sludge does not meet the standards, the sludge is still used to remediate soil. Basically, the rumen C/N ratio is low because the high N value is related to the high population of bacteria and protozoa in the rumen [30; 31], while they are useful to improve soil quality.

4. Conclusion

Slaughterhouse waste treatment with the application of biomethanization technology is able to reduce the content of liquid waste, i.e., rumen content resulting in a decrease in biochemical oxygen demand at an average of 72%. It also produced methane gas by 170.26 liters/kg rumen via 20 minutes of stirring treatment. The average temperature of the research substrate was 26.43°C, with a pH of around 7. C/N sludge 9.01. In conclusion, biomethanization technology is feasible to be used for processing slaughterhouse waste.

5. References

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