Evaluation of biogas potential from organic waste: wastewater and solid wastes

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Abstract. The poor management of waste can lead to multiple environmental problems like in soil, water, and air pollution. Beside the current energy crisis occurs, need alternative energy sources that can replace, one of which is biogas. Biogas is a gas resulting from the fermentation anaerobic of organic materials. The aim of this work is to study to compare the biogas produced from organic waste, namely household waste, sago processing liquid waste and poultry manure. The research was conducted in a laboratory scale anaerobic reactor with a volume of 1,000 mL at room temperature. The results showed that the volume of biogas produced from anaerobic fermentation of sago processing wastewater was 17.481 mL (84 days fermentation). Biogas produced from household waste (7%) is 687 mL, for 35 days. Volume biogas from poultry manure (50%) 1,200 mL (60 days fermentation).

1. Introduction

Energy demand in Indonesia continues to increase from year to year. The energy crisis occurs because most of the energy sources come from fossil fuel. Fossil fuels are the oldest energy that cannot be renewed and the supply is running low over time[1]. The world demand for oil (BBM) continues to increase rapidly from year to year, while world oil production has reached its peak [2]. This condition results in scarcity of fuel oil (BBM), this is due to the limited amount of petroleum oil and requires a long time for its formation process. Therefore, efforts are needed to find alternative energy sources. According to the Presidential Regulation of the Republic of Indonesia Number 5 of 2006 concerning national energy policies to develop alternative energy sources as a substitute for fuel oil. This policy leads to the production of alternative energy to replace fossil fuels that can be renewed [3]

Biogas is a potential energy produced from the fermentation process of organic materials in anaerobic conditions [4]. Although biogas technology has been developed for a long time, many countries are now applying biogas technology as an alternative energy source. The application of biogas has several advantages over fossil fuels, mainly because it’s ecofriendly and renewable source [5].

Biogas fermentation is conducted with the help of anaerobic microbes. Microbes in the formation of biogas play an important role in breaking down organic compound and small molecule such as biogas. The biogas is produced is the fermentation results of various types of bacteria in a consortium. The biogas fermentation substrate could produceds from livestock manure such as cow manure, buffalo, pig manure, goat, and chicken dung. In addition, according to [6], biogas can also be made from human waste, agricultural waste biomass or a mixture of the two, in the digester.
The biogas produced will be optimal if the substrate used meets nutrients for the growth of bacteria involved in biogas fermentation [7]. Nutrients needed in biogas production, according to Bardiya [8] and [9], C / N ratio ranging from 20 to 30. The biogas substrate must also contain optimal nitrogen, namely 1.45%, while the optimum phosphorus and potassium is 1.10% [10].

The process of forming biogas occurs in four stages, namely the hydrolysis, acidogenesis, acetogenesis and methanogenesis stages [11]. In the first stage in the biogas formation process, there will be a decomposition of complex organic compounds (from waste), into simpler compounds [12]. In the acidogenesis stage, simple monomer fermentation occurs into short organic acids such as propionic acid, butyric acid, lactic acid, alcohol. The bacteria involved in this stage are acid-forming microbes such as Pseudomonas, Escherichia, Flavobacterium, and Alcaligenes. In the acetogenesis stage, most of the acid fermentation results are oxidized to acetic acid, carbon dioxide, and hydrogen which will become a substrate for methanogenic bacteria. The last stage is methanogenesis, according to [12] 70% of the methane formed is produced from acetic acid and the remaining 30% is generated from the conversion of hydrogen and carbon dioxide. This process is assisted by methane bacteria.

Most of the household waste and municipal wates are potential materials substrate. Sago processing liquid waste that comes from sago pulp and filtering process (extraction) and starch deposition. This liquid waste can reach 94-97% [13] with C: N ratio of 105:0.12 [14; 15]. Composition of household organic waste. That largest proportion is leaf waste (32%), water (29.8%), paper (17.5%) and food (16%) and a small amount of wood [16]. Chicken manure has a C / ratio. N is 17.71 [17] and the nutrient content consists of N 1%, P 0.80%, and K 0.40% [18].

2. Material and method

2.1. Biogas Fermentation Substrate Extraction
The sago waste is taken from the river around the sago processing plant, Sampara Southeast Sulawesi. The extract of the beef rumen is taken from the Slaughterhouse (RPH) at Kendari City. Household waste, taken from housing in Kendari city. Chicken manure is obtained from laying hen farmers in Baruga Southeast Sulawesi. Cow manure is obtained from cattle breeders in Sindangkasih Southeast Sulawesi.

2.2. Biogas Production

| Biorekator | Substrates | Source of microbes | Volume |
|------------|------------|--------------------|--------|
| Household waste | | | |
| 1 | 5% | Sewer water: cattle rumen (2: 3) | 1000 mL |
| 2 | 7% | 5% | 1000 mL |
| 3 | 10% | 5% | 1000 mL |
| Sago liquid waste | | Cow rumen | |
| 1 | 90% | 10% | 1000 mL |
| 2 | 80% | 20% | 1000 mL |
| 3 | 75% | 25% | 1000 mL |
| 4 | 70% | 30% | 1000 mL |
| Chicken manure: cow dung | | Source of microbes | |
| 1 | 50%: 0% | Chicken manure, cow manure. | 1000 mL |
| 2 | 0% : 50% | 1000 mL |
| 3 | 40%: 10% | 1000 mL |
| 4 | 30%: 20% | 1000 mL |
| 5 | 20%: 30% | 1000 mL |
| 6 | 10%: 40% | 1000 mL |

Reactor biogas produced during the fermentation process will be flowed through a tube into a 1000 ml measuring cup filled with water and installed upside down. The volume of biogas is calculated by
measuring the volume of water that is pressed. The volume of water pushed is proportional to the volume of biogas produced.

3. Results and discussion

3.1. Biogas from Household Organic Waste

The results of the proximate analysis of household organic waste showed high levels of crude fiber, fat and protein (Table 2). Therefore, organic waste is very well used as a carbon source for biogas-producing microorganisms.

Table 2. Proximate Data of Household Organic Waste

| No | Proximate Analysis      | Percentage |
|----|-------------------------|------------|
| 1  | Water Content           | 61.08%     |
| 2  | Ash content             | 5.21%      |
| 3  | Crude Fiber Content     | 21.5%      |
| 4  | Protein Content         | 5.95%      |
| 5  | Fat Content             | 6.2%       |

The source of microorganisms for making biogas from household waste is taken from cow rumen fluid, water and sewage sediment. Microbes from cow rumen are bacteria and protozoa that are capable of producing cellulase enzymes which function to digest cellulose into organic acids, and can produce biogas in the form of methane. Water and sewage sediments contain a lot of organic matter such as leaf, vegetable, rice and other human activity wastes, thus enabling anaerobic microorganisms to live and reproduce [19]. Therefore, microbes from cattle rumen fluid and sewage sediments are good starters to make biogas.

Figure 1. Variation in the concentration of organic waste

Figure 1 shows that at a 10% (w/v) concentration of organic waste there was a decrease in the amount of biogas produced. This occurs because at these concentrations there is an increase in carbon sources for microorganisms that play a role in the process of forming biogas. If there is too much C element in the material (high C/N), then the N element will run out first, so the C element remains. This will cause the bacteria to stop working (Susilowati, 2009). The conversion of organic compounds into
CH₄ (methane gas) and CO₂ (carbon dioxide gas) requires a C / N ratio requirement between 20-25%. The value of the C / N ratio above 25% causes a fast consumption rate by methanogenesis bacteria, which will reduce the production of biogas.

3.2. Biogas from sago processing wastewater

The chemical composition of the liquid sago waste meets the criteria to be used as a raw material for biogas production. These substances can be used by microorganisms as nutrients, so that biogas can be formed. The results of the proximate analysis of sago wastewater are presented in Table 3.

| Component      | Score  |
|----------------|--------|
| Carbohydrate   | 0.69%  |
| Carbon         | 2412 mg / L |
| Nitrogen       | 980.20 mg / L |
| C / N          | 2.46   |
| Protein        | 3.69%  |
| Ash            | 4.05%  |

Carbon and nitrogen components are the main nutrients for the growth of microorganisms in producing energy. The relationship between the amount of carbon and nitrogen is indicated by the value of the C / N ratio (Anunputtikul, 2004). Based on the results of the analysis, it shows that the amount of carbon and nitrogen contained in the liquid sago waste is 2412 mg / L and 980.20 mg / L, and the C / N ratio is 2.46 (Table 3). [14] stated that the high content of organic matter will have a success rate of obtaining a high volume of biogas.

| sago liquid waste: cow's rumen fluid | Total Biogas Volume (mL) | CO₂ volume (mL) | Gas Volume without CO₂ (mL) | Biogas without CO₂ (%) |
|-------------------------------------|--------------------------|-----------------|-----------------------------|-------------------------|
| 90%:10%                             | 6197                     | 70.16           | 6126.84                     | 98.86                   |
| 80%:20%                             | 5901                     | 82.81           | 5818.19                     | 98.60                   |
| 75%:25%                             | 7881                     | 81.57           | 7799.43                     | 98.96                   |
| 70%:30%                             | 17481                    | 105.37          | 17375.63                    | 99.39                   |

Biogas production for the sago liquid waste substrate occurred at week 8-10. This condition occurs because, the time for each stage of biogas formation using the sago liquid waste substrate lasts a long time (Table 4). At 8-10 weeks, simple monomer fermentation will occur into short organic acids such as propionic acid, butyric acid, lactic acid, alcohol and biogas by acid-forming bacteria such as Pseudomonas, Escherichia, Flavobacterium, and Alcaligenes [19].

The results of biogas production as seen in Figure 2, show that the total biogas production resulting from each composition has a different volume, the largest total volume of biogas produced is from the mixture of 100 g chicken dung and 400 g cow manure (P4), that is 3070 mL. This can be due to the appropriate mixture of ingredients between cow dung substrate and chicken manure substrate, so as to produce good production. Meanwhile, the lowest total biogas production resulted from the addition of 200 g of chicken manure and 300 g of cow dung (P3) with a total production of 550 mL. This could be because the composition has a non-optimum C / N ratio of 17.51, a low C / N ratio will cause the gas produced to be relatively low too [20].
Figure 2. Biogas volume for 9 weeks. Ka: Chicken Manure; Ks: Cow Manure; P1: Chicken Manure: Cow Manure (4:1); P2: Chicken manure: Cow manure (3:2); P3: Chicken Manure: Cow Manure (2:3); P4: Chicken Manure: Cow Manure (1:4)

4. Conclusion:
Based on the results of the research that has been done, the following conclusions are obtained:
• The total volume of biogas produced from the substrate of household organic waste during 3 weeks were 550 mL. The content of methane gas in biogas is 75.89% (v/v).
• The total volume of biogas from the optimal sago liquid waste substrate after fermentation at 11 weeks were 17,481 mL. The content of methane gas in methane gas is 99.39% (v/v).
• The largest volume of biogas produced is in the treatment of a mixture of 100 g chicken manure and 400 g cow manure (P4), which is 3070 mL, after 9 weeks of fermentation.

5. References
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