Utilization of livestock manure as a source of biogas for renewable energy

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Abstract. Research on energy resources other than oil and gas continues to be conducted. Indonesia as an agricultural country has abundant natural resources that can be used as an alternative energy source, namely bioenergy. One type of bioenergy is biogas which is derived from organic waste from plants and livestock manure. In this study, optimization of the utilization of livestock manure as a source of biogas is carried out by creating a household biogas system. The type of reactor in this study is a fixed digester. Livestock manure came from five cattle with the amount of around 15 kg/day of each. The ratio of livestock manure and water is of 1:1. Optimization is done by functional test and combustion test on the 15th day. The range of tests is 30 – 40 of pressure. And it reaches an optimum value at a pressure of 40. The temporary gas reservoir made from tires that are connected between the digester tank and the stove is used to maintain the gas supply from the digester tank. Moreover, the flame can burn steadily for up to more than one hour of use. Finally, this biogas system from livestock manure is expected to be used as alternative energy for a rural area.

1. Introduction
The energy crisis is a serious problem for many countries in the world because the conventional energy source that has been widely used, namely oil, is getting low and cannot be renewed. Therefore, the world needs renewable energy to overcome the energy crisis. The development of alternative energy sources continues to be carried out in Indonesia. There are at least six sources of New Energy and Renewable Energy (EBT) as alternatives owned by Indonesia, namely water, solar, wind, ocean currents, bioenergy, and geothermal energy. The total potential of the six resources is estimated at 441.7 GW with the realized capacity of only 8.89 GW or 2% of the existing potential. The government has targeted the energy mix derived from EBT by 23% with a total power of 92.2 million tonnes of oil equivalent (Mtoe) in 2025 in Presidential Regulation Number 22 of 2017 concerning the General Plan for National Energy (RUEN). Based on this, the Government is consistent in continuing to maximize the economic use of EBT [1].

Indonesia is an agricultural country with abundant agricultural and livestock resources. Besides being used as organic fertilizer, waste from agriculture and livestock can also be used as an alternative energy source, namely biogas. The use of biogas is part of the renewable energy program of the Government to increase energy access for the community through the use of EBT, especially...
bioenergy. Of the 23% energy mix target, bioenergy is expected to contribute 9.7% or 23 MTOE (Metric Ton Oil Equivalent) with details of 13.8 Million KiloLiter of Biofuels, 8.4 Million tonnes of Biomass, and 489.8 Million m$^3$ of Biogas [2].

Biogas is a gas that can be burned and produced through anaerobic activity (without oxygen) in the digester from organic materials such as livestock manure, household waste, and agricultural waste. Biogas is a mixture of gases produced from a fermentation process of organic matter by bacteria without oxygen. The composition of the biogas produced is methane gas (CH$_4$) around 55-75%, carbon dioxide gas (CO$_2$) about 25-45%, and other gases in a small proportion [3-7].

Methane gas (CH$_4$) as the main component of biogas is a good fuel with a high heating value, which is about 4800 to 6700 kcal/m$^3$, while pure methane gas contains 8900 Kcal/m$^3$ of energy [3]. Therefore, biogas can be used for lighting, cooking, moving machines, and so on.

Biogas provides many added-value benefits to society from organic waste. In agriculture, anaerobic processing of livestock manure and organic food scraps provides benefits to the agricultural sector. Among them, financial diversification, and risk mitigation through energy sales, supporting local processing of agricultural production, reducing the need for and costs of commercial fertilizers. From an economic perspective, the green economy benefits of biogas are also enormous. Also, local job creation in technical, manufacturing, and construction/trade, economic development generates billions of dollars of investment in rural communities, creation of useful byproducts from waste, act as significant economic multipliers.

Meanwhile, as a renewable energy source, biogas has unique characteristics. Biogas is capable of generating flexible and reliable power, managing intermittent renewable power supplies through storage and flexible power, increasing renewable natural gas (RNG) for injection into the natural gas grid, producing 'green' renewable energy through existing infrastructure, compressed for use as a transportation fuel, or the direct replacement of natural gas derived from fossils in household heating, or industrial, commercial, and institutional processes. Also, the impact on the environment is very good. It removes odor-causing compounds and converts high-energy waste streams into fuel, diverting them from landfill [7].

In this study, a biogas reactor was installed using cattle manure from local cattle farms. Then the biogas reactor is optimized so that farmers can make optimal use of the biogas produced.

2. Method

The type of reactor in this study is a fixed digester. The biogas reactor consists of an inlet, a digester tank, and an outlet for fermentation. While mixing manure with water was done separately. In this study, the biogas reactor uses fiber because of its resistance to corrosion and shock so that it is not easy to crack or leak [8]. Figure 1 shows the scheme and size of the biogas reactor.

In this study, manure came from five cattle with the amount of manure around 15 kg/day of each. The process of filling the digester begins with mixing livestock manure and water in a ratio of 1:1. Then do the stirring until the slurry formed is consistently mixed. For the first filling, an effective microorganism (EM4) was added as a bacterial stimulant to accelerate the breakdown and gas formation. In this initial filing, the amount of slurry that is put into the digester tank is 1.5 m$^3$ with the addition of 2 kg of EM4. On the 1-5th day after filling, the gas starts to form, but the composition of the gas is still a lot of mixture between CO$_2$ gas and a small amount of methane gas. Therefore, the exhaust is carried out by opening the gas inlet valve. The average retention time of solids retained in the digester tank is from 15-35 days. Then the biogas will be formed in the dome of the digester tank and channeled through the pipe above the dome to the stove. Meanwhile, the remaining fermented waste will come out through the outlet pipe in liquid and solid (sludge) form which can be used as fertilizer. Functional and combustion test was performed by measure the gas pressure and cooking trial using the gas.
3. Result and Discussion

In the manufacture of biogas, livestock manure used must contain a lot of cellulose. Livestock manure that contains much cellulose will be easier to digest by anaerobic bacteria. Stages of biogas formation include the hydrolysis stage (dissolving stage), acidogenesis (stage of acidizing), and methanogenesis (methane gas formation phase). At the hydrolysis stage of insoluble material such as cellulose, polysaccharides, and fats are converted into water-soluble substances such as glucose. Bacteria serve to decompose long chains of carbohydrates, proteins, and fats into shorter parts. For example, polysaccharides are converted into monosaccharides. This stage takes place at a temperature of 25°C in Digester. Then in the stage of acidogenesis, the acid bacteria produce acetic acid in an anaerobic atmosphere. This stage takes place at a temperature of 25°C in Digester. The bacteria will produce acids that will serve to convert the short compounds to the results of hydrolysis to simple organic acids such as acetic acid, H₂, and CO₂, therefore this bacteria is also called acid-producing bacteria (Acidogen). It is an anaerobic bacteria that can grow on acidic conditions. To produce acetic acid, the bacteria require oxygen and carbon obtained from dissolved oxygen in the solution. Furthermore, in the stage of methanogenesis, methane bacteria form methane gas slowly by anaerobic. This process lasts about 14 days with a temperature of 25°C in the digester. Biogas consists of methane gas (CH₄), carbon dioxide gas (CO₂), Oxygen gas (O₂), hydrogen sulfide gas (H₂S), and hydrogen gas (H₂). Of these, the most determinative of the biogas quality is methane gas and carbon dioxide gas. If the CH₄ level is high, the biogas will have a high heating value. Conversely, if the level of CO₂ is high, it will result in a low calorific value of the biogas. The following equation shows the reactions occurring at all three levels [9]

\[
\begin{align*}
(C_6H_{10}O_5)n + nH_2O & \rightarrow n(C_6H_{12}O_6) \\
(C_6H_{12}O_6)n + nH_2O & \rightarrow CH_3CHOHCOOH \\
& \rightarrow CH_3CH₂CHOHCOOH + CO₂ + H₂ \\
& \rightarrow CH₃CH₂OH + CO₂
\end{align*}
\]

\[
\begin{align*}
4H₂ + CO₂ & \rightarrow 2H₂O + CH₄ \\
CH₃CH₂OH + CO₂ & \rightarrow CH₃COOH + CH₄ \\
CH₃COOH + CO₂ & \rightarrow CO₂ + CH₄ \\
CH₃CH₂CH₂COOH + 2H₂ + CO₂ & \rightarrow CH₃COOH + CH₄
\end{align*}
\]

In this study, a functional and combustion test was carried out on the 15th day by opening the gas line valve. The pressure of the gas produced was measured using a U-shaped manometer connected to the stove. The principle of this manometer uses Pascal's law, namely when gas flows from the digester.
tank, the water in the manometer will flow to the other side. If the gas pressure is too large, the water in the manometer will be pushed out. Therefore, to maintain or control the flow, gas is introduced into a trap before entering the manometer. Furthermore, testing the use of gas to light a fire was carried out. The test starts for the pressure of 30-40, as shown in Figure 2. It is known that the flame is optimum at a pressure of 40.

![Figure 2. A gas test for some pressures condition (a) 30, (b) 35, and (c) 40.](image)

In this test, the flame can burn steadily for up to one hour of use. After that, it starts to fade and die because the gas pressure that is formed in the digester tank has reduced and it is unable to push the gas out so it has to wait a while. From experiments, it is known that the fire can be lit again after 10 minutes. The solution to this problem is by making a temporary gas reservoir. In this study, the temporary gas reservoir is made of tires that are connected between the digester tank and the stove. With this temporary storage, the stability of the gas supply from the digester tank can be maintained.

Furthermore, the digester continues to fill the waste of livestock continuously resulting in optimal biogas. In this respect, the volume of the organic load is an important operational parameter, which indicates how much slurry can be fed into the digester. In this study, the volume of digester used was 2.5 m³. The volume of slurry per day can be calculated using the following equation:

\[ V_s = \frac{m}{\rho} \]  

(1)

\( V_s \) is the volume of slurries [m³], \( m \) is the mass of substrate [Kg/day], and \( \rho \) is the mass density of water [Kg/m³]. Another important parameter in biogas is the hydraulic retention time (HRT). The HRT is the average time interval when the substrate is kept inside the digester tank. HRT is correlated to the digester volume and the volume of substrate fed per time unit, according to the following equation [10] :

\[ HRT = \frac{V_d}{V_s} \]  

(2)

Where HRT is hydraulic retention time [days], \( V_d \) is a volume digester [m³], and \( V_s \) is the volume of slurries [m³/day]. In this study, the total mass of manure is 75 Kg/day and the density of water is 1000 Kg/m³. Therefore, the volume of slurry that can be made is 0.075 m³/day. Moreover, for volume digester 2.5 m³ and slurry mass 0.075 m³/day the HRT value is about 33 days.

4. Conclusion

Based on the results, it can be concluded that biogas from livestock manure can be used as an alternative energy source especially in rural areas. The performance of biogas reactors is strongly
influenced by the size of the reactor, the amount of slurry, and hydraulic retention time. The optimization of these three factors will result in good and sustainable biogas quality.

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