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Feasibility Study on the Production of Biogas in Dairy Farming

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Abstract. The purpose of this study was to evaluate feasibility study on the development of biogas in dairy farming. In short of the production process, the biogas was produced by utilizing waste from dairy farming industry (i.e. cow’s manure and cassava peel). The production of biogas was analyzed from engineering perspective with several economic evaluation parameters, including gross profit margin, internal rate return, payback period, net present value, and so on. The engineering analysis result showed that the production of biogas is prospective using current technologies. Mass balance calculation showed that 1 kg of cow’s manure supported with 0.30 kg of cassava peel waste from cows’ leftover can be converted into near to 0.20 kg of biogas. Assuming 1700 kg of cow’s manure per month, the production of more than 300 kilograms of biogas can be obtained, showing the excellent prospect for solving the environmental issues in dairy farming industries. In the economic evaluation, the result showed that direct conversion of biogas is not profitable. To confirm the potentiality of the biogas project for being applied in industrial uses, three types of projects were compared, including production of “biogas only”, “fresh milk production only”, and “combination of biogas and fresh milk production”. The result suggested that to get project profitable, the biogas production must be applied with the dairy farming such as milk production. Moreover, the profitability analysis of this “combination between biogas and fresh milk production” is higher than that of “fresh milk production only”. Since the biogas production can give excellent benefit on both profit and solving environmental issues in dairy farming industries, further developments from this study must be done.

1. Introduction

Dairy farming is one of the largest agroindustries in Indonesia. This industry mainly focuses on the production of fresh milk, this type of industry mainly produces daily 10 liters/cattle that only satisfies one fourth of the national demand for fresh milk [1], making the Indonesian government to patch the leak by import. Indeed, this circumstance encourages more farmers and industries to increase the production.

The development in the agroindustrial sector gives beneficial effects for not only human but also surrounding environment. This can be found in the increases in the number and the types of pollutants from the industrial sector and then into the environment [2]. In spite of the demand of the milk production, the boost in the dairy industry meets problems, especially in huge amount of
waste, including cows’ manure and cassava peel from cows’ leftover. Cassava is typically used as the main food for cow in addition to grass. Direct disposal these wastes create problems in water and air pollutions, contaminating water, changing ecosystem, giving dust and smelly air condition. [3,4]. One of the prospective methods to remove waste element in the waste water treatment is a membrane biofilter [4]. Thus, methods for solving these problems are inevitable.

One of the effective treatments for solving wastes from dairy farming industry is biogas production [5], through the fermentation process to decompose organic matter through anaerobic fermentation conditions (See Figure 1). When using dairy farming waste, the process is assisted by a microorganism from cows’ manure itself. To obtain optimum condition for microorganism to work optimal, the fermentation process must be conducted at temperature of between 30°C and 35°C [6]. The fermentation produces mostly methane and carbon dioxide. Then, the quality of the product depends on the organic waste used. Thus, when using kitchen waste, garden, cow manure, and domestic waste as a main source for the fermentation process, biogas in different qualities and quantities will be generated [7]. Methane is the major component of natural gas [8].

Biogas is an excellent energy source due to its excellent burning process. Biogas is flammable and its burning process does not produce smoke as produced by fuel oil or natural gas [3]. Although the biogas is potential to be used for alternative energy, this energy source can be ignited only when having a methane level of at least 57% [9,10]. Thus, additional treatment to purify as well as increasing the methane level must be added in the production process.

Here, the purpose of this study was to evaluate the feasibility study on the biogas production based on the dairy farming industry. Biogas was made from a mixture of cows’ manure and cows’ leftover (e.g. tapioca liquid waste). The production of biogas was evaluated from engineering perspective with several economic evaluation parameters, including gross profit margin (GPM), internal rate return (IRR), payback period (PBP), cumulative net present value (CNPV), break even point (BEP), profitability index (PI) on sales to investment. Optimization of the process for gaining excellent profit but at the same time solving the environmental issues was done. Indeed, this study will give beneficial information for further development.

2. Methods
In this preliminary plant design, biogas is produced from a mixture of cows’ manure and tapioca liquid waste. Tapioca liquid waste was produced from cassava peel as a cows’ leftover. The product of biogas was methane gas that is potentially used for energy source. The design of the reactor is used as a medium-scale design, in which detailed designed processes are shown in Figure 1.

![Figure 1. Flow Chart for the Production of Biogas](image)

To support economic analysis, the data collection process for economic evaluation is based on the average price in the online shopping web. All data are then calculated by a simple mathematical
analysis. The production of biogas with various conditions, whether combined with fresh milk production or not, was tested. The biogas production was analyzed with several economic evaluation parameters, including GPM, IRR, PBP, CNPV, BEP, and PI sales to investment.

3. Results and discussion

Figure 1. shows the processing chart for the production of biogas based on cow’s manure and tapioca liquid waste. As discussed in the above, tapioca liquid waste was obtained from cows’ leftover. The process can be explained in the following. First, tapioca liquid waste and cows’ manure with a ratio of 1: 3 was used. Then, the mixture was put into digester tank via a small inlet pipe. The digester tank is a closed system tank. The optimum condition was fixed at 30 – 35°C to get excellent production. Inside the digester tank, microorganisms from the cow manure do fermentation process for reshuffling the organic component into methane (CH₄) and carbon dioxide (CO₂). In general, the fermentation in the digester occurs in several steps: hydrolysis, acidification, and methane gas formation.

The first step is the hydrolysis of organic material via bacterial fermentation. Long-chain organic material (e.g. complex carbohydrates, proteins, and lipids) breaks into short-chain components.

The second step is acidification, in which the bacteria produce acids for converting short chain compounds from the hydrolysis step into acetic acid. To maintain the pH condition in the range of 7 and 8, buffer must be added. In addition to acetic acid, alcohols, organic acids, amino acids, dihydrogen sulfide (H₂S), CH₄, hydrogen (H₂), and CO₂ are also produced. Additionally, since the bacteria also live in acidic circumstance and require oxygen to produce acetic acid, some oxygen gas must be added into the digester. The third step is the methane gas formation using bacteria fermentation, known as methanogenesis. The process converts acetic acid into CH₄ and CO₂. The reaction is described as [11]:

\[
\begin{align*}
\text{CH}_4\text{COOH} & \rightarrow \text{CH}_4 + \text{CO}_2 + \text{H}_2\text{O} \\
2\text{H}_2 + \text{CO}_2 & \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}
\end{align*}
\]

The final product in the anaerobic fermentation process is a mixture of CH₄ (55 - 75%), CO₂ (25 - 45%), H₂ (1 - 5%), and other gases such as H₂S (0 - 3%). Since the content of CO₂ in biogas is still very large, digester product cannot be used directly.

Thus, to reduce CO₂, the product from digester is introduced into NaOH solution. NaOH was selected due this material is relatively cheap, easy accessible, and non-toxic [12]. The process is conducted in the absorption-separator column, in which the digester product is bubbled from the bottom of the column. CO₂ is absorbed, while CH₄ is released to the top of the column. The reaction during the CO₂ absorption process can be written as [13]:

\[
\begin{align*}
\text{CO}_2(g) & \rightarrow \text{CO}_2(g) \\
\text{CO}_2(g) + \text{NaOH(aq)} & \rightarrow \text{NaHCO}_3(\text{aq}) \\
\text{NaOH(aq)} + \text{NaHCO}_3(\text{aq}) & \rightarrow \text{Na}_2\text{CO}_3(s) + \text{H}_2\text{O(l)}
\end{align*}
\]

Finally, after the absorption process, the product can be utilized for commercial uses.

Based on the above processes (Figure 1), calculating the mass balance can be done with several assumptions:

1. Cleaned peel cassava contains 35% of dry matter [14].
2. 1000 kilograms of cleaned peel cassava can produce 514 kilograms of liquid waste [14].
3. One cow can produce 25 kilograms of cows’ manure per day [15]. Thus, taking 3 cows in the dairy farming industry will create 2250 kilograms of cow manure per month.
4. The efficiency of cows in generating manure is about 50%. If there is an excess in manure, the manure itself will be dumped and buried into the land.
5. The conversion of biogas from the cow manure is 75%. Thus, total production of biogas from 6 cows (adding efficiency of manure generation) is 16875 kilograms per month.
6. The biogas produced from digester contains CH₄, CO₂, and H₂O of 60, 35, and 0.30%, respectively [16], and the rest is omitted as organic components.
7. Losses gained from mechanical process are 5%.
   Based on the above assumptions, a mixture of 500 kg of tapioca liquid waste and 1678 kg of cows’ manure can generate 315 kg of methane per month. Then, putting the methane into a gas tube with a volume of 3 kg per bottle can produce 105 gas tubes. And the reason for the tapioca liquid waste was chosen because of it can be easily obtained from turmeric, which is commonly used and largely available in Asia [12].

   Analysis of the gross profit margin is presented in Table 1. This table compared three possible routes: “biogas only”, “fresh milk production only”, and “combination of biogas and fresh milk production”. Various gross profit margin values were obtained, in which the highest value was for the “combination of biogas and fresh milk production” project. The production of “biogas only” will create an unprofitable project since all the raw materials must be provided and purchased.

   Table 1. Estimated GPM for various projects relating to biogas from Dairy Farming industry

<table>
<thead>
<tr>
<th>Type of project</th>
<th>GPM (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas only</td>
<td>USD 2874</td>
</tr>
<tr>
<td>Fresh Milk production only</td>
<td>USD 20148</td>
</tr>
<tr>
<td>Combination of Biogas and Fresh Milk</td>
<td>USD 24457</td>
</tr>
</tbody>
</table>

   Based on the above engineering perspective gained from mass balance calculation, the process is feasible for industry. Further, scaling up process of this project will give more benefits. However, further economic evaluation must be added. Indeed, several assumptions for economic evaluation must be made:
   1. The length of the project operation is 20 years with the total TIC of 85791 USD for converting 3780 kg of cow’s manure per year.
   2. The labor wage is 2040 USD annually, and the biogas production plant employs 2 labors.
   3. The discounted rate in this project is 15%.
   4. The income tax is 10%.
   5. The project does not progress with loan from bank.
   6. The sales of biogas only, fresh milk production only, and combination of biogas and milk production are 2898 USD, 22995 USD, and 25893USD.
   7. Using 1 USD conversion equal to Rp 10000.

   Analysis of CNPV informing the relationship between selection of the processes and the potentiality of the project to be applied in practical uses. The CNPV suggested that the production of “biogas only” results in the unprofitable project, whereas the “combination of biogas and milk production” is the best. Analysis of payback period confirmed that the production of biogas is not worth, while those of “fresh milk production only” and “combination of biogas and milk production” have 7 and 6 years for regaining the initial investment fund. The main problems for the unprofitable project of “biogas only” are because the profit from the sale of biogas is so small. Thus it is not enough to meet other unexpected costs. The boost of profit was obtained when applying project of “combination of biogas and milk production”, in which was higher than that of “fresh milk production only”. This is because the project has sales advantage of a combination of fresh milk and biogas is large enough to meet the cost of other unexpected needs. Analysis of CNPV for the production of biogas and fresh milk shown in Figure 2 different types of curves were obtained.
To confirm the profitability analysis of the project, other economic analyses were also done (See Table 2). This table shows in detail PI sales to investment, IRR, BEP, and last CNPV on the project.

Table 2. Analysis of IRR, BEP, and last CNPV on the project

<table>
<thead>
<tr>
<th>Type of project</th>
<th>PI to investment</th>
<th>IRR (Percent Discounted Rate)</th>
<th>BEP</th>
<th>Last CNPV/TIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas Only</td>
<td>0%</td>
<td>300%</td>
<td>N/A</td>
<td>0%</td>
</tr>
<tr>
<td>Fresh milk production only</td>
<td>29%</td>
<td>300%</td>
<td>1</td>
<td>28%</td>
</tr>
<tr>
<td>Combination of Biogas and milk production</td>
<td>38%</td>
<td>300%</td>
<td>1</td>
<td>37%</td>
</tr>
</tbody>
</table>

In the case of BEP, the “biogas only” is unprofitable. The BEP analysis for “fresh milk production” needed 84 times of the production cycles, whereas that for “combination of biogas and fresh milk production” is 72 times of the production cycles. Then, these profitability analyses were supported by PI sales to investment, in which the “fresh milk production only” and “combination of biogas and milk production” was 33 and 42%, respectively. The latest CNVP for both projects were also magnificent with values of USD 9457 and 12546, respectively. Based on this analysis, “combination of biogas and milk production” is more profitable than “fresh milk production only” and “biogas only”. The IRR can be obtained when the CNPV is zero, in which this will be 300% of discount rates. Meanwhile the total investment cost for production for “biogas only” and “combination biogas and milk production” is USD 33541, whereas investment cost for production “fresh milk production only” is USD 32653, which show that project is unprofitable by investment. The reason of this happening is due production uses conventional method and the production is inefficiency.

4. Conclusion
Biogas production in dairy farming industry has been evaluated from engineering perspective and economic feasibility study. Engineering perspective showed that the biogas production is potentially done using current technology. However, the economic evaluation showed different views. The production of “biogas only” is incompatible for practical uses since it results unprofitable project. To
improve the potentiality of the biogas project, the present study compared three types of projects, including “biogas only”, “fresh milk production only”, and “combination of biogas and fresh milk”. The result showed that when the biogas production is applied with the dairy farming such as milk production, advantageous production is obtained. Moreover, the profitability analysis of this combination between biogas and milk production is higher than that of milk production only. The main reason for the excellent profitability for combination of biogas and fresh milk is because the sales advantage of a combination of fresh milk and biogas is large enough to meet the cost of other unexpected needs. Since the biogas can give excellent benefit on both profit and solving environmental issues in dairy farming industries, further development from this study must be done.

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