Economic Evaluation of the Production Ethanol from Cassava Roots

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Abstract. The purpose of this study was to evaluate the prospective production of ethanol from cassava in Indonesia. The study was conducted in two parameters, engineering perspectives and economic evaluation that involves several economic parameters (e.g. gross profit margin, internal rate return, payback period, cumulative net present value, breakeven point, and profitability index on sales to investment). The engineering analysis results the potentiality of the ethanol production from cassava roots, using fermentation followed with distillation processes. This analysis was supported by the excellent attainment of economic evaluation of GPM, BEP, PBP, and other analysis. However, the good profitability results were obtained only in the specific condition, in which the minimum requirement for the amount of cassava must be passed. Since cassava is highly abundant in tropical countries, the present analysis is important for giving knowledge for the further potential utilization of cassava.

1. Introduction

Cassava (Manihot esculenta Crantz) is one of the productive crops in tropical region, such as Indonesia, Brazil, Thailand, and Nigeria. Cassava has been widely used from food, beverages, to bioethanol production. This makes cassava being produced intensively. Approximately, 21 million tons of cassava is produces annually in the last 7 years (2008-2015) in Indonesia [1]. Indeed, supported by the low cost of cassava, this incredible amount of cassava production can deliver as a new potential for ethanol production [2-4].

Regarding the cassava production for ethanol fabrication, microbial fermentation technology can be used. In short, ethanol synthesis is from starch hydrolysis [5]. Since cassava contains starch content of about 20-30%, 7 kg of cassava leads to the production of 1 L of green energy bioethanol [6]. To increase the production of cassava, Abidin et al. [7] reported that the potential conversion of cassava peel for producing bioethanol via fermentation. Zhu et al. [8] also reported that cassava pulp, a byproduct of cassava-starch industry, can also be synthesized to bioethanol using Simultaneous Saccharification Fermentation(SSF) and Separate Hydrolysis Fermentation(SHF). Perez, et al. [9,10] reported the ethanol production from cassava starch that gives 53% recovery using amylotic enzyme. For the separation processes, water-ethanol solution was used. Then, to dry ethanol [11-17] and adsorb water of up to 22% of its mass [18], activated molecular sieve was used. Although the papers have shown the prospect from the generation of ethanol from cassava, the production strategies are not completed with the potential information how to upgrade and scale up into practical uses. Indeed, to understand the potentiality of conversion cassava into ethanol in large scale production, economic evaluation is required.

Here, the purpose of this study was to evaluate the prospective production of ethanol from cassava in Indonesia. The analysis was completed with engineering perspectives for the production of ethanol via fermentation of cassava and economic evaluation that involves several economic parameters, including gross profit margin (GPM), internal rate return (IRR), payback period (PBP), cumulative net present value (CNPV), breakeven point (BEP), and profitability index (PI) on sales to investment.
engineering analysis result showed that the ethanol production from cassava roots is possible by involving the fermentation followed by distillation processes. This analysis was also supported by the economic evaluation showing convincing excellent GPM values. Despite the potential production process from engineering perspective, other economic parameters showed that similar tendency for BEP, PBP, and other analyses. However, the good profitability results were obtained only in the specific condition, in which this condition was analyzed by varying the minimum amount of cassava. Analysis inventory control policies are important to be understood, including carrying cost, ordering cost, warehouse renting cost, and buying cost [3]. Along with a good project management, via a stage-gate approach, ideas are generated with the help of forward-backward process fermentation. Some of the routes are then selected, designed, and compared to each other, technically and economically [4].

2. Methods
This study collected all costs and prices from several commercially available online stores. The experimental parameters from other research papers were adopted to synergize the engineering analysis and economic evaluation results. Enzyme amount for the processes were calculated stoichiometrically and fitted to the commercially available enzyme specification. To ensure the analysis of total investment cost, Lang factor was adopted [14]. The economic evaluation parameters used in this study were GPM, BEP, PBP, IRR, CNPV, and PI. Therefore, to simplify the analysis, this study used assumption that one USD is equivalent to IDR 13300, and the import fees and shipping fees from either raw material or instrument purchased were omitted in the economic evaluation.

3. Results and discussion
The water from water source is flown to the filter then to the washing chamber by pump. In the washing chamber, cassava is washed with water to remove the sand in cassava. The washed cassava is then dried in the oven approximately for 2 hours to remove the water from cassava. The dried cassava is then grinded by the grinder to make small sizes of cassava. The grinded cassava is then moved to the reactor and added water and buffer to create pH 5 [9] to make cassava slurry. The cassava slurry is added α-amylase and reacted in 65°C for 15 minutes for liquefaction process, which is to convert the starch in cassava to maltose [9]. Then, amyloglucosidase is added and reacted in 60°C for an hour to convert maltose to glucose. Next, the solution is boiled for 10 minutes and cooled to room temperature [9]. The hydrolysate, the mixture of all the reaction from reactor, is then moved to the fermentor and the pH is set to 7 [9]. Yeast (Saccharomyces cerevisiae) is added for the fermentation process [9, 16]. In addition, peptone is also added to fermentor as a nitrogen source [9,13]. The fermentation takes place approximately 3 days [6,9] at 28-30°C [16]. The fermentation mixture is then distilled twice to produce ethanol of up to 70-80%. To produce ethanol fuel-grade, the solution containing ethanol 70-80% is re-distilled to produce approximately 85%. To produce approximately ethanol 90%, the 80% of ethanol is re-distilled. Finally, to get 99.7% of ethanol, solution is adsorbed by activated molecular sieve 3A [11,12, 17]. Illustration of the processing steps for the ethanol production from cassava is shown in Figure 1.
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Figure 1. The process diagram of ethanol production from cassava roots

The waste of this production consists of the solid waste from fermentation could be used as a heat source [15,19]; however, the waste management of this processes would not be discussed in this study.

To calculate the mass balance of this process, we used the following assumptions:
1. The process used is conventional method [15].
2. Operation temperature is 28°C.
3. The lost cassava mass during washing is assumed approximately 5%.
4. Cassava contains 60.25% water and 27.7 Starch content[6].
5. The water and cassava ratio Matumoto, et al. [10], is 2, based on.
6. The saccharification efficiency is approximately 80% [9].
7. The glucose fermentation to ethanol conversion is approximately 84% [9].
8. The ethanol lost during distillation is approximately 10%.
9. Molecular sieves have been activated chemically.

Based on the calculation of the mass balance, 1 kg of cassava roots could produce approximately 0.11 liter of ethanol 70% and 0.099 liter of ethanol fuel grade. This result was different from Atmodjo et al. [6]. The main reason is mainly due to the assumptions used (i.e. raw material or product lost during the processes in the mass balance). However, the calculation approach to the experimental result is still good enough and therefore can still be used for scaling-up processes and approximated in the economic evaluation.

The gross profit margin of the ethanol production result was calculated from the production of ethanol from 200 kg cassava roots daily. Engineering point of view shows the project is profitable. However, to ensure the analysis, additional other economic parameters are needed (See Table 1).

Table 1. The approximation of Gross Profit Margin on Ethanol production classified by the percentage volume in 100 ml/bottle sales

| Ethanol Type                  | Price(USD/100ml) | Approx. Gross Profit margin |
|------------------------------|------------------|-----------------------------|
| 70% v/v                      | 0.41             | USD 0.47/kg                 |
| 99.7%(Fuel Grade Ethanol)    | 0.71             | USD 0.53/kg                 |
Thus, to evaluate the economic evaluation, the following assumptions are used:

1. The labor wage is IDR 18,000,000 annually or approximately USD 1,353.38 the project employed 5 workers as a labor.
2. The basic electricity cost is assumed to be IDR 1000 per kWh (near to 0.1 USD/kWh).
3. The length of the operation of this business is 20 years.
4. The discounted rate is 15% annually.
5. The income tax is 10%.
6. Import and shipping fees of the material or equipment purchased are omitted in economic evaluation.

Relationship between investment gained to the year of production of ethanol 70% and fuel grade from cassava roots. The production was assumed for the production of 200 kg of ethanol daily. The results showed that the PBP are approximately 5 and 9 years for ethanol 70% and fuel-grade, respectively. From the graph, the business of ethanol 70% is still emerging after 20 years of production although there is a decline for the fuel-grade ethanol production in near to 20 years of production. Based on the GPM, ethanol fuel-grade is more profitable due to the price and purity (See Figure 2).

![Figure 2. The relationship between the CNPV/TIC with the year of production of ethanol 70% and fuel grade from 200kg cassava roots daily. TIC is the total investment lost.](image)

To support the economic evaluation for ethanol production from cassava roots, in the perspective of PI, IRR and BEP, ethanol 70% production based on those parameters and investment gain are more profitable and durable based on the IRR and BEP results. The final CNVP showed the value of USD 32,185 for ethanol 70% (191 % of investment back) and USD 33,871 for fuel-grade ethanol (175 % of investment back). In 20 years, the investment gain from these productions would be USD 767 and USD 727 annually, respectively, for 70% and fuel-grade ethanol. Meanwhile, the total investment cost for the production for ethanol 70% and fuel grade are $16,830 and 19,314, respectively, informing that this business is not yet profitable by investment. The reason of this condition could be due to the inefficient production (conventional method), high-cost distillation equipment (conventional distillation), and the storage cost (cost of more than the main raw material cost itself). To improve the business, the direct sun drying can be used to reduce drying cost. Another method of fermentation can be used such as Simultaneous Saccharification Fermentation (SSF) which could reduce energy and
time significantly [15]. The use of fractional distillation is advisory to reduce the number of distiller and give better yield of the ethanol. The economic evaluation for ethanol production from cassava roots, in the perspective of PI, IRR and BEP shown in table 2.

Table 2. Economic parameters for ethanol production from cassava roots.

| Product                  | Profit-to-Investment (%) | Payback Period (Years) | IRR (%) | BEP (cycle) | Last CNVP/TIC |
|--------------------------|--------------------------|------------------------|---------|-------------|---------------|
| Ethanol 70%              | 77%                      | 5                      | 43.86%  | 50          | 191.240%      |
| Ethanol 99.7% (fuel-grade) | 61%                     | 6                      | 35.610% | 60          | 175.37%       |

4. Conclusion

The present study demonstrates the engineering and economic evaluation for the production of ethanol 70% and fuel-grade from cassava roots. The engineering point of view showed that the project is profitable. However, economic evaluation revealed that the production is not attractive result. This is because of several reasons, including inefficient production (conventional method), high-cost distillation equipment (conventional distillation) high-cost drying, and the storage cost (cost of more than the main raw material cost itself). However, since cassava is abundant in the tropical areas, further development from this study must be done, especially for converting cassava into better valuable product.

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