The use of banana peels as raw materials of bio-alcohol production

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Abstract. Indonesia's energy demand has increased in recent years in line with the increase in economic growth and population in Indonesia. Most of this energy is derived from non-renewable sources such as oil, natural gas, and coal. These trends will have a significant impact on energy depletion. One solution to overcome this problem is developing alternative energy resources to replace petroleum, such as bio-alcohol. The objective of this study was to analyze the potential of bio-alcohol production from organic waste, that is, banana peel. This research is experimental. Bio-alcohol was obtained through a fermentation process of 3 types of banana peels waste, including Raja banana (\textit{Musa acuminata}×\textit{M. balbisiana}) peel, Agung banana (\textit{Musa paradisiaca}) peel, and Nangka banana (\textit{Musa acuminata}×\textit{M. balbisiana}) peel. Fermentation was conducted using variations of \textit{Saccharomyces cerevisiae} of 1\%, 3\%, and 5\% with a fermentation time of 5 days. All experiments were performed in duplicate. The results showed that the highest value of bio-alcohol was produced from the waste of Raja Nangka peel at a concentration of 5\% \textit{Saccharomyces cerevisiae}, which was 1.70\% (p-value <0.05). This study suggests the potential of banana peel waste in producing bio-alcohol as alternative energy in the future.

1. Introduction

Indonesia's energy demand has increased in recent years in line with the increase in economic growth and population in Indonesia. Most of this energy is derived from non-renewable sources such as oil, natural gas, and coal. Total final energy consumption (without traditional biomass) in 2018 was around 114 MTOE consists of the transportation sector, industry, households, commercial and other sectors were 40\%, 36\%, 16\%, 6\%, and 2\%, respectively [1]. On the other hand, the production of non-renewable sources has to decrease. For example, petroleum production over the last ten years has decreased, from 346 million barrels (949 thousand bpd) in 2009 to around 283 million barrels (778 thousand bpd) in 2018 [1]. The usage of non-renewable sources has an essential impact on energy depletion. One solution to overcome this problem is developing alternative energy resources to replace petroleum, such as bio-alcohol.
Alcohol is a chemical derived from raw plant materials containing starch such as cassava, sweet potato, corn, and sago is usually referred to as bio-ethanol [2]. The raw material used for fuel ethanol can vary depending on the plant structure [3]. The previous studies found that the bio-ethanol derived from rice straw [4], sugarcane dregs [5], pineapple skin [6], cocoa bean shell [7], and banana weevil [8] with different results. Baharuddin et al. found that the highest volume of bioethanol was on the 7th day, with the highest purity level in rice straw was 0.24% [4]. Meanwhile, research of Budiyati and Bandi resulted in bio-ethanol production of banana weevil was 61.20% through hydrolysis process of HCl 0.3 N at 90°C. Until now, the utilization of various banana peels has never been studied further.

Indonesia is a tropical country that has various types of flora. One type of flora that is spread throughout Indonesia and has much diversity is the banana. In general, banana peels are discarded or used as animal feed. The more the banana consumption, the more banana peel will be wasted. Banana peel contains carbohydrates so that they can be processed into bio-alcohol. The objective of this study was to analyze the potential of bio-alcohol production from organic waste, that is, banana peel. The various banana peels were used to compare the result. These banana peels derived from endemic banana from Indonesia, there were Raja banana (Musa acuminate × M. balbisiana), Agung banana (Musa paradisiaca) and Nangka banana (Musa acuminate × M. balbisiana).

2. Methodology
This research is experimental. Bio-alcohol was obtained through a fermentation process of 3 types of banana peels waste, including Raja banana (Musa acuminate × M. balbisiana) peel, Agung banana (Musa paradisiaca) peel, and Nangka banana (Musa acuminate × M. balbisiana) peel. Fermentation was conducted using variations of Saccharomyces cerevisiae of 1%, 3%, and 5% with a fermentation time of 5 days. All experiments were performed in duplicate.

The sample used in this research was collected from banana sellers in Surabaya City and Sidoarjo Regency, East Java. Two hundred grams of banana peels were weighed, then sliced into small pieces and blended with 100 ml of distilled water until it becomes smooth and homogeneous [9].

![Figure 1. Banana peels sample.](image)

Each substrate put into Erlenmeyer flask 500 mL. Variations of Saccharomyces cerevisiae of 1%, 3%, and 5% were added to the flask. Each flask was covered by cotton and plasticine connected to the hose into the water to prevent air contamination. The pH of each substrate was 4-5. Fermentation duration was five days at room temperature.

After five days, the samples were distilled using simple distillation. The bio-alcohol concentration was determined using the gravimetric method. The final calculation was carried out to determine the percentage of the yield by dividing bio-alcohol production with the mass of raw material by using the following formula derived from Borzani (2006) [10]:

$$\eta = \frac{M_e}{M_s} \times 100$$  \hspace{1cm} (2.1)
Where $\eta$ is the fermentation efficiency, $M_s$ is the initial mass (raw material), and $M_e$ is the bio-alcohol final mass in the aqueous phase. Considering not only the ethanol present in the medium aqueous phase, in this case we used bio-alcohols terminology, we did not add the value of stoichiometric ethanol yield factor.

We used the conventional method without the hydrolysis stage before fermentation [2,4,6,7] to analyse the potential of the production of bio-alcohol derived from the raw material we used. A conventional method is one method that has been in use for a long time without pre-treatment. In this case, it is hydrolysis pre-treatment.

![Figure 2. Fermentation process.](image)

Figure 2. Fermentation process.

We compared the bio-alcohol production using the statistical analysis with one-way anova (significant level of 0.05). The hypotheses of this research are:

1. $H_0$ = There is no difference between the type of banana peels and variations of *Saccharomyces cerevisiae* on the bio-alcohol content
2. $H_1$ = There is a difference between the type of banana peels and variations of *Saccharomyces cerevisiae* on the bio-alcohol content.

3. Results and discussion

This research compares three types of the banana for yielding the bio-alcohol derived from banana peels. The tree variations of *Saccharomyces cerevisiae* were used to compare the results. Based on the research, we found that Raja banana peel produces the highest bio-alcohol concentration at 3% of *Saccharomyces cerevisiae*, while the others banana peel produces the highest bio-alcohol concentration at 5% of *Saccharomyces cerevisiae*. The results from the research are shown in figure 3.

![Figure 3. Bio-alcohol production from Raja banana peel.](image)

Figure 3. Bio-alcohol production from Raja banana peel.
Figure 4. Bio-alcohol production from Agung banana peel.

Figure 5. Bio-alcohol production from Nangka banana peel.

Bio-alcohol production through conventional fermentation (without hydrolysis) showed low efficiency from all types of banana peels. The highest percentage of bio-alcohol production from Raja banana peel, Agung banana peel, and Nangka banana peel was 1.05%, 1.52%, and 1.70%, respectively. The highest value of bio-alcohol was produced from the waste of Raja Nangka peel at a concentration of 5% Saccharomyces cerevisiae, which was 1.70%. Based on statistical analysis, there was a significant difference between the type of banana peels on the bio-alcohol content (p-value <0.05). Meanwhile, there was no significant difference between variations of Saccharomyces cerevisiae on the bio-alcohol content (p-value >0.05). According to bio-alcohol content and statistical analysis, Raja Nangka banana peel produces the highest concentration of bio-alcohol, among others.

Table 1. Bio-alcohol production from three types of banana peels (%).

| Treatments            | Raja banana peel | Agung banana peel | Nangka banana peel |
|-----------------------|------------------|-------------------|-------------------|
| 1% of Saccharomyces cerevisiae | 0.8914a          | 0.4216a           | 1.3394b           |
| 3% of Saccharomyces cerevisiae | 1.0527a          | 1.3598a           | 1.6253b           |
| 5% of Saccharomyces cerevisiae | 0.9321a          | 1.5275a           | 1.7092c           |

*α = Means within columns having different letters are significantly different according to the least significant difference (LSD) at 0.05 level of probability.

Hydrolysis is a process of degradation of cellulose in the form of polysaccharides into monosaccharides [11]. Glucose is a type of monosaccharide containing six carbon atoms [12]. Saccharomyces cerevisiae is used in fermentation to convert glucose into alcohol [13]. According to Frazier and Westhoff (1978), the fermentation process can be divided into two steps: (a) The first step of fermentation, takes place in an aerobic state (presence of dissolved O2 and O2 on the flask surface, serves to multiply Saccharomyces cerevisiae which the appearance of gas carbonic acid can characterize, the reaction is as follows: C6H12O6 + 6O2 → 6CO2 + 6H2O + 36 ATP. In the first stage of fermentation, there is no ethanol production or very little ethanol will be produced; (b) The second step, the fermentation process, takes place in a state of anaerobic. Saccharomyces cerevisiae and its enzymes are at the optimum stage so that the fermentation will take place, the yeast converting the glucose to ethanol by the reaction: C6H12O6 → 2C2H5OH + 2CO2 + 2ATP [11].

A previous study showed that hydrolysis enhanced the concentration of bio-ethanol. Three types of hydrolysis commonly used for bio-ethanol production are acidic hydrolysis [2, 7, 14], enzymatic hydrolysis [9,11], and thermal hydrolysis [8,15]. The hydrolysis stage is usually conducted before fermentation to give the substrate an optimum condition. In general, Saccharomyces cerevisiae is an acidophilic organism and, as such, grows better under acidic conditions. The optimal pH range for yeast growth can vary from pH 4 to 6, depending on temperature, the presence of oxygen, and the strain of
yeast [16]. In our research, the pH of each substrate was 4-5. We assumed that the pH range had reached the optimum pH for *Saccharomyces cerevisiae* to convert the glucose into bio-alcohol. However, the result shows low efficiency compared to previous research on bio-alcohol production from banana weevil with hydrolysis pre-treatment resulted in high efficiency at 61.20%.

Based on the research, we suggest that *Saccharomyces cerevisiae* needs an optimum pH for transforming glucose to bio-alcohol and needs readily glucose derived from carbohydrates. Blending the banana peels into smooth pulp did not produce enough glucose. Therefore, the banana peels should be hydrolysed with various techniques to produce more glucose.

4. Conclusions
This study was aimed at comparing three types of banana peels as raw materials to produce bio-alcohols. We calculated the efficiency of bio-alcohol production compared to initial mass. The study revealed that the highest percentage of bio-alcohol production from Raja banana peel, Agung banana peel, and Nangka banana peel was 1.05%, 1.52%, and 1.70%, respectively. The highest value of bio-alcohol was produced from the waste of Raja Nangka peel at a concentration of 5% *Saccharomyces cerevisiae*, which was 1.70% (p-value <0.05). We suggest further research to put the hydrolysis stage before the fermentation process to enhance the result. However, this study suggests the potential of banana peel waste in producing bio-alcohol as alternative energy in the future.

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