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The Effect of Yeast Types on the Production of Bioethanol from the Waste of Pondoh Snake Fruit (*Salacca zalacca*)

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Abstract

The need for fuel oil as an energy source is increasing every day, while fossil energy reserves are running low; therefore, to meet fuel needs, it is necessary to develop alternative fuels that are renewable and environmentally friendly. One of them is bioethanol, namely ethanol made from plants containing starch, sugar, and cellulose, such as pondoh snake fruit waste. This research aims to determine the quantity of bioethanol, calorific value, and flame test results, with various types of yeast, that is, fermented cassava (tape) yeast and bread yeast. The bioethanol production process in this research utilizes a Pasteurization–Fermentation–Distillation process. The pasteurization used a water bath at a constant temperature of 70^{0}C for 30 minutes. The fermentation process was conducted for 4 days, followed by a 5-hour distillation. The bioethanol produced in this study has the best of the yeast variety of bread yeast, where the highest volume is 17.5 ml, the heating value is 4.215,21 cal/g, and the flame test has the highest flame height of 18 cm with a flame duration of 8 minutes. The flame test results of bioethanol with variations of bread yeast produced a blue-orange flame, while bioethanol with variations of tape yeast produced a bluish-orange flame.

Keywords: Bioethanol, calorific value, pondoh snake fruit, bread yeast, tape yeast

1. Introduction

Due to population expansion, economic expansion, and urbanization, energy demand has been rising quickly. On the other hand, from an ecological and economic perspective, conventional energy sources are not sustainable over the long term [1]. Besides that, a considerable amount of greenhouse gases is released into the atmosphere as a result of the ongoing burning of fossil fuels [2].

Presidential Regulation of the Republic of Indonesia Number 5 of 2006, concerning National Energy Policy, states that the utilization of alternative renewable energy is carried out through the development of plant-based energy, often referred to as Biofuels [3]. Bioethanol is a kind of liquid biofuel made from biomass (organic materials) characterized by sugar, starch, and cellulose components. This biomass is processed biologically with the help of enzymes and fermentation [4].

Based on its characteristics, bioethanol has been recognized as the most popular biofuel due to its exceptional ability to lower carbon dioxide emissions, which are the primary cause of greenhouse gas emissions and contribute to global warming. Utilizing bioethanol as a novel biofuel source lessens reliance on traditional gasoline, resulting in an annual decline in production [5].

Nowadays, the majority of bioethanol is made from agricultural feedstock, such as maize in the US and sugarcane in Brazil. In the EU, bioethanol is made from wheat and sugar beet. According to a 2021 report by the Renewable Fuels Association, the United States is the world's largest producer of ethanol, with an estimated yearly production of over 13,000 million gallons, or more than half of the total production worldwide. Otherwise, Brazil produces about 8000 million gallons of bioethanol annually [6].

In Indonesia, several types of biomass from agricultural waste are abundantly available, one of which is snake fruit (Salacca zalacca) waste. The potential for using snake fruit as a raw material for bioethanol is very high. It is a type of biomass that thrives in the tropics and can produce fruit throughout the year. However, these plants go through a harvest season and a crisis at specific times. There is a post-harvest issue since the market cannot sell all of it during harvest time. Due to the poor quality, the harvest issue is not worth selling, resulting in more waste [7].

Mranggen Hamlet, Salamsari Village, Srumbung District, Magelang Regency, Central Java Province, is an area where the majority of the population owns pondoh snake fruit plantations. When harvest season arrives, snake fruit is abundant, leaving behind large quantities of unsold fruit. The rotting snake fruit pulp is organic waste that can be processed into a useful product by converting it into bioethanol. Besides containing sugar, snake fruit waste also contains starch, making it a suitable raw material for bioethanol production. The snake fruit has a carbohydrate content of 20,90 grams, so that the snake fruit can be used as raw material for bioethanol [8].

The most crucial aspect of the bioethanol production process is fermentation. This fermentation process breaks down sugar into bioethanol and carbon dioxide, induced by enzymes within the microbial cell mass. The fermentation process is a biochemical process in which a chemical change or reaction occurs with the help of microorganisms when they come into contact with suitable food substances for their growth [9].

Fermentation in the bioethanol process is the conversion of sugar into alcohol. It is influenced by the use of *Saccharomyces cerevisiae* (yeast), which acts as a sugar-breaking microorganism. There are two common types of yeast in the commercial market: bread yeast and fermented cassava (tape) yeast. Bread yeast is a type of *Saccharomyces cerevisiae* that has been previously selected for commercial purposes. The selected *Saccharomyces cerevisiae* is a microorganism that can ferment sugar effectively in dough and grow rapidly. Meanwhile, tape yeast is used, which is not a pure culture but a mixture of genera containing species such as *Aspergillus, Saccharomyces cerevisiae, Candida*, and *Hansenula*, as well as *Acetobacter*. These genera co-exist synergistically and work continuously [10].

The objective of this research is to study the influence of different types of yeast on the production of bioethanol from pondoh snake fruit waste. It is hoped that the results of this research will facilitate the production of bioethanol from snake fruit waste, making biofuel a key component of the solution to fuel oil depletion.

2. Research Method

The materials used in this study were pondoh snake fruit waste, obtained from the local fruit market. It also used variations of yeast, including bread yeast and fermented cassava (tape) yeast. Both yeasts are readily available in baker's stores, easy to use, and affordable. Ice water was used in this study as a cooler in the distillation process.

Before the main experiment, a preliminary test was conducted to determine the bioethanol production method that would be used during the research. The preliminary test involved testing the total sugar content in snake fruit waste. If the raw materials have a high sugar content, the method for making bioethanol does not go through the hydrolysis process, but goes directly to the pasteurization process of the raw materials, followed by fermentation and distillation.

The fermentation process was carried out using simple equipment such as that shown in Fig.1.

Fig.1. Equipment for bioethanol fermentation of snake fruit waste

The fermentation process was done using two bottles, as shown in Figure 1. The large bottle contained the raw material, snake fruit waste, ready for fermentation. The small bottle contained water. An aquarium hose was connected to the large and small bottles to allow CO_2 gas flow to the small bottle. This was to prevent CO_2 explosions upon successful alcohol fermentation. The success of the fermentation process was indicated by the appearance of CO_2 gas bubbles in the water in the small bottle.

The distillation process of the fermented snake fruit waste after successfully converting it into alcohol, as carried out in this study, is shown in Fig.2.

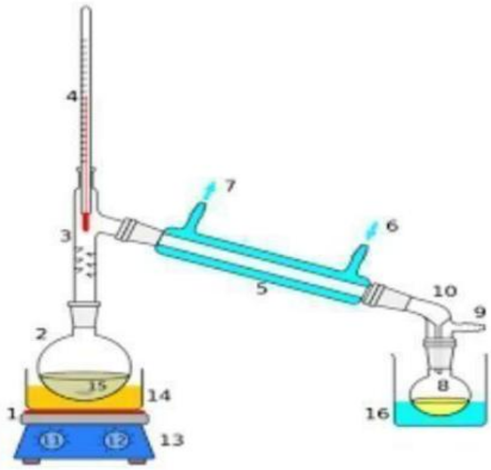

Fig.2. Equipment for the bioethanol distillation process

Image caption:

1. Electric stove
2. Glass flask, containing the fermented liquid
3. Glass tube, through which the alcohol vapor flows at its boiling point
4. Thermometer
5. Condenser tube
6. Condenser water inlet valve
7. Condenser water outlet valve
8. Glass flask, containing the produced bioethanol
9. Bioethanol outlet valve
10. Glass tube through which the bioethanol flows after the condenser
11. Start button on the electric stove
12. Heating temperature regulator on the electric stove
13. Control box and stand for the electric stove

The first step of the main experiment was to ground the waste, then squeeze and filter it. The filtrate was pasteurized at a constant temperature of 70°C for 30 minutes and then cooled to a normal temperature of 30°C. The filtrate was then fermented by adding *Saccharomyces cerevisiae*, a type of yeast found in bread and tape yeast, along with urea and NPK, and by adjusting the pH. After 4 days of fermentation, distillation was performed to produce a high concentration of bioethanol [11].

The bioethanol produced from the fermentation process was distilled to separate the water content from the fermented bioethanol. It was hoped that separating the water would increase the calorific value of the bioethanol produced. The water was separated by heating it to the boiling point of ethanol, which is 78°C. At this temperature, the alcohol boils and vapor is released. This vapor was channeled through a pipe and then condensed with ice water, turning it into a liquid. The condensed liquid was collected in a provided volumetric container, resulting in the quantity of bioethanol produced [12].

The distillate of bioethanol was then tested for its calorific value using a calorimetric bomb apparatus to determine its quality. Then, it was compared to the calorific value of gasoline in general on the market.

Besides that, the flame test in this study was performed to test bioethanol with the parameters of flame height, flame duration, and flame color, which aimed to determine the quality of the bioethanol flame. The results of these observations and measurements can be used as an indicator that the bioethanol produced can be used for fuel and can produce good-quality bioethanol.

3. Results and Discussion

3.1. Preliminary Test

This research began with a sugar content test of unfit pondoh snake fruit used as a raw material for bioethanol. There are two methods for bioethanol production: via hydrolysis or non-hydrolysis. Hydrolysis is the process of converting polysaccharides into monosaccharides (sugars), enabling the material to be used for bioethanol production. The hydrolysis method was chosen based on the sugar content of the raw material, allowing for a known sugar content for the bioethanol production process. For raw materials with a high sugar content, the bioethanol production method does not require hydrolysis. The results of preliminary tests of total sugar content on pondoh snake fruit waste were presented in Table 1.

Table 1. Laboratory test results for the total sugar of pondoh snake fruit waste

No	Analysis	Test I	Test II	Average
1	Reduction Sugar	37,81%	37,86%	37,83 %
2	Total Sugar	74,81%	74,91%	74,86 %
3	Cellulose	0,49%	0, 2415 %	0,365 %

Source: Laboratory result, 2025

The test results showed that pondoh snake fruit waste had a total sugar content of 74.86%. This total sugar value indicates that the bioethanol production process from pondoh snake fruit waste does not require hydrolysis, as its total sugar content exceeds 70%. Therefore, in this study, the liquid from the squeezed snake fruit was directly processed into bioethanol without hydrolysis.

3.2. Main Experiment

Table 2 shows the data obtained from the main experiments, that is, bioethanol volume, calorific value, and flame test of each variable.

Table 2. The bioethanol volume, calorific value, and flame test results

No	Variable	Volume (ml)	Calorific value (Cal/g)	Flame test
1	Bread Yeast	17,5	4.215,21	18 cm height, 8 minutes, blue dominant flame
2	Tape yeast	14	3.874,38	15 cm height, 5 minutes, Orange dominant flame

Source: Experiment result, 2025

The variations in the use of Saccharomyces cerevisiae in the study resulted in different volumes of bioethanol produced. Table 2 showed that the largest volume of bioethanol was obtained from the bioethanol produced using *Saccharomyces cerevisiae* from bread yeast. The volume of bioethanol from bread yeast was 17.5 ml, while from tape yeast, the volume of bioethanol was 14 ml.

According to Irvan et al. (2015), bread yeast is optimal for short-term fermentation. Bread yeast is a type of yeast (*Saccharomyces cerevisiae*) that has been previously selected for commercial purposes. The selected Saccharomyces cerevisiae can ferment sugar effectively in dough and grow rapidly. Meanwhile, tape yeast is less optimal because the yeast used is not a pure culture but a mixture of genera that have different species [10].

In this study, the *Saccharomycetes cerevisiae* used is a type of mixed culture. The advantage of using mixed cultures is reducing the risk of other microbes that are not actively fermenting. In the food sector, the use of mixed cultures can produce a specific aroma. The using mixed inocula, attention must be paid to the nutritional needs of the microorganisms. A good mixed culture is a succession model so that between organisms do not compete but support each other for product formation. Yeast contains microorganisms that carry out fermentation, and this culture medium is in the form of small granules or a liquid nutrient. The microorganisms used in yeast generally consist of bacteria and fungi, namely Rhizopus, Aspergillus, Mucor, Amylomyces, Endomycopsis, Saccharomyces, Hansenula, Anomala, Lactobacillus, Acetobacter, and so on. Therefore, yeast itself is a substance that causes fermentation, namely the conversion of sugar into alcohol.

On the other hand, observations and measurements of the influence of variations in the type of *Saccharomyces cerevisiae* on the calorific value of the bioethanol produced are used as an indicator that the bioethanol produced can be utilized and produce good bioethanol. The calorific value of a fuel is an important property that must be known from a fuel. In determining the calorific value of a fuel can be determined by testing or by estimation based on the basic composition of a fuel [13].

Calorific value is the amount of heat energy released by a fuel during the oxidation of the chemical elements present in the fuel [14]. The calorific value, or energy value, of a substance, usually a fuel, is the amount of heat released during the combustion of a specified amount. Energy value is a characteristic of each substance.

The calorific value of bioethanol from Pondoh snake fruit waste with bread yeast is higher than that of bioethanol from snake fruit waste with tape yeast. This is because the tape yeast is made with the addition of spices and other microorganisms, so it contains not only *Saccharomyces cerevisiae* but also several other types of microorganisms. Bread yeast contains more *Saccharomyces cerevisiae* than tape yeast, resulting in a higher alcohol content. Bread yeast reproduces very quickly and produces fermentation that can change starch or sugar into carbon dioxide and alcohol [10].

Bread yeast produces a higher calorific value because *Saccharomyces cerevisiae* is better prepared for fermenting bioethanol sugars. It contains *Saccharomyces cereviseae,* which has undergone selection, mutation, or hybridization to improve its ability to ferment sugars in dough and grow rapidly. *Saccharomyces cerevisiae* in yeast form can be used directly as an ethanol inoculum, eliminating the need for special inoculum preparation [15]. Bread yeast is a dry material containing Saccharomyces cereviseae cells that are ready to be activated [16].

The calorific values from the test results in Table 2 were then compared with the calorific values of gasoline, a fossil fuel used by the public in Indonesia, namely Pertalite, which has a calorific value of 43.031 kJ/kg or 10.277 Cal/g. It can be seen that the calorific value of bioethanol is not yet the same as the calorific value of gasoline on the market, but the value is close. The superior calorific value of gasoline on the market is due to the higher water content in bioethanol compared to gasoline on the market.

In the research conducted, the distillation process was only carried out for 5 hours. This may have meant that the water and alcohol were not completely separated, thus increasing the water content in the bioethanol produced. The remaining water content in the bioethanol produced can affect the combustion process during application. This is consistent with research conducted by Damanhuri (2006), which states that during combustion, the first process is the evaporation of the water contained in the material. This means that the higher the water content in bioethanol, the higher the energy required to evaporate the water, resulting in lower heat output [17].

Regarding the flame test, Table 2 shows that various types of bread yeast produced a flame length of 8 minutes, while various types of tape yeast produced a flame length of 5 minutes. The highest flame height was 18 cm for bread yeast, and the lowest was 15 cm for tape yeast. The results of the bioethanol flame test were influenced by the Saccharomyces content in each yeast. Baker's yeast produced a longer flame because the Saccharomyces in bread yeast is better prepared to ferment bioethanol sugars.

Fig.3 shows the flame colors from the combustion of bioethanol produced using bread yeast and tape yeast.

(a) **(b)**

Fig 3. The flame colour of bioethanol with bread yeast (a) and tape yeast (b)

Fig.3 shows that the flame from the bread yeast bioethanol is predominantly blue, while the flame from the tape yeast is predominantly orange. This is because the calorific value of the bread yeast bioethanol is higher than that of the tape yeast bioethanol, resulting in a better flame. The important property of an energy means the property that determines the content of an energy; in this case is the energy content of the fuel. The higher the calorific value of a fuel, the more flammable the material will be [18].

4. Conclusion

The volume of bioethanol produced from pondoh snake fruit waste by the variety of bread yeast is more than the Saccharomyces variety of tape yeast. The Saccharomyces variety of bread yeast produced 17.5 ml, while the bioethanol produced by the variety of tape yeast produced 14 ml. The calorific value of bioethanol from pondoh snake fruit waste with bread yeast is higher than tape yeast, that is 4.215,20 cal/g compared to 3.874,38 cal/g. The flame duration during the combustion process of bioethanol using bread yeast was longer than that of bioethanol using tape yeast. Likewise, the flame height of bioethanol from bread yeast produced a higher flame than bioethanol using tape yeast, with the bread yeast producing a flame that is predominantly blue, rather than the bioethanol from tape yeast, which is predominantly orange.

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