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Density and Specific Gravity Characteristics of Bioethanol Due to Variations in Fermentation Duration and Distillation Temperature

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ABSTRACT: Bioethanol is an environmentally friendly alternative fuel that can be produced from biomass, one of which is pineapple (Ananas comosus). This study aims to analyze the effect of fermentation time and distillation temperature on the physical properties of bioethanol, especially density and specific gravity. The fermentation time variations used were 5, 7, and 9 days, while the distillation temperature was varied at 60°C, 75°C, and 80°C. The results showed that fermentation time and distillation temperature affected the characteristics of the bioethanol produced. In 5days fermentation, the density and specific gravity values tended to be higher than those of longer fermentations. As the fermentation time increased up to 9 days, there was a decrease in density and specific gravity, indicating an increase in ethanol content. In addition, increasing the distillation temperature from 60°C to 80°C generally caused an increase in density and specific gravity, which is thought to be due to the distillation of components other than ethanol. The lowest density value was obtained after 9 days of fermentation at a distillation temperature of 60°C (0.81 gr/ml), while the highest value occurred after 5 days of fermentation at a temperature of 80°C (0.84 gr/ml). The same trend was also shown by the specific gravity. Thus, the combination of longer fermentation and lower distillation temperatures produces better quality bioethanol.

KEYWORDS: bioethanol; pineapple; fermentation time; distillation temperature; density; specific gravity

I. INTRODUCTION

Global energy demand continues to increase in line with population growth and industrial activity, particularly in the transportation and manufacturing sectors. High dependence on fossil fuels has created serious problems, both in terms of limited reserves and environmental impacts in the form of increased greenhouse gas emissions that contribute to climate change [1,2]. Therefore, the development of alternative, renewable and environmentally friendly energy sources is crucial to support future energy sustainability.

One widely developed alternative energy source is bioethanol. Bioethanol is an alcohol-based fuel produced through the fermentation of biomass containing sugar, starch, or cellulose with the help of microorganisms, particularly Saccharomyces cerevisiae [3,4]. Bioethanol has the advantages of being renewable, having lower carbon emissions than fossil fuels, and being able to be used as a blended fuel in gasoline engines without significant modification [5]. With these advantages, bioethanol is a prime candidate for the transition to clean energy.

The use of biomass-based waste feedstock is a major focus in the development of next-generation bioethanol. This is because waste utilization not only increases resource efficiency but also reduces environmental pollution [6,7]. One potential biomass waste is pineapple (Ananas comosus) waste, which has a high sugar content and can be directly fermented into ethanol [8,9]. Furthermore, the abundant availability of pineapples in tropical regions makes it an economical and sustainable feedstock for bioethanol production.

The bioethanol production process generally consists of several main stages: pretreatment, hydrolysis, fermentation, and distillation. In the fermentation stage, microorganisms convert sugars into ethanol through biochemical processes, while the distillation stage aims to separate the ethanol from the mixture based on differences in boiling points [10,11]. The effectiveness of these two stages significantly determines the quality of the bioethanol produced, making optimization of process parameters crucial.

Fermentation time is a critical parameter affecting the amount of ethanol produced. The longer the fermentation time, the more substrate can be converted into ethanol until a certain optimum condition is reached. However, fermentation that is too long can cause a decrease in microorganism activity and the possibility of ethanol degradation [12]. Previous research has shown that increasing fermentation time significantly affects ethanol content and its physical properties, including density [9].

Furthermore, distillation temperature also plays a crucial role in determining bioethanol purity. Distillation carried out at an inappropriate temperature can cause the evaporation of compounds other than ethanol, thus reducing the quality of the final product. Conversely, temperatures that are too low can result in suboptimal separation [11]. Therefore, controlling the distillation temperature is a crucial factor in obtaining high-purity bioethanol.

The physical properties of bioethanol, such as density and specific gravity, are important indicators in determining fuel quality. Density is related to the density of a substance, while specific gravity is the ratio of a substance's density to water. Bioethanol with a higher ethanol content generally has a lower density, so this parameter is often used as an indirect indicator of ethanol purity [5,10]. Therefore, analysis of these two parameters is crucial in evaluating bioethanol quality.

Various studies have been conducted to examine bioethanol production from pineapple-based materials, focusing on parameters such as fermentation time, type of microorganism, and process method. The results indicate that varying fermentation conditions can significantly affect bioethanol yield and quality [8,13]. However, most studies still examine these parameters separately, and few have evaluated the combined effect of fermentation time and distillation temperature simultaneously.

However, in practice, these two parameters interact and collectively determine the final characteristics of bioethanol. The lack of comprehensive studies on the interaction of these two variables presents a research gap that requires further exploration. Therefore, this study was conducted to analyze the effect of fermentation time and distillation temperature on the physical properties of bioethanol made from pineapple (Ananas comosus), with parameters observed including density and specific gravity. The results are expected to contribute to the optimization of the bioethanol production process and support the development of sustainable biomass-based alternative energy.

II. RESEARCH METHOD

This experimental study aimed to analyze the effect of fermentation time and distillation temperature on the physical properties of bioethanol made from pineapple (Ananas comosus). The study consisted of several main stages: raw material preparation, fermentation, distillation, and testing the physical properties of the bioethanol.

The raw material used in this study was fresh pineapple (Ananas comosus) obtained from a local market. Supporting materials included Saccharomyces cerevisiae yeast as the fermentation microorganism, clean water, and additional chemicals, if necessary, to support the fermentation process. The main equipment used included a blender, fermenter, simple distillation apparatus, thermometer, pycnometer, and measuring cylinder.

The initial stage of the study was raw material preparation. The pineapple was cleaned of dirt, then cut into small pieces and crushed using a blender to obtain pineapple juice. The pineapple juice was then filtered to remove the pulp and the liquid was used as a fermentation substrate. The substrate was then placed in a sterilized fermentation vessel.

The fermentation process was carried out by adding Saccharomyces cerevisiae yeast to the pineapple juice. Fermentation was carried out anaerobically at room temperature. The fermentation periods used in this study varied from 5 days, 7 days, and 9 days. During the fermentation process, the container was tightly closed to maintain anaerobic conditions and prevent contamination from the external environment. After the fermentation period was reached, the fermented solution (fermentate) was separated for the next stage.

The next stage was distillation, which aims to separate ethanol from the fermented mixture. The distillation process was carried out using a simple distillation apparatus with varying heating temperatures of 60°C, 75°C, and 80°C. The temperature was monitored using a thermometer throughout the process. The resulting vapor was then condensed into a liquid and collected as bioethanol distillate.

Next, the physical properties of bioethanol were tested, including density and specific gravity. Density measurements were performed using the pycnometer method. An empty pycnometer was first weighed, then filled with the bioethanol sample and reweighed to determine the sample mass. The volume of the pycnometer was precisely known, so the density could be calculated using the equation:

$$\rho = m / V \qquad (1)$$

where ρ is the density (gr/ml), m is the sample mass (g), and V is the volume (ml).

Specific gravity is calculated as the ratio of the density of bioethanol to the density of water at the same temperature, expressed as:

$$SG = \rho_{sample} / \rho_{water} \qquad (2)$$

where ρ_{water} is assumed to be 1 gr/ml under standard conditions.

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This study used a factorial experimental design with two independent variables: fermentation time (5, 7, and 9 days) and distillation temperature (60°C, 75°C, and 80°C), resulting in nine treatment combinations. Density and specific gravity were measured for each treatment to determine the effect of each variable on bioethanol quality.

The test data were analyzed descriptively by comparing the density and specific gravity values for each treatment variation. The analysis was conducted to identify trends in changes in the physical properties of bioethanol due to variations in fermentation duration and distillation temperature. The results were then presented in tabular form and discussed to draw conclusions regarding the best conditions for producing optimal-quality bioethanol.

III. RESULTS AND DISCUSSION

Based on the research results, data on the density and specific gravity of bioethanol obtained from pineapple (Ananas comosus) with varying fermentation times (5, 7, and 9 days) and distillation temperatures (60°C, 75°C, and 80°C) were obtained. The data indicate a significant influence of these two variables on the physical properties of the resulting bioethanol.

In general, the density of the bioethanol obtained ranged from 0.81 gr/ml to 0.84 gr/ml. This value is within the characteristic range of bioethanol, where the density of pure ethanol at room temperature is approximately 0.79 gr/ml. This difference indicates that the resulting bioethanol still contains other components, such as water or other volatile compounds, that are distilled.

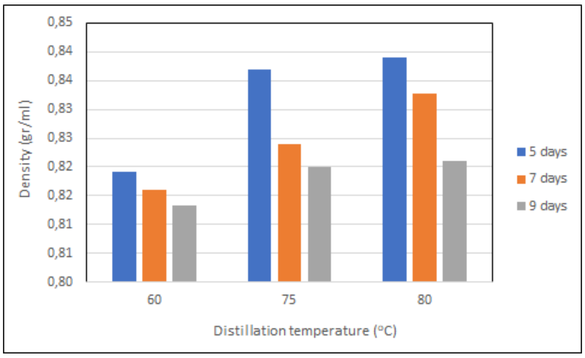

Figure 1. Graph of the relationship between distillation temperature and density

The effect of fermentation time on density shows a clear trend (Figure 1). During 5days fermentation, density values tended to be higher than those for 7days and 9days fermentations. This is because in the early stages of fermentation, the conversion of sugar to ethanol has not yet occurred optimally, resulting in relatively high water and other solute content. As fermentation time increases to 9 days, the Saccharomyces cerevisiae microorganism works more effectively to convert sugar to ethanol, increasing the ethanol content in the solution and causing a decrease in density. This trend aligns with previous research indicating that increasing fermentation time increases ethanol production until it reaches optimum conditions.

However, the decrease in density is not always linear. Under some conditions, particularly at higher distillation temperatures, there is a tendency for density to increase again. This indicates an interaction between fermentation time and distillation temperature in determining the final characteristics of bioethanol.

The effect of distillation temperature on density also shows a consistent pattern (Figure 1). At a distillation temperature of 60°C, a lower density value was obtained compared to temperatures of 75°C and 80°C. This indicates that at lower temperatures, the distillation process is more selective in evaporating ethanol, resulting in a distillate with higher purity. Conversely, at higher temperatures, other components such as water and heavy compounds are also evaporated, increasing the density of the resulting bioethanol.

The lowest density value was obtained with a combination of 9 days of fermentation and a distillation temperature of 60°C, at 0.81 gr/ml, while the highest density value occurred with a 5days fermentation and a distillation temperature of 80°C, at 0.84 gr/ml. This indicates that the combination of a longer fermentation time and a lower distillation temperature produces better-quality bioethanol.

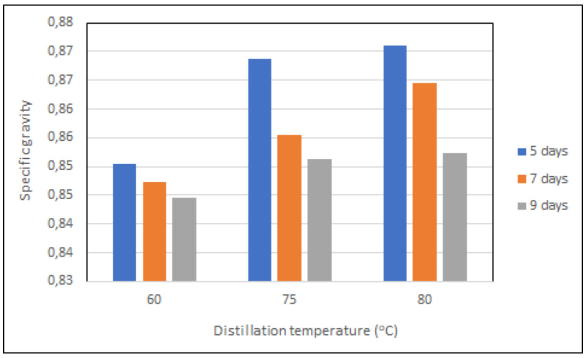

Figure 2. Graph of the relationship between distillation temperature and specific gravity

The same trend is also shown by the specific gravity value (Figure 2). Specific gravity is a parameter directly related to density, so changes in density are directly proportional to changes in specific gravity. A lower specific gravity value indicates a higher ethanol content in the sample.

Therefore, the results of this study indicate that increasing the fermentation time up to 9 days results in a lower specific gravity, indicating increased bioethanol purity.

Furthermore, increasing the distillation temperature from 60°C to 80°C leads to an increase in the specific gravity value (Figure 2). This reinforces the indication that higher temperatures make distillation less selective, allowing components other than ethanol to evaporate, reducing the quality of the bioethanol.

The interaction between fermentation time and distillation temperature is a crucial factor in determining bioethanol quality. Optimal fermentation time allows for maximum sugar conversion to ethanol, while the correct distillation temperature ensures efficient ethanol separation. The combination of these two parameters determines the density and specific gravity values, which are indicators of bioethanol quality.

The results of this study concluded that the best conditions for producing optimal-quality bioethanol were a 9days fermentation period and a distillation temperature of 60°C. These conditions yielded the lowest density and specific gravity values, indicating a higher ethanol content compared to other variations.

These results align with the basic principles of fermentation and distillation, where increasing fermentation time increases ethanol production, while lowering distillation temperatures improves separation selectivity. Therefore, optimizing these two parameters is crucial for improving the efficiency and quality of pineapple-based bioethanol production.

IV. CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the fermentation time and distillation temperature have a significant effect on the physical properties of bioethanol made from pineapple (Ananas comosus), especially density and specific gravity. Increasing the fermentation time from 5 days to 9 days causes a decrease in the density and specific gravity values, which indicates an increase in ethanol content due to increasingly optimal sugar conversion by fermentation microorganisms. Conversely, increasing the distillation temperature from 60°C to 80°C tends to increase the density and specific gravity values. This indicates that higher distillation temperatures cause the separation process to be less selective, so that components other than ethanol such as water are also evaporated and reduce the purity of bioethanol. The best treatment combination was obtained at a fermentation time of 9 days and a distillation temperature of 60°C, with the lowest density value of 0.81 gr/ml. This condition indicates that optimizing a sufficiently long fermentation time and a relatively low distillation temperature can produce bioethanol with better quality.

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