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Utilization Of Sweet Sap From Sorghum Stalk As Bioethanol With Variation Of Yeast In The Fermentation Process

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Abstract – Awareness to anticipate the future crisis of fossil fuel, particularly oil, has encouraged efforts to find alternative sources of fuel, especially those derived from plants, one of which is bioethanol. Bioethanol is a renewable fuel with high economic value. From various potential plant sources that can be developed into alternative fuel, one of them is sweet sap from sorghum stalk. This research aims to determine the effect of different types of yeast on the volume, alcohol content, and specific gravity of bioethanol produced from sorghum stalk. The variations of yeast used in this research were tapay yeast, baker's yeast, and turbo yeast, with a yeast mass of 10 g/L, NPK (nitrogen, phosphorus, potassium) mass of 0.6 g/L, and urea mass of 0.5 g/L. Bioethanol was produced from the sweet sap through a 3-day fermentation process, with a sample volume of 3 liters, followed by distillation using a vacuum distillation apparatus. The research was conducted at room temperature and pressure so that all sweet sap obtained the same treatment before being given different types of yeast. The results of the research showed that the highest alcohol content was obtained from the fermentation process using tapay yeast, followed by baker's yeast and turbo yeast. Meanwhile, the largest volume of bioethanol was obtained from the fermentation process using turbo yeast. The highest specific gravity of 0.9456 was also obtained from the fermentation process using turbo yeast, while the lowest was obtained from the fermentation process using tapay yeast.

Keywords – stalk sorghum; yeast; alcohol content; specific gravity

I. INTRODUCTION

The scarcity of fossil fuels, especially oil, has become a critical issue nowadays. Even in some remote areas, the supply of fossil fuels has become scarce, at least in some developing countries. As a result, the prices have increased, and it has had a negative impact on the quality of life. Therefore, efforts have been made to find alternative sources of energy for a long time. The utilization of raw materials from plants, animals, or even waste by applying the latest technology has been studied to obtain alternative fuels. The goal is to obtain a substitute fuel for both spark ignition and compressed ignition engines [1].

Various types of alternative fuels, including biofuels, hydrogen, natural gas, and electricity, have been explored. However, there are several challenges related to the development and implementation of these alternative fuels. The challenges commonly faced include technological obstacles, such as difficulty in producing alternative fuels at an affordable and efficient cost. Policy issues, such as the lack of support and incentives from the government. Inadequate infrastructure, challenges in developing safe and efficient technology for storing and transporting alternative fuels. Competition with well-established and easily accessible fossil fuels in the market. Challenges in creating a large enough market for alternative fuels to compete economically with fossil fuels [2].

Of several types of alternative energy, bioethanol is one of the promising ones. Bioethanol is a biochemical liquid produced through the fermentation of sugar from carbohydrate sources with the help of microorganisms, followed by the distillation process. Starchy, cellulose, and sucrose-containing plants are used as raw materials. The most commonly used method for producing bioethanol is fermentation and distillation. Bioethanol can be used as a substitute for oil, depending on its purity level. Bioethanol with a purity level of 95-99% can be used as a substitute for premium gasoline, while 40% purity level is used as a substitute for kerosene [3].

Several commonly used raw material sources for bioethanol production include sugarcane, corn, wheat, cassava, agricultural waste, organic waste, and others [4]. Sugarcane contains a lot of sugar which can be converted into ethanol through the fermentation process, thus it is commonly used for bioethanol production [5]. Corn is the second-largest source of bioethanol raw material after sugarcane [6]. Meanwhile, wheat is also a commonly used raw material source for bioethanol production. The starch content in wheat can be converted into sugar through the hydrolysis process and then fermented into ethanol [7]. Agricultural waste and organic waste such as straw, corn stalks, and rice husks can also be used as raw materials for bioethanol through the hydrolysis and fermentation process [8]. In addition to the above sources, other raw materials such as wood, seaweed, and microalgae are also being developed as sources of bioethanol raw materials. However, their use is still limited due to high production costs [9].

From the previous research conducted, it was found that the use of specific enzymes can increase bioethanol production [10]. Similarly, the use of more efficient sugarcane preparation technology and the selection of the right yeast can increase bioethanol production and reduce production costs [11]. The use of solid-state fermentation technology with the appropriate use of enzymes is also believed to reduce production costs [12]. From the various research results above, it can be concluded that the use of appropriate technology such as a combination of enzymatic hydrolysis and solid-state fermentation or pretreatment technology of raw materials with the use of organic solvents or sulfuric acid can increase bioethanol production.

In addition, several research results using various yeast variations have also been conducted. One study proved that the use of a mixture of Saccharomyces cerevisiae and Candida tropicalis yeast in solid-state fermentation can increase bioethanol production with high ethanol levels [13]. Likewise, the use of Saccharomyces cerevisiae and Pichia stipitis yeast in solid-state fermentation can increase bioethanol production from corn cobs [14].

Sorghum has also been studied to produce bioethanol. These studies show that sorghum can be used as a raw material for bioethanol production with special pretreatment technology, acid hydrolysis, enzymatic hydrolysis, or a combination of enzymatic hydrolysis and solid-state fermentation with yeast variations such as Saccharomyces cerevisiae, Saccharomyces uvarum, Zymomonas mobilis, or Pichia kudriavzevii [15].

However, research that uses of sweet sap from sorghum stalk for bioethanol production and studies the physical properties of the resulting bioethanol is still scarce. Understanding and knowing the physical properties of bioethanol is essential as vehicle engines require specific standards in both physical and chemical properties. The proper physical properties of bioethanol will improve vehicle performance and reduce emissions. This understanding is particularly important for bioethanol produced with the available yeast variations on the market. Therefore, this research is conducted to fill the gap in information that is still lacking to obtain a complete picture of the benefits of bioethanol obtained from sweet sap from sorghum stalk.

II. RESEARCH METHODS

This study used sorghum stalk obtained from farmers in West Nusa Tenggara province, Indonesia. Sorghum stalks were harvested and washed before being pressed using a sorghum grinding machine. After all the leaves on the sorghum stalk were cleaned, the stalk was ready to grind. The resulting sorghum juice was then filtered to remove any unwanted impurities.

The sorghum juice was then heated to a temperature of 80-90 °C to obtain a Brix value of 16%. The Brix value was measured using a refractometer as shown in Figure 1. In addition to increasing the Brix value, this heating process also aimed to kill any bacteria present in the sorghum juice, so that the fermentation process could proceed properly.

Fig. 1. Refractometer

Fig. 2. Vacuum distillation apparatus

The next step is to make a starter culture which is 10% of the volume of the sample to be fermented. Then, urea and NPK fertilizer are added to the sweet sap at a rate of 0.5 g/L and 0.6 g/L, respectively, based on the volume of the starter to be used. The next step is to add yeast, where three types of yeast are used: tapay yeast, baker's yeast, and turbo yeast. Tapay yeast is a dry starter culture consisting of a microbial consortium in the form of yeast (Saccharomyces cerevisiae), fungi (Mucor, Rhizopus, and Amylomyces), and cocci bacteria [16]. Each yeast is added at a rate of 10 g/L of the starter mass to be used for fermentation. After that, the starter is placed in a bottle and shaken until all the mixtures are evenly mixed. The starter is then left in an aerobic state for 12 hours. The adjusted Brix and weight of the sorghum sweet sap are then mixed with the prepared starter.

The fermentation process is carried out at room temperature and will last for 3 days. Brix measurements are taken every day until day 3 to ensure that the fermentation process is proceeding well. The resulting fermented liquid is then distilled. The distillation process is carried out at a temperature of 80°C ± 5°C, with an initial sample mass of 1000 ml per sample. The distillation apparatus used is a vacuum distillation with a sample capacity of 500 ml per distillation, which takes approximately 2 hours (Figure 2). Thus, each sample is distilled twice to produce the 1000 ml sample.

The physical properties studied include alcohol content, specific gravity, and density. Alcohol content is determined by taking a 100 ml sample and measuring the alcohol content using an alcoholmeter. Determination of specific gravity begins with determining the density of bioethanol using a hydrometer. The specific gravity value is then calculated using equation 1.

$$SG = \frac{bioetanol\ density}{aquades\ density} \quad (1)$$

III. Results And Discussion

3.1. The Effect of Yeast on Brix Value

The parts of sorghum that can be used to produce bioethanol are the seeds, stalks, and stalk residues. In this study, the sample used was the filtered and heated juice (sweet sap) extracted from sorghum stalk, which was treated to eliminate bacteria that could damage the juice. The sorghum stalk sap was then poured into a jerrycan with a mass of 3000 grams, and 10% of it was separated to be used as a starter material.

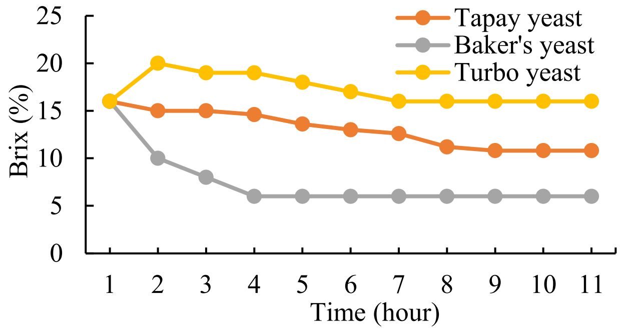

Fig. 3. The relationships between starter fermentation duration and Brix values

Figure 3 shows the changes in Brix values when sorghum sweet sap starters are given with three different types of yeast and left for several hours. Overall, all starters experienced a decrease in Brix values. Although there was an increase in Brix values in the first hour when the starter was given turbo yeast. From the three types of yeast used, baker's yeast showed the largest decrease in Brix values. This decrease in Brix values indicates that the sugar present is consumed quickly by the yeast. The fermentation process requires sugar to produce energy for yeast. During this process, yeast will consume some of the sugar in the starter, so the concentration of sugar in the starter will decrease and the Brix value will also decrease [17]. In addition to sugar, yeast also requires other nutrients such as vitamins, minerals, and proteins to survive and reproduce. The consumption of nutrients by yeast can also cause a decrease in Brix values in the starter [18]. The difference in Brix values indicates that each yeast has a different composition, which affects the speed of sugar consumption in the starter.

3.2. The Effect of Yeast on Ethanol Content

Ethanol is obtained through carbohydrate fermentation with the help of a catalyst (yeast). During this process, a group of bacteria found in the yeast will break down the carbohydrates into glucose, which is then broken down into ethanol, one of the expected fermentation products in this study. After the fermentation process is complete, the next step is distillation. From Figure 4, it is shown that the highest ethanol content was obtained from tapay yeast, which is 48.54%, followed by baker's yeast at 47.19% and the lowest was turbo yeast at 35.95%. There are several factors that affect the formation of alcohol after fermentation. These factors include the type of yeast, nutrient availability, pH, temperature, and fermentation time. In this study, the last three factors were the same for each type of yeast variation used. Therefore, it can be predicted that the high alcohol content produced in the fermentation using tapay yeast may be due to the availability of sufficient nutrients, allowing bacteria to produce a lot of alcohol.

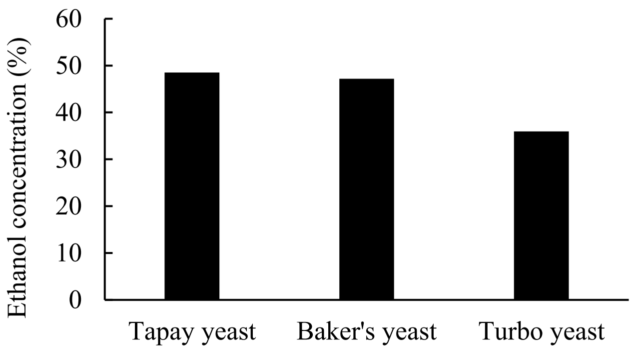

Fig. 4. The ethanol concentration produced from various yeast

3.3. The Effect of Yeast on the Volume of Bioethanol

The volume of bioethanol in this study was measured by pouring the obtained bioethanol into a measuring glass placed on a flat surface and directly reading the result shown on the measuring glass. The volume of ethanol in Figure 5 was obtained from the distillation of fermented sweet sap at a rate of 1000 mL/sample.

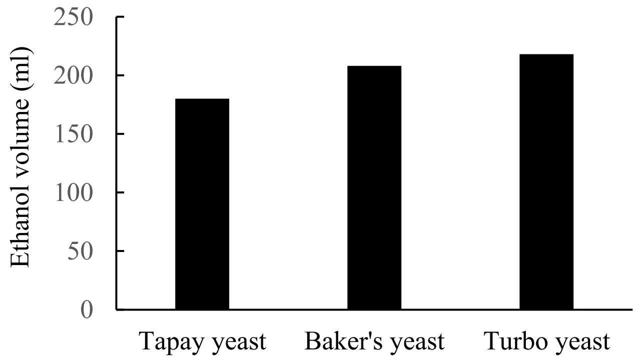

Fig. 5. The volume of ethanol produced from various types of yeast

As shown in Figure 5, the vacuum distillation method produced the highest volume of bioethanol for the baker's yeast at 218 ml, followed by the turbo yeast at 208 ml, and the lowest volume was obtained from the tapay yeast at 180 ml. It can be observed from the figure that as the ethanol content increases, the volume of ethanol produced decreases. As the distillation process was carried out at a temperature of 80°C, a certain amount of water vaporized and mixed with ethanol, which caused a decrease in the alcohol content. These results indicate that different types of yeast will produce different volumes of bioethanol. Some literature suggests that Saccharomyces cerevisiae is the best in breaking down sugar into ethanol [19]. Therefore, it can be considered that baker's yeast contains a sufficient amount of this type of bacteria compared to the other two types of yeast.

3.4. The effect of Yeast on Specifig Gravity

Specific gravity is the ratio of the mass of a given volume of fuel to the mass of an equal volume of water at a specified temperature. From Figure 6, it can be seen that the highest specific gravity value is obtained from the bioethanol produced using turbo yeast, with a value of 0.9456, followed by baker's yeast with a value of 0.9241, and the lowest specific gravity value is obtained from tapay yeast with a value of 0.9209. The higher the density of the bioethanol, the higher the specific gravity obtained, and vice versa. Specific gravity is also related and has an impact on the value of the bioethanol concentration produced, as the specific gravity value will be inversely proportional to the value of the bioethanol concentration obtained. The higher the bioethanol concentration obtained, the lower the specific gravity value obtained. This occurs because the higher the bioethanol concentration, the lower the weight of the bioethanol, which causes the density and specific gravity to decrease.

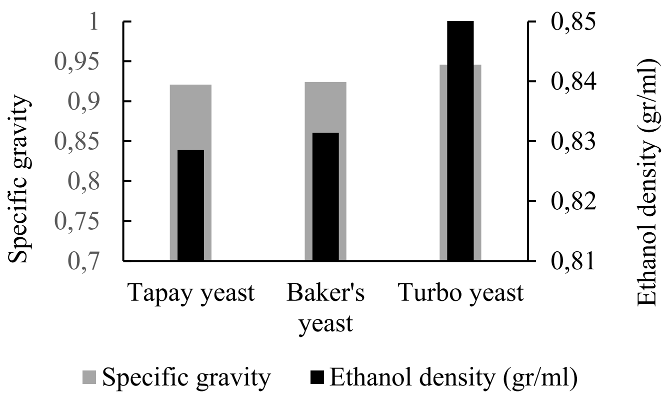

Fig. 6. Specific gravity and density of ethanol

IV. Conclusion

Based on the results of this study, several conclusions can be drawn. The Brix value of the starter will decrease as the fermentation process progresses and depends on the type of yeast used. Baker's yeast is indicated to have more bacteria, thus showing the lowest Brix decrease. However, in terms of producing alcohol concentration, tapay yeast showed the best performance compared to other types of yeast because it produced the highest ethanol concentration, resulting in the least volume of ethanol produced. Meanwhile, the highest volume of ethanol was obtained from fermentation using turbo yeast. Similarly, because tapay yeast produced the highest ethanol concentration, the specific gravity obtained was also the lowest compared to baker's yeast and turbo yeast.

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