

UTILIZATION OF ARABICA COFFEE HUSK FROM THE PULPING PROCESS FOR BIOETHANOL PRODUCTION

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ABSTRACT

One of the sugar sources that can be used as a raw material for bioethanol production is the waste from Arabica coffee husk. This waste is chosen as the base material for bioethanol production due to its high reducing sugar content, its non-competition for food resources, and its abundant availability. The research employs the yeast *Saccharomyces cerevisiae* using fermentation methods to investigate the effects of fermentation time and yeast dosage on achieving optimal bioethanol concentration. This study varied the fermentation times at 62, 72, and 82 hours, as well as the addition of yeast at 0.5 g, 1 g, and 1.5 g. The resulting fermentation liquid was then distilled, and the bioethanol concentration was tested using a refractometer. Subsequently, the bioethanol concentration was analyzed using gas chromatography. The results showed that at a fermentation time of 72 hours with 1.5 g of yeast, bioethanol production reached 62%, with a concentration of 97.72% (% v/v).

Keywords: *bioetanol, fermentasi, kopi, Saccharomyces cerevisiae, khromatografi gas.*

1. INTRODUCTION

The waste generated from the process of separating coffee husks from coffee beans (pulping process) in the form of biomass is abundant, yet only a small percentage is utilized for animal feed and compost. Coffee fruit consists of the exocarp, also known as the fruit skin, which is the outermost part of the coffee fruit; the mesocarp, also referred to as the flesh, is the sweet part with a high water content; the endocarp or husk is the hardest part of the coffee and is made up of cellulose and hemicellulose; the spermoderm, or testa, is the thinnest layer that adheres to the coffee husk; and the endosperm, or seed kernel, is the part of the coffee fruit that is processed into ground coffee (Bressani et al., 1972).

Fermentation commonly carried out in Arabica coffee processing aims to dissolve the mucilage layer present on the surface of the coffee bean husk. Additionally, fermentation can reduce bitterness and enhance the “mild” flavor profile in brewed Arabica coffee (Coffee bean fermentation process, 2011). The duration of fermentation in coffee processing varies depending on the type of coffee, temperature, humidity, and

the thickness of the coffee pile in the bag. The end of fermentation is marked by the dissolution of the mucilage layer surrounding the husk, with fermentation times ranging from 12 to 36 hours.

To convert coffee husk waste into bioethanol, the method used is fermentation. Microbial assistance plays a crucial role in converting sugars contained in the raw materials. One type of yeast capable of converting sugar into bioethanol is *Saccharomyces cerevisiae*. The yeast's ability to convert is quite limited unless energy is provided for yeast growth, such as the addition of urea and NPK.

According to Buckle et al. (1987), microorganisms require a food supply that serves as an energy source and provides the essential chemical elements for cell growth. These basic elements include carbon, oxygen, sulfur, phosphorus, magnesium, iron, and trace amounts of other metals.

Observational data indicated that after 24 hours of fermentation, the initial temperature before fermentation was 29°C, and after fermentation, it rose to 31°C. This increase is due to the metabolic processes of microorganisms, during which they release

CO₂, resulting in a temperature rise (Coffee bean fermentation process, 2011).

The selection of microorganisms is based on the type of carbohydrate used as the medium. To produce alcohol from starch and sugar, *Saccharomyces cerevisiae* yeast is utilized. This selection aims to obtain microorganisms that can grow rapidly, tolerate high sugar concentrations, produce significant amounts of alcohol, and withstand that alcohol (Riswan S, 2009). *Saccharomyces cerevisiae* has a round cell shape and reproduces vegetatively by budding and forming asexual spores. Yeast is a type of microorganism similar to fungi that reproduces very quickly and produces fermentation that can convert starch and sugar into carbon dioxide and alcohol (Ridwansyah, 2003). Yeast (khamir) used for

baking and brewing is purer in population and mainly consists of *Saccharomyces cerevisiae*. This yeast type can produce biomass that is highly beneficial for industries producing fermented food and beverages.

The bioethanol resulting from fermentation can be further purified through distillation at a temperature of 80°C to achieve the desired concentration. The objective of this research is to determine the appropriate quantity of *Saccharomyces cerevisiae* yeast and fermentation time to obtain the best bioethanol concentration from bioethanol production using waste coffee husks from Arabica coffee processing.

2. RESEARCH OBJECTIVES, BENEFITS AND LIMITATIONS

The primary objective of this research is to assess the conversion of coffee husk waste from Arabica coffee pulping into bioethanol through fermentation. Specifically, it aims to identify the optimal quantity of *Saccharomyces cerevisiae* yeast and fermentation time to maximize bioethanol yield. The benefits of this research include addressing coffee production waste management, promoting renewable energy through bioethanol, and offering insights for improving fermented food and beverage products.

3. RESEARCH METHODS

3.1 Materials

The materials used are coffee husk waste from the wet processing of Arabica coffee obtained from CV. Nutrisi Aceh, Takengon. The yeast used is *Saccharomyces cerevisiae* (Mauripan), along with NPK and urea. The equipment used includes a set of fermentation apparatus, distillation equipment, a refractometer, a pH meter, and gas chromatography equipment.

However, limitations exist, such as variability in fermentation effectiveness based on factors like coffee type and environmental conditions. The yeast's conversion efficiency also depends on the availability of nutrients and energy sources. Additionally, the economic viability of bioethanol production is influenced by market dynamics. Overall, this research seeks to enhance understanding of bioethanol production from coffee husks, while addressing its potential and the challenges involved in the fermentation process.

3.2 Sample Preparation

The coffee husk from the wet milling process is collected in a plastic container.

1. Fermentation Process

0.5 kg of coffee husk from the pulping process is blended with 1:2 water. All materials are placed into a fermentation vessel. Add 0.2 grams of NPK and 0.5 grams of urea, varying the yeast to 0.5, 1, and 1.5 grams for each fermentation vessel. Incubate by sealing the fermentation vessel tightly, connecting a U-shaped tube to the lid. After

fermentation is complete, the sample is filtered using cheesecloth.

2. Distillation Process

The fermented waste is then distilled. The distillation process is conducted at a temperature of 78°C. The distillate formed is tested for refractive index using a refractometer, and the concentration is analyzed using gas chromatography.

4. RESULTS AND DISCUSSION

One of the renewable energy sources is bioethanol. Bioethanol is ethanol produced from biomass that contains carbohydrates and cellulose, such as cassava, molasses, sweet sorghum, and others. Therefore, efforts are being made to find alternative raw materials from the non-food sector for ethanol production. One such alternative is coffee husk waste obtained from the coffee pulping process.

Coffee fruit contains various chemical compounds, including sugars (sucrose). When ripe coffee fruit is tasted, it is sweet. The sugar content in coffee fruit is primarily found in the skin and mucilage. According to Bressani et al. (1972), the mesocarp, also known as the flesh of the fruit, is the part that tastes somewhat sweet and has a high water content, with a composition of 12.14% dry weight.

The initial pH of the blended coffee husk waste is 4.67. This is consistent with Poedjiadi A's (1994) statement that the optimal growth temperature for *Saccharomyces cerevisiae* is 28–36°C and the optimal pH for yeast cell growth is 4.5–5.5. According to Ridwansyah (2003), the most important part of the mucilaginous layer (mucilage) is the protopectin component, which is an insoluble complex where meta-cellular lactate from the fruit flesh occurs. This material breaks down during the fermentation process. Some argue that the breakdown of the mucilage is a result of the action of enzymes found in coffee fruit, including a type of catalase that breaks down protopectin in coffee fruit.

Fermentation is usually carried out for 30–70 hours, depending on the fermentation temperature, pH, and sugar concentration. The success of fermentation is typically indicated by the presence of alcohol after 12 hours (Nur Khamdyah, 2010).

In this study, coffee husks did not undergo hydrolysis first, resulting in the advantage that the enzymes present in fresh coffee waste did not immediately die. This method of fermentation significantly helps to speed up the fermentation time, which only lasts 72 hours, whereas fermentation preceded by hydrolysis can kill all bacteria and decomposing microorganisms present in the liquid waste of the blended coffee husks. In comparison, Siswati et al. (2011), who performed hydrolysis, achieved the best fermentation time of 7 days.

Hydrolysis is expected to convert cellulose into glucose, thereby increasing the sugar content that will be further converted into bioethanol by added bacteria. However, only those bacteria will play a role in converting glucose into bioethanol, leading to slow adaptation, lag, and death phases.

The concentration of bioethanol obtained from coffee husk waste has results that differ significantly from those of this study. Siswati et al. (2011) found that using *Zymomonas mobilis** could increase the bioethanol yield to 51.02% with a concentration of 38.68%, with a fermentation time of 7 days.

Zymomonas mobilis has several advantages compared to *Saccharomyces cerevisiae**, including its ability to grow facultatively anaerobically and its high-temperature tolerance, greater conversion capability, resistance to high ethanol concentrations, and low pH, as well as its ability to produce 92% of its theoretical ethanol yield. The optimal fermentation process temperature with *Zymomonas mobilis* is in the pH range of 4–7 (Gunasekaran, 1999).

In this study, the assistance of catalase-type enzymes in coffee waste (Coffee bean fermentation process, 2012) significantly aids in accelerating the fermentation process. This is in part because the reducing sugars from

the coffee husk waste can be directly consumed by the yeast and are not sugars derived from cellulose hydrolysis. After fermentation, the sample is distilled at a temperature of 78°C.

The distillation of the ethanol-water mixture takes 3 hours. The bioethanol resulting from distillation is tested for refractive index using a refractometer. Laboratory analysis provides data on yield and alcohol concentration, as shown in Table 1 below:

Table 1. Results of Bioethanol Analysis from Arabica Coffee Husk Waste

Fermentation Time (Hours)	Yeast Amount (g)	Ethanol Concentration (%)	Yield (%)
62	0,5	35,3	0,79
	1	37	0,77
	1,5	43,7	0,82
72	0,5	48,7	1,02
	1	53,7	1,06
	1,5	62	1,26
82	0,5	33,7	0,75
	1	27	0,79
	1,5	40,3	0,86

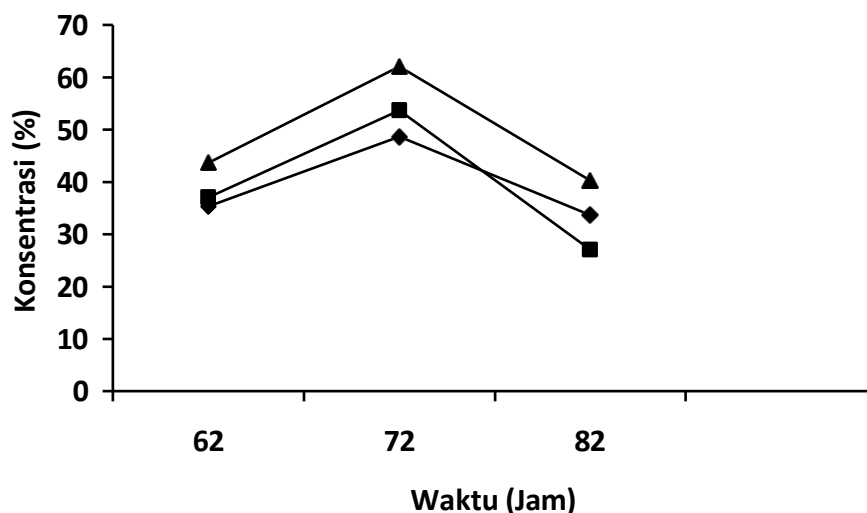


Figure 1. Curve of the Effect of Fermentation Time on Ethanol Concentration (◇) Yeast 0.5 g, (□) Yeast 1 g, (△) Yeast 1, 5 g

The fermentation process lasted between 62 hours, 72 hours, and 82 hours. The results of the experiment on the effect of fermentation time on ethanol concentration are shown in Figure 1. The optimal time for the fermentation process is found to be 72 hours. Therefore, the fermentation process to produce bioethanol is very likely to occur even without the aid of nutrients like urea and NPK to support the growth of *Saccharomyces cerevisiae* yeast. However, the amount of bioethanol produced is very minimal.

For example, with the addition of 0.5 grams of yeast, the concentration of bioethanol produced on the first day was 35.3%. On the first day, the yeast was still in the adaptation phase. After being in the substrate for 24 hours (1 day), the yeast began the process of converting sugar into bioethanol, with some converting into CO₂. In this case, the amount of yeast significantly affects the concentration of bioethanol obtained. Using 1.5 grams of yeast produced a yield of 0.82%, which is higher than the yields of 35.3% and 37% from 0.5 grams and 1 gram of yeast, respectively. Even without added yeast, fermentation could still convert the sugar content present in the liquid waste of coffee husks. However, the fermentation process over 24 hours would not be complete.

The incomplete fermentation without yeast is due to two factors: first, although *Saccharomyces cerevisiae* spores exist in open air, their population would not be as high compared to when they are specifically mixed into the coffee pulp. Second, open air also contains *Acetobacter aceti* bacteria, which will convert sugar into acetic acid. The activity of *Acetobacter aceti* will inhibit the growth of *Saccharomyces cerevisiae*, resulting in incomplete fermentation. With the assistance of yeast, *Acetobacter aceti* is suppressed and does not thrive. The increase in the population of one type of yeast inhibits the growth of other bacterial types (Coffee Bean Fermentation Process, 2011). Fermentation with the help of yeast will shorten the fermentation time.

Research conducted by Iswati, N.D et al. (2011) on coffee husk waste produced results that are quite different from this study. The use of *Zymomonas mobilis* was able to increase bioethanol yield to 51.02% with a concentration of 38.68%, with a fermentation time of 7 days.

After 72 hours, the concentration and yield of bioethanol rose to 62%, while at 82 hours, the concentration dropped to 40.3%. In the simple distillation process, the yield of bioethanol that could be separated from water was only around 62%. Bioethanol and water can form an azeotropic solution, making it difficult to obtain pure bioethanol with a distillation concentration above 62%. This is consistent with the statements of Kosaric et al. (1993) and Seader and Kurtyka (1984), which indicate that at pressures > 0.114 bar (11.5 kPa), ethanol and water can form an azeotropic solution (a solution that boils like a pure liquid: the vapor and liquid compositions are the same). In atmospheric conditions (1 atm), this mixture consists of 95.57% (mass) or 97.3% (volume) or 89.43% (mol) ethanol, and 4.43% (mass) or 2.7% (volume) or 10.57% (mol) water. At this condition, the solution boils at a temperature of 78.15°C.

Over 1 to 2 days, the yeast undergoes a growth phase (log phase), as indicated by the increasing amount of bioethanol produced. After this growth phase, the yeast enters a stationary phase, shown by a horizontal curve, due to declining food supply. Then at 82 hours, yeast activity begins to decrease, entering a death or decline phase. The yeast becomes unproductive, leading to a downward trend in the curve.

Determination of Optimal Yeast Dose

The fermentation process was conducted by varying the amount of yeast. The amount of yeast added was based on the assumption that 1 liter of substrate requires about 5-10% yeast to convert sugar into bioethanol. From Table 1, a curve of the effect of yeast mass on bioethanol concentration can be created, as shown in Figure 2.

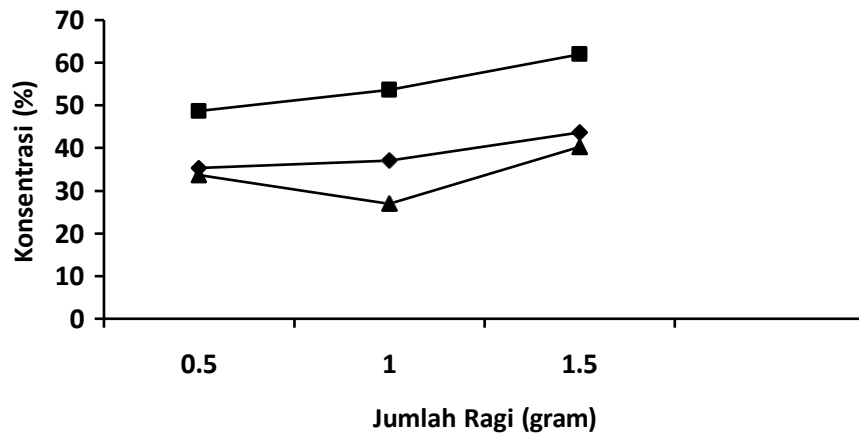


Figure 2. Curve of the Effect of Yeast Amount on Bioethanol Concentration

In Table 1 and Figure 2, it is shown that the addition of yeast leads to a higher concentration of bioethanol produced. For example, with an addition of 1.5 g of yeast and a fermentation duration of 72 hours, a bioethanol concentration of 62% is achieved. The coffee husk waste fermented for 72 hours with a yeast dose of 1.5 g yields the highest ethanol concentration. This indicates that one cannot assume that longer fermentation

times and higher doses of yeast will always result in increased bioethanol concentrations. For instance, during the 82-hour fermentation with a yeast dose of 1.5 g, the resulting bioethanol concentration was lower than that of the 72-hour fermentation with the same yeast dose, where the bioethanol concentration was 40.3%.

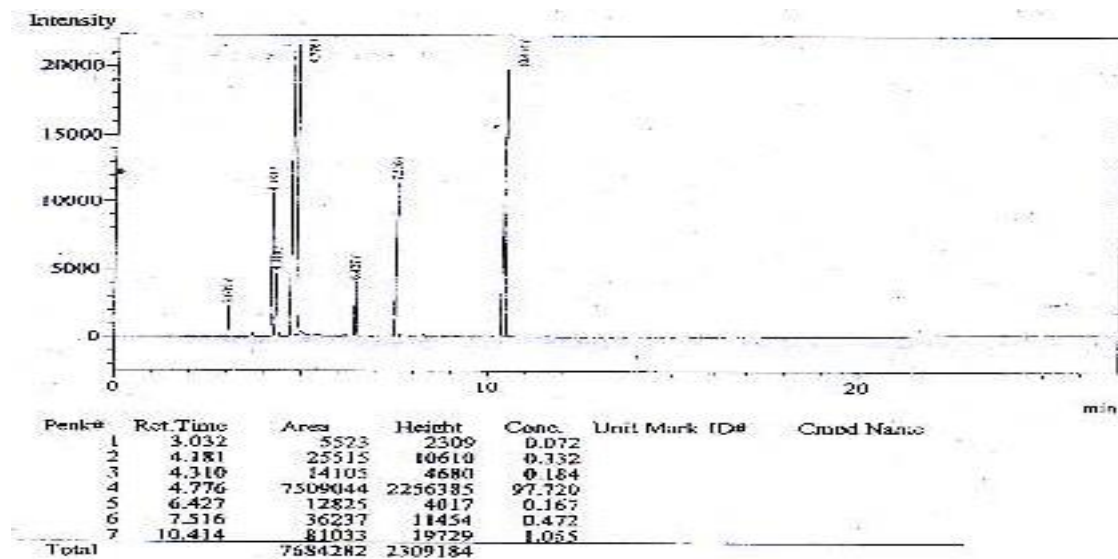


Figure 3. Gas Chromatography Analysis of Bioethanol Distillation Products

The analysis through gas chromatography yielded a Retention Time (RT) of 4.788 minutes, with the obtained bioethanol concentration at 97.72%.

CONCLUSION

The results of the analysis indicate that the sample analyzed is the expected product, which is bioethanol. The bioethanol obtained from the GC test has a concentration of 97.72% after 72 hours of fermentation. This is also related to the reduction of glucose (reducing sugar) at each fermentation time.

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