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Fermentation Experiment of Arabica Coffee (*Coffea arabica L.*) from Dolok Sanggul with Variation of Gas Condition at Isothermal Temperature

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ABSTRACT

Indonesia is one of the largest coffee producing and exporting countries in the world. One of the types of coffee that is famous in Indonesia is arabica coffee. This study examines the impact of different gas environments (open, semi-closed, and closed) on the fermentation process of Arabica coffee beans (Coffea arabica L.) at various temperatures (40°C, 60°C, and 80°C). The key factors analyzed were the moisture content and pH levels of the beans after fermentation and roasting. The findings revealed that both gas environment and temperature had a significant effect on the moisture content and pH of the beans, with higher temperatures (80°C) leading to a faster reduction in moisture. Additionally, the pH level was higher under open gas conditions. This research offers valuable information on how fermentation conditions influence the chemical properties and qualities of Arabica coffee beans.

Keywords: Arabica coffee, fermentation, gas environment, temperature, pH

1. INTRODUCTION

Indonesia is one of the largest coffee producing and exporting countries in the world. After palm oil, rubber, and cocoa, coffee is Indonesia's fourth largest export in terms of foreign exchange earnings. Indonesian coffee has a unique aroma and taste and is one of the largest coffee producing and exporting countries in the world. Coffee is one of the plantation products that is used as a refreshing drink with a very distinctive taste. Coffee is now the most popular beverage in the world after water and tea.[1,2]

One of the famous types of coffee in Indonesia is Arabica coffee. Arabica coffee has a better taste and lower caffeine than robusta coffee, making it safer to consume. The taste of coffee is not only determined by the type of coffee and the production process, the process of processing coffee into ready-to-eat drinks also

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affects the taste of the coffee produced. Coffee processing begins with healthy fruit sorting, fruit peeling, fermentation, drying, dry bean peeling, bean sorting, roasting, grinding and cooling. Different temperatures and roasting lengths result in the quality of coffee with different flavors. The secondary processing process is the process of processing coffee beans into ground coffee and knowing the characteristics of ground coffee is one of the efforts to provide added value to coffee products. For this reason, it is necessary to conduct research to determine the influence of the initial temperature and level factors on the physical properties and taste of Arabica coffee. One of the reasons for the difference in the length of roasting time at each roasting level is the moisture content contained in the coffee beans. The higher the moisture content of the coffee beans, the value of the heat capacity of the coffee beans will increase. Coffee fermentation generally has a slower adaptation phase.[3,4]

Fermentation is a metabolic process, both without oxygen (anaerobic) and with oxygen (aerobic). Coffee fermentation is essential for removing mucus from coffee skins. Coffee mucus contains polysaccharides (pectin), cellulose, and starch. Mucus can prolong the time it takes to dry coffee beans.[5] Fermentation in this study is spontaneous fermentation or fermentation that takes advantage of the surrounding or environmental conditions. Therefore, a higher and constant temperature is needed to accelerate the drying of the coffee beans.

Febrianti et al. (2019) stated that fermentation has a great influence on pH values. The longer the fermentation, the lower the pH value. Temperature plays an important role in the speed or slowness of the fermentation process of coffee beans. The fermentation process is a very important stage where the coffee beans remain green and have a very high content of chemical compounds, especially at the acidity level. Ridwansyah (2003) also stated that the factor that affects the pH level is fermentation, the longer the fermentation process, the lower the acidity level.

2. EXPERIMENTAL

2.1 Chemicals, Equipment and Instrumentation

Research on the variation of gas conditions at isothermal temperature after fermentation in Arabica coffee, which is native to Dolok Sanggul, was carried out in the Chemistry laboratory of Universitas Negeri Medan. Coffee processing involves fermentation and heating processes such as drying and roasting.[8] Where the fermentation time carried out on coffee beans is about 2 – 3 hours for each temperature: 40°C; 60°C; and 80°C. As the main confusion in this study is the fermentation temperature and the length of fermentation time. These two factors can affect the final result of fermentation and the change of coffee beans.

The materials used in this study are fresh coffee beans, hot water, aluminum foil and without the use of any chemicals. While the tools used in this study are oven, pH meter, thermometer, 100 mL beaker glass, analytical scale, pan, and blender. With three variations of gas conditions tested, namely; open condition: where the fermentation container is not closed, allowing free air to enter the container; Semi-closed condition: the fermented aluminum foil is only partially covered with a porous lid, allowing little air to enter; and closed conditions: the fermentation container is tightly closed to avoid air entering the container.

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2.2 Research Procedure

After all the equipment is ready, the coffee beans are put into the fermentation container according to the variation of gas conditions that have been determined, namely open containers (Anaerobic), semi-closed containers (Semi-Anaerobic), and open containers (Control Without Fermentation). Each container is set at a certain temperature so that the fermentation process continues to run optimally. Coffee beans in open containers will be exposed to free air, while coffee beans in semi-closed and closed containers will be exposed to a limited amount of air.

During the fermentation process, parameters such as temperature, are measured periodically. The temperature in the fermentation vessel is monitored using a thermometer to ensure that the temperature remains constant. The pH of coffee beans is measured using a pH meter to monitor changes in acidity during fermentation.

After the fermentation process is complete, the roasting process is carried out to turn the coffee beans into ready-to-brew coffee. After roasting, the coffee beans are ground using a blender and brewed to test for differences such as pH between different samples. The sample weighed 0.8 grams on a cup that had a known weight. Then the sample is baked for 2-3 hours at a temperature of 40°C, 60°C, and 80°C. After baking, the sample is removed and cooled for 15 minutes then weighed and the weight is recorded. Moisture content formula: (initial weight - final weight) / (initial weight) x 100%.

The acidity of coffee is measured using a pH meter. The sample was weighed as much as 0.8 grams and dissolved with water in a ratio of 1:5 then homogenized for 30 minutes and then measured.

Based on the data obtained, the change in the mass of evaporated coffee water at each temperature is associated with the change in energy in the system, which is then calculated to obtain a gas volume equivalent to the ideal gas. The formula used in the isothermal analysis of gases is: $PV = nRT$, with P = Pressure (atm); V = Volume (L); n = Number of moles of gas; R = Ideal gas constant (0.0821 L-atm/(mol-K)); and T = Temperature (K).

3. RESULTS AND DISCUSSION

The fermentation optimization process is aimed at obtaining optimal conditions in the fermentation process in the form of the number of fungi used, fermentation temperature, and fermentation process duration.[9] And of course to get better quality coffee beans due to the influence of temperature. The processing and drying procedures used by various manufacturers differ significantly, due to technological, environmental, and economic factors as well as the need[10] in conducting research as efficiently as possible.

The fermentation that is carried out periodically produces dried coffee beans, this is in line with the statement from Febrianti et al. (2019) who said that temperature plays an important role in the speed or slowness of the coffee bean fermentation process. But contrary to their next statement, which reads; The fermentation process is a very important stage where the coffee beans remain green. This is due to the fact that in their study, the fermentation of coffee beans was carried out at a constant room temperature, ranging from 25-30°C. Meanwhile, this fermentation is carried out at a relatively very high temperature. So as to speed up the drying rate. Which then makes it easier to grind, when the skin from the coffee beans is easily peeled off.

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On the other hand, the concept of gas isothermal in thermodynamics, which describes the relationship between temperature and gas volume in a process that takes place at a constant temperature, can be used to analyze the fermentation process of coffee, especially in terms of gas production during the fermentation process.[11] Therefore, isothermal conditions are the focus of this study because fermentation under constant temperature allows for more precise monitoring of the effect of gases on changes in pH, chemical composition, and sensory characteristics of coffee beans.

3.1 Moisture Content

Moisture content is an important parameter in determining product quality, especially in ingredients that undergo a fermentation process. It is determined by drying in an oven, with gravimetric analysis used to calculate moisture content based on the difference in sample weight before and after drying.[12,13] Based on data from moisture content experiments on fermented materials at 40°C, 60°C, and 80°C, it is evident that moisture content changes depending on fermentation temperature and material closure conditions.

At 80°C, the data indicate a significant decrease in moisture content under closed, semi-closed, and open conditions. The highest reduction occurred in closed conditions, with moisture content decreasing from 18.95% to 13.74%. Meanwhile, in semi-closed and open conditions, the decrease was less pronounced. This reduction in moisture content is due to higher temperatures, which accelerate evaporation and drying of fermented materials. High temperatures also enhance microbial and enzymatic activity, promoting the decomposition of material components and further reducing moisture content. Additionally, higher temperatures facilitate the opening of material pores, allowing water to evaporate more efficiently.

At 60°C, the moisture content also decreases, though the variation is smaller compared to that at 80°C. This indicates that lower temperatures (60°C) lead to slower evaporation rates, yet still contribute to a reduction in the material's moisture content. A temperature of 40°C results in a smaller decrease in moisture content. At this temperature, the fermentation and drying processes proceed more slowly, as reflected in the data, which show a lower reduction in moisture content compared to higher temperatures. However, under open and semi-closed conditions, the moisture content still exhibited a significant decrease, albeit less pronounced than at 60°C and 80°C.

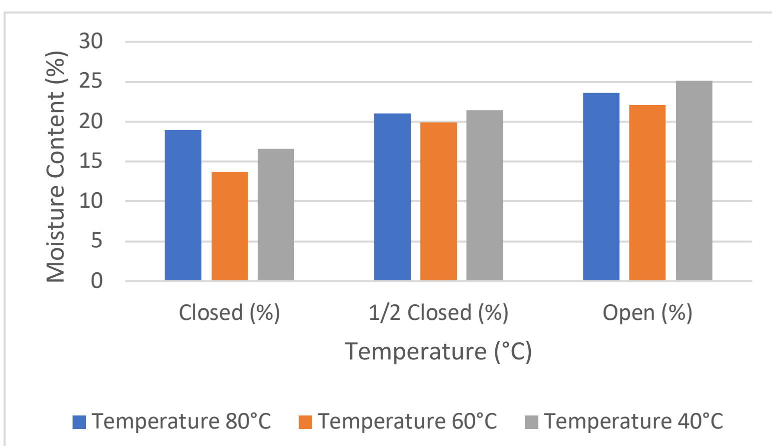

Figure 1. Moisture Content Relative to Temperature and Closing Conditions

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In line with Zainuddin and Tomina (2021), prolonged fermentation leads to a lower moisture content in coffee powder. Experimental results indicate that the fermentation duration at 60°C is longer than at 80°C but shorter than at 40°C. Additionally, the study findings suggest that constant temperature and environmental conditions during coffee bean fermentation significantly impact the moisture content of the fermentation material. High temperatures accelerate water evaporation, whereas low temperatures slow the evaporation process. A faster reduction in moisture content at higher temperatures indicates that fermentation and drying are more efficient under these conditions. However, even at 40°C and 60°C, moisture content continues to decrease, albeit to a lesser extent than at 80°C.

Higher temperatures accelerate evaporation and fermentation, which leads to a faster decrease in moisture content. However, under certain conditions, such as lower temperatures, a decrease in moisture content still occurs even at a slower rate.

3.2 pH of Fermentation Liquids

The pH value is the total concentration of hydrogen ions (H) in a solution, which expresses the acidity and alkalinity of the solution. Because pH is formed from quantitative information expressed by the degree of acidity or alkalinity related to the activity of the hydrogen ion.[14] The pH value of the fermentation liquid can be seen in the figure.

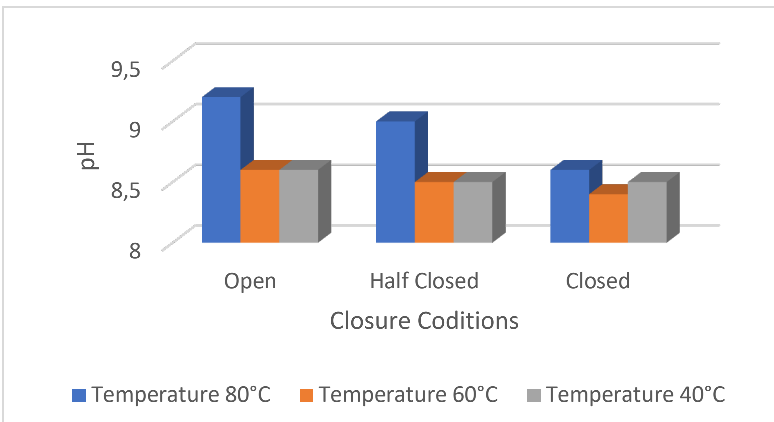

Figure 2. The pH to temperature and closure conditions

Any increase in temperature will lead to a decrease in its viscosity and an increase in the mobility of its ions in it. An increase in temperature can also lead to an increase in the number of ions in the solution due to the dissociation of molecules (this is especially true for weak acids and bases). Since pH is a measure of the concentration of hydrogen ions, changes in the temperature of the solution will be reflected by subsequent changes in pH.[15]

Analysis of pH data at a wide range of temperatures and closure conditions reveals several important trends. At 80°C, the highest pH was found in the open system (9.2), followed by the closed system (9.0), and the lowest in the semi-closed system (8.6). This suggests that at high temperatures, reactions that

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increase alkalinity are more pronounced, with open systems benefiting from greater exposure to oxygen and evaporation.

At 60°C, the pH value is almost identical under all conditions (8.5 to 8.6), indicating a stable pH in the system. At 40°C, the pH value tends to be more uniform (8.4 to 8.6), indicating that the lower temperature slows down the reaction and makes the pH value more stable throughout the closure conditions.

Overall, temperature plays an important role in influencing pH, with high temperatures increasing pH variability, while low temperatures result in more consistent pH values. Closing conditions affect pH more at high temperatures, but the effect decreases as the temperature decreases. These findings suggest that temperature and closure conditions work together to influence the chemical reactions that regulate pH, with temperature being the more dominant factor.

3.3 Gas Volume Equivalent to Ideal Gas

The Ideal Gas Law is a simple equation that shows the relationship between temperature, pressure, and volume for a gas.[16] In this case, the evaporation that occurs is the result of a change in mass or moisture content, which corresponds to the change in energy in the system, and can be attributed to the temperature for its isothermal relationship. And based on the available experimental data, the change in mass at various temperatures, namely 40°C, 60°C, and 80°C, will be associated with the evaporation of water at that temperature.

The first step is to convert the temperature from Celsius to Kelvin (K), because the ideal gas formula requires the temperature in Kelvin: Temperature 40°C = 313.15 K; Temperature 60°C = 333.15 K; Temperature 80°C = 353.15 K. Then, we can calculate the number of moles of evaporated water based on the change in water mass at temperatures of 40°C, 60°C and 80°C. Then using the value of 1 atm to obtain the equivalent gas volume value at each temperature, which in order is 1.11 L; 1.99 L; and 3.09 L.

The gas isotherms in this experiment were analyzed by correlating changes in temperature, gas volume, and gas composition produced during coffee fermentation. The use of the ideal gas law ($PV = nRT$) can provide an understanding of how gas conditions (open, closed, and semi-closed) affect fermentation, pH, and moisture content.

In addition, higher temperatures accelerate fermentation and evaporation, while lower temperatures slow them down, which is reflected in various changes in pH and moisture content at 40°C, 60°C, and 80°C.

4. CONCLUSION

Based on the results of experiments on water evaporation at 40°C, 60°C, and 80°C, it can be concluded that temperature has a significant effect on the rate of water evaporation. The higher the temperature, the greater the change in the evaporated water mass. Calculating the volume of the gas equivalent to the number of moles of water evaporated at various temperatures shows a clear relationship between temperature and gas volume, which can be explained using the ideal gas formula. At higher temperatures, the volume of gas produced is larger, indicating that the energy required for the evaporation process increases as the temperature rises. And the lower the temperature used during fermentation, the more neutral the pH value of the coffee beans will be.

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REFERENCES

1. Parnadi, F., & Loisa, R. (**2018**). Analisis Daya Saing Ekspor Kopi Indonesia Di Pasar Internasional. Jurnal Managemen Bisnis Dan Kewirausahaan, 02(4), 52–61.
2. Handayani, R. (**2024**). Effect of Fermentation Duration in Cafein Currency in Robusta Coffee (Coffea canephora) from PTPN XII Jember. Indonesian Pharmacopeia Journal, 1(1), 26-31.
3. Mardjan, S. S., Purwanto, E. H., & Pratama, G. Y. (**2022**). Pengaruh Suhu Awal Dan Derajat Penyangraian Terhadap Sifat Fisikokimia Dan Citarasa Kopi Arabika Solok. Journal of Agricultural Engineering/Jurnal Keteknikan Pertanian, 10(2).
4. Saripah, S., Aini, A. F., Manfaati, R., & Hariyadi, T. (**2021**). Pengaruh Suhu Lingkungan dan Waktu Fermentasi Biji Kopi Arabika Terhadap Kadar Kafein, Etanol, dan pH. In Prosiding Industrial Research Workshop and National Seminar, Vol. 12, pp. 124-128.
5. Haile, M., & Kang, W. H. (**2019**). The role of microbes in coffee fermentation and their impact on coffee quality. Journal of Food Quality, Vol. 1, 4836709.
6. Febrianti, D., Prastowo, S. H. B., & Supriadi, B. (**2019**). Pengaruh Suhu dan Waktu terhadap Fermentasi Biji Kopi. FKIP e-Proceeding, 4(1), 54-56.
7. Ridwansyah. (**2003**). Pengolahan Kopi. Departemen Teknologi Pertanian.
8. Ardiansyah, D., Tjota, H., & El Kiyat, W. (**2018**). Peran Enzim dalam Meningkatkan Kualitas Kopi. JURNAL AGRI-TEK: Jurnal Penelitian Ilmu-Ilmu Eksakta, 19(2).
9. Rollando, R., Monica, E., Sitepu, R., & Susanto, F. H. (**2022**). Pelatihan pembuatan biji kopi fermentasi untuk kelompok republik tani mandiri desa kucur malang. Peduli J. Pengabdi. Kpd. Masy, 6(1), 22-28.
10. Girma, B., & Sualeh, A. (**2022**). A Review of Coffee Processing Methods and Their Influence on Aroma. Int. J. Food Eng. Technol, 6(7), 7-16.
11. Panggabean, E. (**2019**). Buku Pintar Kopi. Jakarta: PT Kawah Media Pustaka.
12. Zainuddin, A., & Tomina, S. (**2021**). Efek lama fermentasi terhadap karakteristik fisik dan kimia kopi pinogu. Gorontalo Agriculture Technology Journal, 4(1), 35-43.
13. Sachriani, S., & Yulianti, Y. (**2021**). Analisis Kualitas Sensori dan Kandungan Gizi Roti Tawar Tepung Oatmeal Sebagai Pengembangan Produk Pangan Fungsional. JST (Jurnal Sains Terapan), 7(2), 26-35.
14. Anggraini, S. P. A., Yuniningsih, S., & Sota, M. M. (**2017**). Pengaruh pH terhadap Kualitas Produk Etanol dari Molasses melalui Proses Fermentasi. Reka Buana: Jurnal Ilmiah Teknik Sipil dan Teknik Kimia, 2(2), 98-105.
15. Ashton, J. J. B. C., & Geary, L. (**2011**). The effects of temperature on pH measurement. Tsp, 1(2), 1-7.
16. Tenny, K. M., & Cooper, J. S. (**2017**). Ideal gas behavior.

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