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Analysis of the effect of fermentation duration on the organoleptic properties of dried cocoa beans (*Theobroma cacao* L.) at *Nglanggeran* Agricultural Technology Park

Annisa Ayu Permata[1], Nurul Hidayah[1*]
[1]*Food Technology Study Program, Universitas Ahmad Dahlan, Jl. Ahmad Yani, Tamanan, Banguntapan, Bantul, Yogyakarta, 55166, Indonesia*
[*]*Corresponding author: nurul.hidayah@tp.uad.ac.id*

ABSTRACT

The post-harvest process of cocoa fruits includes fruit harvesting, cracking, wet bean sorting, fermentation, drying, dry bean sorting, and packaging. One of the post-harvest processes that significantly affects the quality of cocoa beans is fermentation. The fermentation process, facilitated by acetic acid and lactic acid bacteria, aims to reduce moisture content, enhance aroma and flavor, and improve the quality of cocoa beans. Acetic acid bacteria, such as Acetobacter and Gluconobacter, contribute to acetic acid production, giving cocoa beans their characteristic flavor. These bacteria convert alcohol into acetic acid, a process crucial for developing the beans' flavor. On the other hand, lactic acid bacteria, like Lactobacillus and Pediococcus, play a role in the breakdown of complex compounds, enhancing the aroma. These bacteria produce lactic acid, which contributes to the beans' aroma. One factor that influences the success of cocoa fruit fermentation is the duration of fermentation. The optimal fermentation time for cocoa fruits is 5 – 6 days. If it is less or exceeds the optimal time, the fermentation of cocoa fruits will not be perfect. The duration of cocoa fruit fermentation has been proven to affect the aroma, taste, texture, and color of dried cocoa beans.

Keywords: Cocoa, Fermentation, Post-harvest process of cocoa, Organoleptic

INTRODUCTION

Fermentation, a crucial process in cocoa post-harvest processing, is the main focus of this research. Cocoa beans that undergo fermentation have significantly better quality than those that do not. Non-fermented cocoa beans, as demonstrated by Misnawi et al. (2002), lack the characteristic chocolate aroma during roasting and may even result in astringent and bitter flavors. In contrast, fermented cocoa beans produce higher quality with improved taste and aroma. This is because, during the fermentation process, various chemical and biochemical reactions occur in cocoa beans. These reactions, such as the breakdown of complex compounds and the production of acetic acid, contribute to the development of taste and aroma. The research presented here aims to determine the optimal fermentation duration for cocoa beans, a crucial step that significantly enhances the quality of cocoa beans. The impact of fermentation duration on the quality of cocoa beans is a key aspect of this study.

Fermentation breaks down sugars and citric acid in the cocoa pulp into organic acids, carried out by fermentation microorganisms (Camu et al., 2008). These organic acids induce enzymatic reactions within the cocoa beans, leading to biochemical changes that result in the formation of compounds responsible for cocoa's aroma, taste, and color (Apriyanto et al., 2017). Cocoa bean fermentation essentially serves two primary purposes: to break down the mucilage layer covering the pulp and to create conditions for reactions within the bean during the fermentation process. The pulp, broken down by microorganisms from the environment, detaches from the bean, resulting in clean cocoa beans that can be dried quickly after washing. The chemical and biochemical reactions within the bean are intended to form flavor and color precursors (Haerani, 2012).

According to Rohan (1963), the ideal fermentation container for cocoa is typically a wooden box with 750 kg of fresh cocoa beans. These boxes should have aeration holes on each side, and the optimal

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fermentation temperature for cocoa bean fermentation is 44 – 48 ºC. However, cocoa from individual farmers often does not reach the 750 kg fresh cocoa bean threshold. As a result, farmers may be unable to carry out the fermentation process due to the limited capacity. Researchers have employed double-walled box-type fermentors with capacities ranging from 10 – 50 kg of cocoa beans to provide a practical and cost-effective solution for achieving good cocoa bean fermentation. This approach is more suitable for small-scale farmers and helps ensure proper fermentation despite the lower quantities of cocoa beans.

During fermentation, aeration is performed every 2 days by thorough mixing. This mixing is essential to ensure that the heat generated during the fermentation process is distributed evenly. The goal is to maintain an even temperature throughout the fermentation mass. The optimal temperature for perfect fermentation typically ranges from 47 – 50°C. Temperature is monitored and recorded daily to assess whether the fermentation progresses optimally. Several factors influence the cocoa fermentation process, including fermentation duration, agitation, climate, aeration, and the fermentation location. Proper control and management of these factors are crucial to achieving the desired quality in cocoa beans. One of the factors that affects cocoa fermentation is the fermentation duration. The length of cocoa fermentation will influence the success of the fermentation process in cocoa. At Nglanggeran Agricultural Technology Park, cocoa beans are fermented for 5 – 6 days to achieve optimal results.

RESEARCH METHOD

Materials

The tools used in this research are fermentation boxes, a cocoa stirrer, rigen, trays, and jute bags. Fermentation box: The fermentation box is a container used for cocoa beans during the fermentation process. It is made of wood and measures 50.2 x 40.8 x 47.6 cm with a capacity of 40 kg. The fermentation box has 1 cm diameter holes spaced 5 cm apart. The material used in this research is 700 grams of wet cocoa beans.

Methods

Mature cocoa pods were selected as the treatment material. Without going through the fermentation process, cocoa pods were harvested and cracked open to extract the beans. Wet cocoa beans that had undergone sorting were then placed in a fermentation box for 5 – 6 days. Before placing the cocoa beans into the fermentation box, the interior walls were lined with banana leaves, and the top was covered with jute bags. This treatment was implemented to prevent direct contact with the air. The fermentation box is made of wood and measures 50.2 x 40.8 x 47.6 cm with a capacity of 40 kg. The fermentation box has 1 cm diameter holes spaced 5 cm apart.

During fermentation, aeration is carried out every 2 days by stirring the contents evenly. This stirring ensures that the heat generated by the fermentation process is distributed evenly. The optimal temperature for achieving perfect fermentation is between 47 – 50 °C. The fermentation temperature is observed and recorded daily to determine whether the fermentation is proceeding optimally or not.

Table 1. Sample code for panelist.

Sample Code	Treatment
231	Fermented for 1 day
732	Fermented for 2 days
964	Fermented for 3 days
634	Fermented for 4 days
590	Fermented for 5 days
134	Fermented for 6 days
535	Fermented for 7 days

Table 1 shows that cocoa beans were divided into 7 samples with different treatments. Each sample was weighed at 100 grams and then fermented for varying durations. Sample 231 was fermented for 1 day, sample 732 for 2 days, sample 964 for 3 days, sample 634 for 4 days, sample 590 for 5 days, sample 134 for 6 days, and sample 535 for 7 days. After fermentation for the specified durations, each

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sample was sun-dried for 6 – 7 days until the moisture content met the requirements of SNI 01-2323-2008. Following this, organoleptic tests were conducted for each sample, evaluating parameters such as aroma, taste, texture, and color.

Data Analysis

The data analysis method used in this research is the descriptive statistical method. Descriptive analysis is a statistical approach used to analyze data by describing or summarizing the collected data without intending to draw conclusions that apply to the general population or generalize findings (Sugiyono, 2012).

RESULT AND DISCUSSION

Organoleptic Test

Organoleptic properties are quality attributes of a product that can be assessed through sensory evaluation. Sensory evaluation involves testing food products based on preferences and willingness to use a particular product. Organoleptic testing, or sensory analysis, is a method of testing that utilizes human senses as the primary tool for measuring the acceptance of a product. Organoleptic testing can provide indications of spoilage, quality deterioration, and other defects in a product (Dhingra & Jood, 2002). In this organoleptic evaluation, a panel of 5 panelists is used. These panelists will observe and differentiate the aroma, taste, texture, and color of each sample and then fill out a prepared questionnaire using the following rating scale. Aroma: Very atypical cocoa (1); Not typical cocoa (2); Somewhat typical cocoa (3); Typical cocoa (4); Very typical cocoa (5). Taste: Very not bitter or acidic (1); Not bitter or acidic (2); Somewhat bitter or acidic (3); Bitter or acidic (4); Very bitter or acidic (5). Texture: Very non-porous (1); Non-porous (2); Somewhat porous (3); Porous (4); Very porous (5). Color: Very non-brown (1); Not brown (2); Somewhat brown (3); Brown (4); Very brown (5). Panelists will use this scale to rate and provide their observations regarding aroma, taste, texture, and color for each sample.

Table 2. Sample code for data tabulation.

Sample Code	Treatment
F1	Fermented for 1 day
F2	Fermented for 2 days
F3	Fermented for 3 days
F4	Fermented for 4 days
F5	Fermented for 5 days
F6	Fermented for 6 days
F7	Fermented for 7 days

Table 2 shows a sample code of long-fermented cacao. Fermentation is essential for enhancing chocolate's aroma and flavor in cocoa beans. Cocoa fermentation occurs anaerobically by citric acid bacteria and aerobically by acetic acid and lactic acid bacteria. Organoleptic testing is a method of evaluation that uses human senses as the primary tool for measuring the acceptance of a product. In the assessment of food products, the sensory properties determine whether a product is accepted. The senses used in evaluating sensory properties include sight, touch, smell, and taste. Meanwhile, a questionnaire is a tool that consists of a list of questions that must be filled out by the respondents who are being assessed (Rahayu, 2001).

Fermentation Analysis

On the first day, the temperatures were recorded as follows: upper part 33.2 °C, middle part 30.1 °C, and lower part 29.4 °C. The average temperature was 30.9 °C. On the second day, the temperatures were as follows: upper part 39.0 °C, middle part 38.0 °C, and lower part 37.0 °C. The average temperature was 38.0 °C. On the third day, the temperatures were as follows: upper part 38.0 °C, middle part 38.0 °C, and lower part 37.0 °C. The average temperature was 37.6 °C. On the fourth day, the temperatures were as follows: upper part 42.0 °C, middle part 43.5 °C, and lower part 43.0 °C. The average temperature was 42.8 °C. On the fifth day, the temperatures were as follows: upper part 44.0

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°C, middle part 45.0 °C, and lower part 38.5 °C. The average temperature was 42.5 °C. On the sixth day, the temperatures were as follows: upper part 46.5 °C, middle part 46.5 °C, and lower part 42.0 °C. The average temperature was 45.0 °C. On the seventh day, the temperatures were as follows: upper part 43.4 °C, middle part 44.3 °C, and lower part 42.1 °C. The average temperature was 43.3 °C.

Table 3. Temperature of Cocoa bean fermentation

Days	Sample	Temperature			Mean
		Top	Middle	Bottom	
1	F1	33.2 ˚C	30.1 ˚C	29.4 ˚C	30.9 ˚C
2	F2	39.0 ˚C	38.0 ˚C	37.0 ˚C	38.0 ˚C
3	F3	38.0 ˚C	38.0 ˚C	37.0 ˚C	37.6 ˚C
4	F4	42.0 ˚C	43.5 ˚C	43.0 ˚C	42.8 ˚C
5	F5	44.0 ˚C	45.0 ˚C	38.5 ˚C	42.5 ˚C
6	F6	46.5 ˚C	46.5 ˚C	42.0 ˚C	45.0 ˚C
7	F7	43.4 ˚C	44.3 ˚C	42.1 ˚C	43.3 ˚C

Based on Table 3, it is evident that the cocoa temperature tends to increase during the fermentation process. This demonstrates the presence of catabolic reactions, specifically the breakdown of glucose into ethanol, involving acetic acid and lactic acid bacteria. In line with the statement by Trognitz et al. (2013), fermentation consists of two phases. The first phase is the anaerobic phase, which lasts on average for two days as yeast converts sugar in the pulp into ethanol through alcoholic fermentation, as evidenced by the temperature increase, which can reach up to 35 °C. Simultaneously, pulp is hydrolyzed, allowing air to enter the mass and creating aerobic conditions that support the initiation of the second phase. During the second phase, oxygen is consumed by acetic acid bacteria to oxidize ethanol into acetic acid, which can be further oxidized into carbon dioxide and water. Because this reaction is exothermic, the mass temperature increases, reaching or exceeding 50 °C.

Aroma Analysis

The aroma or smell of a food product plays a crucial role in determining the quality and enjoyment of that food product. The aroma components of cocoa beans consist of volatile compounds primarily formed from reactions between amine and carboxyl groups. The latter two compounds result from the breakdown of peptides and carbohydrates during fermentation (Biehl et al., 1982).

The Maillard reaction is between reducing sugars and amino acids in heat (Hustiany, 2016). The Maillard reaction, which intensifies during the drying of cocoa beans, produces volatile compounds that include groups of alcohols, ethers, furans, thiazoles, pyrans, acids, esters, aldehydes, imines, amines, oxazoles, pyrazines, and pyrroles (Voigt et al., 1993). Among these compounds, pyrazines significantly contribute to chocolate's aroma and flavor because they are not entirely volatile (Jinap & Zeslinda, 1995).

According to Kayaputri et al. (2014), one of the compounds contributing to the distinctive cocoa aroma is 2,3-butanediol. 2,3-butanediol is an organic compound produced during the alcoholic fermentation process of cocoa beans. Additionally, this compound is also found in cocoa fat. This test employs an organoleptic test with 5 panelists in the age range of 20 – 22 years. Here are the panelists' scores for samples F1 through F7: Sample F1: Four panelists scored 2, one panelist scored 1, and the average score was 1.8. Sample F2: All panelists scored 2, achieving an average score of 2.0. Sample F3: Three panelists scored 2, two scored 3, and the average score was 2.4. Sample F4: All panelists scored 3, achieving an average score of 3.0. Sample F5: Four panelists scored 4, one panelist scored 5, and the average score was 4.2. Sample F6: Two panelists scored 4, three scored 5, and the average score was 4.6. Sample F7: One panelist scored 2, four panelists scored 1, and the average score was 1.2. These scores represent the panelists' evaluations of the aroma characteristics of each sample, with higher scores indicating a more potent or desirable aroma.

Based on the data above, sample F1 has a non-distinct cocoa aroma, sample F2 has a non-distinct cocoa aroma, sample F3 has a non-distinct cocoa aroma, sample F4 has a somewhat distinct cocoa aroma, sample F5 has a distinct cocoa aroma, sample F6 has a highly distinct cocoa aroma, and sample

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F7 has a highly non-distinct cocoa aroma. It can be concluded that the sample with the highest score or a highly distinct cocoa aroma is sample F6, whereas the sample with the lowest score or a highly non-distinct cocoa aroma is sample F7. This demonstrates that the fermentation duration significantly affects the aroma produced by cocoa beans.

Fermentation treatment for 1 and 2 days results in a non-distinct cocoa aroma due to the relatively low pH, leading to acidic properties dominating and hindering the chocolate aroma. Another cause is the absence of aroma precursors due to the incomplete fermentation process and insufficient fermentation time (Nursalam, 2005). Fermentation for 3 and 4 days leads to a less distinct cocoa aroma because the fermentation process is incomplete, resulting in an imperfect aroma formation. Fermentation for 5 days and 6 days produces a perfect and distinct cocoa aroma due to sufficient fermentation time, allowing the fermentation process to proceed correctly. Fermentation for 7 days results in a highly non-distinct and rancid aroma. This is because the fermentation process lasts too long, causing the breakdown of compounds produced during fermentation, such as proteins, sugars, and polyphenols (Rachmatullah et al., 2021). Fermentation leads to a relative increase in fat content and a decrease in non-fat components in cocoa bean kernels (Wahyudi et al., 2008). If the fermentation continues too long, the fat content will oxidize, resulting in a rancid odor.

Flavor Analysis

Taste or flavor is a crucial factor influencing chocolate products' quality. The acidic taste in processed chocolate products is caused by acids that do not entirely evaporate during chocolate manufacturing (Jinap & Zeslinda, 1995). The fermentation process helps in removing the pulp that surrounds cocoa beans and aids in developing chocolate flavor precursors. Cocoa bean pulp contains sugars and polysaccharides fermented by microbes. The activity of these microbes produces metabolites and conditions that lead to the death of the beans and initiate a series of biochemical reactions inside the cocoa beans that generate chocolate flavor precursors (Ho et al., 2015). If cocoa beans do not undergo the fermentation process, the distinctive taste and aroma of cocoa do not form, resulting in a bitter and astringent taste (Pradnyawathi et al., 2019).

This test employs an organoleptic test with 5 panelists in the age range of 20 – 22 years. For sample F1, three panelists chose a score of 5, and two chose a score of 4, resulting in an average score of 4.6. For sample F2, one panelist chose a score of 5, and four chose a score of 4, resulting in an average score of 4.2. For sample F3, three panelists chose a score of 4, and two chose a score of 3, resulting in an average score of 3.6. For sample F4, one panelist chose a score of 4, and four chose a score of 3, resulting in an average score of 3.2. For sample F5, three panelists chose a score of 3, and two chose a score of 2, resulting in an average score of 2.6. For sample F6, all panelists chose a score of 3, resulting in an average score of 3.0. For sample F7, one panelist chose a score of 3, and four chose a score of 2, resulting in an average score of 2.2.

Based on the data above, sample F1 has a very bitter and acidic taste, sample F2 has a bitter and acidic taste, sample F3 has a bitter and acidic taste, sample F4 has a somewhat bitter and acidic taste, sample F5 has a somewhat bitter and acidic taste, sample F6 has a somewhat bitter and acidic taste, and sample F7 has a non-bitter and non-acidic taste. This demonstrates that the fermentation duration significantly affects the taste produced by cocoa beans. A 1-day fermentation treatment results in a very bitter and acidic taste, while 2-day and 3-day fermentation treatments result in a bitter and acidic taste. This is due to the absence of the fermentation process and insufficient fermentation time. A 4-day, 5-day, and 6-day fermentation treatment results in a somewhat bitter and acidic taste, but the 5-day fermentation treatment is the most optimal, producing cocoa's distinctive bitter and acidic taste. This is because the fermentation process occurs at optimal timing. In line with the statement by Rachmatullah et al. (2021), well-fermented cocoa beans have a taste not dominated by bitterness and acidity. A 7-day fermentation treatment results in a non-bitter and non-acidic taste but rather a dominant astringent taste. This is because the fermentation process lasts longer than the optimal time.

During fermentation, the moisture content decreases, increasing other components, such as cocoa's acidic compounds. The water molecule (H_2O) bond breaks down during drying, increasing sugar, protein, minerals, and other components (Rachmat et al., 2006).

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Texture Analysis

According to Lutfiah (2018), texture is a characteristic of a material resulting from the combination of several physical properties, including size, shape, quantity, and the elements that make up the material, which can be sensed by the sense of touch and perception, including the sense of taste and sight. The fermentation and drying processes of cocoa beans lead to a porous texture when split open.

Figure 1. Cut test texture of cocoa.

This test employs an organoleptic test with 5 panelists in the age range of 20 – 22 years. For sample F1, all panelists chose a score of 3, resulting in an average score of 3.0. For sample F2, two panelists chose a score of 3, and three chose a score of 4, resulting in an average score of 3.6. For sample F3, two panelists chose a score of 3, and three chose a score of 4, resulting in an average score of 3.6. For sample F4, two panelists chose a score of 3, and three chose a score of 4, resulting in an average score of 3.6. For sample F5, all panelists chose a score of 4, resulting in an average score of 4.0. For sample F6, two panelists chose a score of 4, and three chose a score of 5, resulting in an average score of 4.6. For sample F7, one panelist chose a score of 4, and four chose a score of 5, resulting in an average score of 4.8.

Based on Figure 1, sample F1 has a somewhat porous texture, sample F2 has a porous texture, sample F3 has a porous texture, sample F4 has a porous texture, sample F5 has a porous texture, sample F6 has a highly porous texture, and sample F7 has a highly porous texture. It can be concluded that the fermentation duration does affect the texture of cocoa beans, but it does not significantly affect it; instead, the porosity of cocoa beans is influenced by the loss of moisture during the drying process. This aligns with the statement by Lutfiah (2018) that low moisture content will make cocoa beans more brittle (porous). In addition to moisture content, cocoa texture affects the number of beans per 100 grams. Beans with a porous texture will affect the bean's weight. The more porous the bean's texture, the more beans there will be per 100 grams, and vice versa.

Color Analysis

Color is a characteristic that determines consumers' acceptance or rejection of a product. According to Kartika et al. (1988), color or appearance is a quality attribute perceived by the consumer's eyes before assessing other quality attributes of the product. The role of color is very prominent because consumers typically form their initial impressions, whether they like or dislike a food product, based on its color (Andarwulan et al., 2011).

The factors that play a role in the formation of color are fermentation time and (Rachman, 1989). During the fermentation and drying processes, the breakdown of polyphenolic compounds occurs. This is related to the higher content of polyphenols in the beans, which promotes the Maillard reaction, aided by polyphenol oxidase, resulting in cocoa color (Puziah, 2005). Simultaneously, there is a reduction in the concentration of polyphenols in the beans through the oxidation of polyphenolic compounds exiting the beans (Minifie, 1989). The color change of cocoa beans is due to the presence of anthocyanins,

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which causes the color to shift from light purple to dark purple (Camu et al., 2008). The fermentation box also influences the color of cocoa beans; a large fermentation box will result in a darker brown color, while a small fermentation box will yield a lighter brown color (Rachmatullah et al., 2021).

Figure 2. Cocoa beans color.

For sample F1, four panelists chose a score of 2, one chose a score of 3, and the average score was 2.2. For sample F2, two panelists chose a score of 2, three chose a score of 3, and the average score obtained was 2.6. For sample F3, two panelists chose a score of 3, three chose a score of 4, and the average score obtained was 3.6. For sample F4, all panelists chose a score of 4; the average score obtained was 4.0. For sample F5, all panelists chose a score of 4; the average score obtained was 4.0. For sample F6, three panelists chose a score of 4, two chose a score of 5, and the average score obtained was 4.4. For sample F7, one panelist chose a score of 4, four chose a score of 5, and the average score obtained was 4.8.

Based on Figure 2, sample F1 has a non-brown color, sample F2 has a slightly brown color, sample F3 has a brown color, sample F4 has a brown color, sample F5 has a brown color, sample F6 has a brown color, and sample F7 has a very brown color. This indicates that the fermentation process affects the color change in cocoa beans. Fermentation treatments of 1 and 2 days did not produce the typical cocoa brown color. When the cocoa beans were split, they still had a purplish hue due to incomplete fermentation and insufficient fermentation time. Fermentation treatments of 3 and 4 days resulted in the typical cocoa brown color, but a purple hue was still noticeable when the cocoa beans were split. Despite incomplete fermentation, the drying process also supported the brown color. Fermentation treatments of 5 and 6 days resulted in the typical cocoa brown color, and when the beans were split, the brown color dominated, and the purple color was hardly visible. This is because the fermentation process had occurred ideally. Fermentation treatment for seven days resulted in a very brown color because the fermentation process was too prolonged, causing the cocoa beans to become dark brown. The results are consistent with the statement by Minifie (1989) that the change in polyphenol composition during fermentation is marked by a reduction in the purple color of cocoa beans and an increase in the intensity of the cocoa brown color.

CONCLUSION

This report concludes that the duration of cocoa bean fermentation affects the aroma, taste, texture, and color of dried cocoa beans. The optimal fermentation duration is 5-6 days.

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