

REGULAR ARTICLE

Identification of Critical Control Points in the Enzymatic Oxidation Stage of CTC Black Tea Processing*Tsamarah Septi Nabila^{*1}, Dianita Kumalasari²***Address:**¹ Food Technology Study Program, Faculty of Engineering, Veteran National Development University of East Java, Jl. Raya Rungkut Madya, Gunung Anyar, Surabaya 60294, East Java, Indonesia.² Food Technology Study Program, Faculty of Engineering, Veteran National Development University of East Java, Jl. Raya Rungkut Madya, Gunung Anyar, Surabaya 60294, East Java, Indonesia.*Corresponding author: 23033010054@student.upnjatim.ac.id**ABSTRACT**

Black tea is one of Indonesia's leading plantation commodities, possessing high economic value and quality that is significantly influenced by the processing method, particularly the enzymatic oxidation stage. This study aims to determine the quality control of the enzymatic oxidation process of black tea using the CTC (Crushing, Tearing, Curling) method at PT Perkebunan Nusantara I Regional 5 Wonosari Plantation, Malang, East Java. The method used was a descriptive approach involving direct observation, interviews, documentation, and monitoring of process parameters during the Field Work Practice. The parameters observed included enzymatic oxidation room temperature, relative humidity (RH), enzymatic oxidation time, the thickness of the tea powder spread, and changes in the color of the tea powder during the process. The results of the observations showed that quality control was carried out by maintaining the temperature and humidity of the enzymatic oxidation room in accordance with company standards so that the polyphenol oxidation process could proceed optimally. In addition, enzymatic oxidation time and the thickness of the tea powder layer were also controlled to support the formation of the characteristic color, aroma, and flavor of black tea. Proper control of process parameters was able to produce black tea of a quality that met company standards, both physically and sensorially.

Keywords: black tea, CTC, enzymatic oxidation, quality control**INTRODUCTION**

Tea (*Camellia sinensis*) is one of the leading plantation commodities with high economic value and is widely consumed by people in various countries. In addition to serving as a refreshing beverage, tea is also known to contain bioactive compounds such as catechins, flavonoids, and polyphenols that act as natural antioxidants (Wibowo et al., 2022). The tea industry continues to grow in tandem with rising market demand for high-quality tea products, in terms of color, aroma, and flavor (Nasution et al., 2024).

The quality of black tea is influenced by various factors, ranging from the quality of raw materials to post-harvest processing. One of the key stages in black tea processing is enzymatic oxidation, or fermentation, which plays a role in developing the characteristic color, aroma, and flavor of black tea. During this process, catechin compounds are oxidized into theaflavins and thearubigins, which determine the sensory characteristics of the final product (Pratama & Triardiando, 2024). Controlling enzymatic oxidation conditions such as temperature, relative humidity, enzymatic oxidation time, and the thickness of the tea powder spread are important factors in producing optimal tea quality (Liem & Herawati, 2021).

The CTC (Crushing, Tearing, Curling) system is the most widely used method for processing black tea in the industry because it is considered more efficient and capable of producing a relatively uniform product quality (Ramanda et al., 2021). In this system, tea leaves undergo crushing, tearing, and curling, which accelerates enzymatic oxidation. Inaccurate control of the enzymatic oxidation process can lead to a decline in tea quality, such as a less vibrant infusion color, a weak aroma, and suboptimal flavor (Pratama et al., 2022). Quality control during the enzymatic oxidation stage is a critical aspect in maintaining the consistency of CTC black tea quality in the tea processing industry.

PT Perkebunan Nusantara I Regional 5 Wonosari Plantation is one of Indonesia's CTC black tea processing facilities that implements quality control at every stage of the production process. Monitoring of enzymatic oxidation process parameters is conducted to ensure product quality meets company standards and market demands. The objective of this study is to examine the quality control of the enzymatic oxidation

process for CTC (Crushing, Tearing, Curling) black tea at PT Perkebunan Nusantara I Regional 5 Wonosari Plantation.

MATERIAL AND METHODS

Research Time and Location

The research was conducted from May 4 to May 11, 2026, at PT Perkebunan Nusantara I Regional 5 Wonosari Plantation, Singosari Subdistrict, Malang Regency, East Java. Observations were made at the black tea processing unit using the CTC (Crushing, Tearing, Curling) method, specifically during the enzymatic oxidation stage.

Materials and Equipment

The main material used in this study was wet tea powder produced by the CTC (Crushing, Tearing, Curling) method. The equipment used included a thermo-hygrometer, a ruler, a Transpeed, a fermentation machine, and documentation tools.

Research Methodology

The research methodology employed was a descriptive method using a direct observation approach during the Field Work Practice. Data collection was conducted through observation of the production process, interviews with processing supervisors and production operators, and documentation of activities during the enzymatic oxidation process of CTC black tea.

Research Procedure

Observations were made on the enzymatic oxidation process after CTC-ground tea powder was conveyed to the Fermenting Machine Unit via a conveyor belt. The tea powder was spread evenly on the fermentation belt to a thickness of 5–7 cm. The enzymatic oxidation process took place in the Fermenting Machine Unit, which consists of five belt levels, allowing the tea powder to undergo enzymatic oxidation gradually until the specified enzymatic oxidation time was reached. During the process, observations were made of the fermentation chamber temperature, relative humidity (RH), thickness of the tea powder layer, and the rate of enzymatic oxidation using instruments provided in the fermentation chamber. The tea powder that had undergone enzymatic oxidation was then moved on to the drying stage.

Observation Parameters

The parameters observed include fermentation chamber temperature (°C), relative humidity (RH) (%), the thickness of the tbaruea powder layer (cm), the rate of enzymatic oxidation, and changes in the color of the tea powder during the enzymatic oxidation process. The observational data were analyzed descriptively and compared with the company’s standard operating procedures.

RESULTS AND DISCUSSION

The enzymatic oxidation process is one of the key stages in the production of black tea using the CTC (Crushing, Tearing, Curling) method, as it influences the development of color, aroma, flavor, and the distinctive characteristics of black tea. In this process, the CTC-ground tea powder undergoes controlled oxidation within the Fermenting Machine Unit, with adjustments made to temperature, humidity, tea powder thickness, and enzymatic oxidation time. Quality control at this stage is carried out by monitoring process parameters to ensure the oxidation reaction proceeds optimally, thereby ensuring the resulting black tea meets company standards. The results of the enzymatic oxidation parameter observations are presented in Table 1.

Table 1 Observation Results of Enzymatic Oxidation Parameters in CTC Black Tea

Date	Room Temperature (°C)	Time (minutes)	Relative Humidity (%)	Thickness (cm)
04/05/26	26,4	75	88.4	7
05/05/26	24,8	78	87.5	6.2
06/05/26	26,1	78	88.1	6.17
07/05/26	25,5	75	86.6	6.83
08/05/26	25,2	72	85.4	7
09/05/26	26,8	75	87.4	6.67
11/05/26	24,7	77	84	7

Room Temperature

Based on the observations in Table 1, the room temperature during the enzymatic oxidation process ranged from 24.7 to 26.8°C. The highest temperature was recorded on May 9, 2026, at 26.8°C, while the lowest temperature occurred on May 11, 2026, at 24.7°C. When compared to the Standard Operating Procedure (SOP) for Enzymatic Oxidation of CTC Black Tea at PTPN I Regional 5 Wonosari Plantation, which specifies 16–26°C, most of the observation results met the company's standards, although there was one instance where the temperature slightly exceeded the maximum SOP limit. In general, room temperature conditions during the observation period remained relatively stable and were sufficient to support the enzymatic oxidation process. A bar chart showing the room temperature during the enzymatic oxidation process is shown in Figure 1.

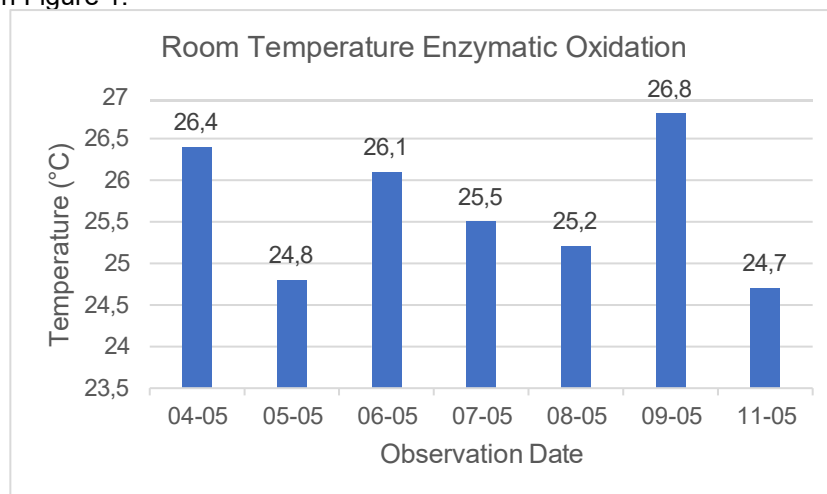


Figure 1 Bar Chart of Room Temperature

Room temperature during the enzymatic oxidation process affects the activity of polyphenol oxidase (PPO) and peroxidase enzymes in oxidizing catechin compounds into theaflavins and thearubigins. Proper temperature control helps maintain optimal color, aroma, flavor, and viscosity of the black tea infusion. If the room temperature is too high, the oxidation rate may proceed too rapidly, leading to increased thearubigin formation and a decline in the tea's sensory quality. Conversely, temperatures that are too low can inhibit the oxidation process, resulting in suboptimal development of the characteristic color and aroma of black tea.

Enzymatic Oxidation Time

Based on the observations in Table 1, the enzymatic oxidation process took between 72 and 78 minutes. The longest enzymatic oxidation time occurred on May 5, 2026, and May 6, 2026, lasting 78 minutes, while the shortest enzymatic oxidation time occurred on May 8, 2026, lasting 72 minutes. This enzymatic oxidation duration is still in line with the process standards at the Wonosari Plantation, PTPN I Region 5, which is 70–90 minutes with an allocation of approximately 16–18 minutes for each enzymatic oxidation belt. A bar chart showing the enzymatic oxidation time is presented in Figure 2.

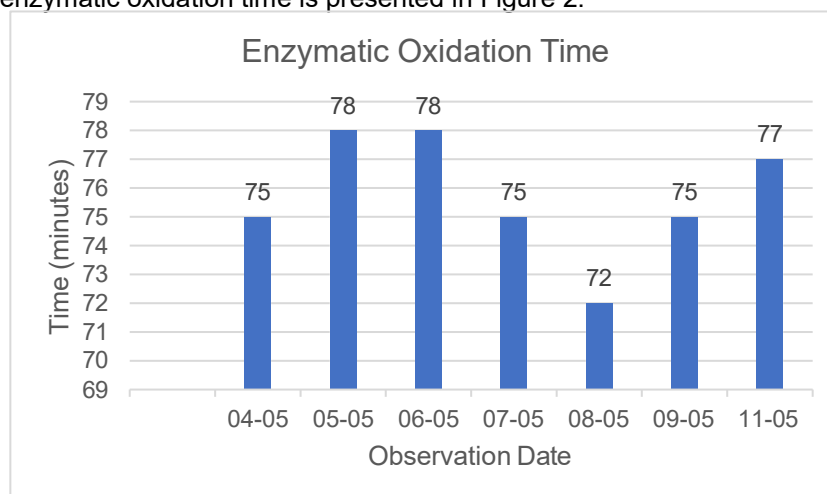


Figure 2 Bar Chart of Enzymatic Oxidation Time

The duration of enzymatic oxidation is controlled by adjusting the speed of the conveyor belt using Transpeed on the Fermenting Machine Unit, which consists of five conveyor belt levels. Proper control of enzymatic oxidation time helps ensure optimal oxidation of polyphenolic compounds, allowing the characteristic color, aroma, and flavor of black tea to develop fully. If the enzymatic oxidation time is too short, the oxidation process may not be complete, while enzymatic oxidation that is too long can reduce the quality of black tea due to excessive oxidation.

Relative Humidity (RH)

Based on the observations in Table 1, the relative humidity (RH) in the enzymatic oxidation chamber ranged from 84% to 88.4%. The highest humidity was recorded on May 4, 2026, at 88.4%, while the lowest humidity occurred on May 11, 2026, at 84%. When compared to the company's SOP of 90–95%, the observation results indicate that the room humidity remains below the company's established standard. A bar chart showing the relative humidity (RH) of the room during the enzymatic oxidation process is shown in Figure 3.

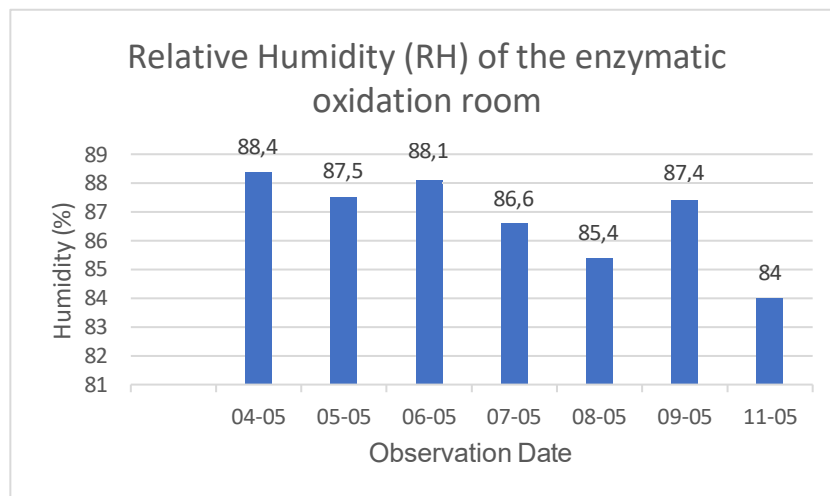


Figure 3 Bar Chart of Relative Humidity (RH)

Relative humidity maintains the moisture content of the tea powder during the enzymatic oxidation process. Appropriate humidity conditions help keep the surface of the tea powder moist, ensuring optimal activity of the polyphenol oxidase enzyme. If the room humidity falls below the SOP standard, the tea powder will lose moisture more quickly, resulting in suboptimal oxidation and reduced formation of theaflavins and thearubigins. This can lead to a less vibrant infusion color, a diminished characteristic aroma of black tea, and a resulting taste that is more bitter and astringent.

Thickness of wet tea powder

Based on the observations in Table 1, the thickness of the wet tea powder on the oxidation belt ranged from 6.17 to 7 cm. The highest recorded thickness was 7 cm, while the lowest was 6.17 cm. When compared to the Standard Operating Procedure (SOP) for Enzymatic Oxidation of CTC Black Tea at PTPN I Regional 5 Wonosari Plantation, which specifies 5–7 cm, all observation results indicate that the wet tea powder thickness meets the company's established standards. The consistency of material thickness throughout the process indicates that the distribution of tea powder on the oxidation belt was carried out effectively and evenly. A bar chart showing the thickness of tea powder during the enzymatic oxidation process is shown in Figure 4.

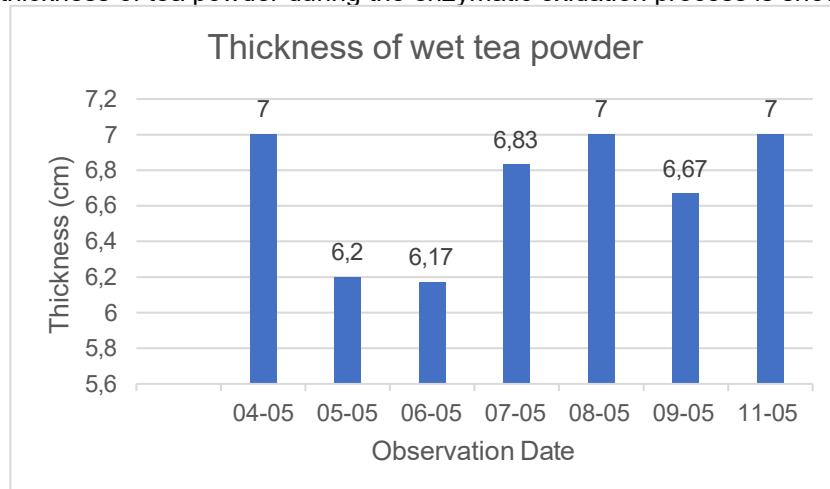


Figure 4 Bar Chart of Thickness of wet tea powder

The thickness of the wet tea powder during the enzymatic oxidation process affects the distribution of air, temperature, humidity, and oxygen availability throughout the entire layer of material. An appropriate thickness allows oxygen to be distributed evenly, ensuring that the activity of the polyphenol oxidase enzyme proceeds optimally throughout the entire tea powder layer. If the thickness of the tea powder exceeds the SOP standard, air circulation and oxygen penetration to the bottom of the tea powder layer may be hindered, causing the oxidation process to proceed unevenly. Conversely, if the layer of tea powder is too thin, moisture loss can occur more quickly, causing enzyme activity to decrease and the oxidation process to become less optimal.

Color Change in Wet Tea Powder

A change in the color of the wet tea powder was observed during the enzymatic oxidation process in the Fermenting Machine Unit. The wet tea powder undergoes a color change from green to reddish-brown, indicating the ongoing oxidation of polyphenolic compounds. This color change indicates that polyphenol oxidase enzyme activity is occurring during the enzymatic oxidation process, forming theaflavins and thearubigins, which play a role in the color formation and characteristic properties of black tea. The color changes in the tea powder before and after the enzymatic oxidation process are shown in Figure 5.



Figure 5 Color Change in Wet Tea Powder Before and After Enzymatic Oxidation

The change in color of the wet tea powder during enzymatic oxidation is one indicator of the success of the enzymatic oxidation process. The reddish-brown color that develops indicates that the oxidation process is proceeding optimally before the wet tea powder enters the drying stage. Controlled processing conditions help produce black tea of a more consistent quality in accordance with company standards.

CONCLUSION

Based on observations of the enzymatic oxidation process of CTC black tea at PT Perkebunan Nusantara I Regional 5 Wonosari Plantation, quality control was carried out by monitoring room temperature, relative humidity (RH), wet tea powder thickness, and enzymatic oxidation time in the Fermentation Machine Unit, which consists of five belt conveyor levels. The observation results indicate that the parameters of room temperature, enzymatic oxidation time, and wet tea powder thickness generally meet the company's operational standards, while relative humidity (RH) remains below the established standard. Controlling process parameters during enzymatic oxidation plays a crucial role in maintaining the activity of the polyphenol oxidase enzyme, ensuring that the formation of the characteristic color, aroma, and flavor of black tea occurs optimally before the drying stage.

Regular monitoring of process conditions must be maintained to ensure the stability of enzymatic oxidation parameters, thereby keeping the quality of the produced black tea consistent with company standards. Additionally, further research on the influence of enzymatic oxidation room temperature and humidity conditions on the final quality of CTC black tea can be conducted to achieve a more optimal enzymatic oxidation process.

ACKNOWLEDGMENTS

The author would like to thank his parents for their prayers, support, and encouragement throughout the writing of this journal. The author would also like to thank Ms. Dianita, his academic advisor, for her guidance, mentorship, and feedback during the writing of this journal. The author would like to thank PT Perkebunan Nusantara I Regional 5 Kebun Wonosari for providing the opportunity and facilities during the fieldwork and data collection for this research. Additionally, the author would like to thank Endrian Menara Imansyah for his assistance and support throughout the process of writing this journal. The author also extends gratitude to all parties who contributed to the successful completion of this journal.

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