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Green Dhool Testing Evaluation of Ortodoks Black Tea Resulting from Enzymatic Oxidation and Drying during Tea Processing

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ABSTRACT

The oxidation process in tea processing can result in tea leaves with varying characteristics, not only the tea leaves quality but also, the brewed quality. Consequently, Green Dhool Testing is necessary to assess the quality of the processed tea leaves in order to ensure that they are of consistent quality, especially at brewed tea. Green dhool testing was performed utilizing trained panelists. The assessed factors from the Green dhool testing include the color and the flavor of brewed tea, and the visual quality of the tea dregs. The results showed the highest value of enzymatic oxidation on days 4 and 6, with an average of 88, and the lowest on day 1, with an average of 68. The highest value of drying was on day 3, with an average of 93, and the lowest on day 10, with an average of 72. The overall score shows a description of B and C, which the factory still accepts. The dhool quality discrepancies are related to several aspects, namely raw materials, contamination, room temperature and humidity, grinding machine conditions, *Fluid Bed Drier* (FBD) inlet temperature, as well as the drying duration and enzymatic oxidation.

Keywords : Black Tea, Drying, Enzymatic Oxidation, Green Dhool

Introduction

Plantation cultivation business includes pre-planting, planting, maintenance, and harvesting including plant type changes (Gilang et al., 2022). The tea processing process can be divided into several types, including through the fermentation process, namely black tea (Rohdiana, 2015). Black tea processing methods are divided into two types, namely the orthodox method and the CTC (crushing, tearing, curling) method (Maska et al., 2022). Orthodox processing systems require a fairly dry degree of senescence (55 – 60% moisture content) with greater grinding and shaping properties. Meanwhile, CTC processing is a grinding process that requires a less dry level of senescence (when the moisture content of tea reaches 68 – 73%) with fairly dense grinding properties.

One of the Tea Factory in Indonesia uses the traditional method, the orthodox method because it can produce tea with high quality such as in the parameters of a smoother and more complex taste and bright brewing color (Sutejo et al., 2018). Quality control of black tea is carried out from leaf picking, processing, and production, to packaging and storage. Quality control at each stage is important to maintain the stability of volatile compounds and antioxidants, which are easily degraded, to ensure product quality is maintained (Rosida & Amalia, 2015).

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Green Dhool Testing is a method used in quality control to assess the quality of tea, especially black tea, based on the results of enzymatic oxidation that affects the color, flavor, and pulp of the tea (Miswadi, 2009). This method includes two stages, testing wet powder after enzymatic oxidation and dry powder after drying, which aims to determine the optimal duration of enzymatic oxidation to ensure the quality of the tea produced is following the expected standards. Enzymatic oxidation itself is an important process in black tea processing, where the enzyme polyphenol oxidase reacts with oxygen to cause changes in catechin compounds to theaflavins and thearubigins that contribute to the color and flavor characteristics of tea (Hamida et al., 2022). Thus, Green Dhool Testing plays a role in evaluating the extent of the enzymatic oxidation process and ensuring that the tea produced is of optimal quality for consumers. Green Dhool Testing necessitates trained panelists to generate reliable test data. This poses a challenge for the home-based tea industry, which lacks access to trained panelists for green dhool testing. Furthermore, green dhool testing is unable to quantitatively demonstrate alterations in chemical components.

Enzymatic oxidation triggers physical changes, such as an increase in temperature and a change in the color of the tea powder from green to copper red (Sukmawati et al., 2012). The test involves steeping the tea powder with hot water and assessing the brewed tea color and flavor and the dregs color, which helps determine the optimal oxidation time to produce high-quality tea (Miswadi, 2009).

Several studies have examined Green Dhool Testing in tea quality evaluation. These studies analyzed the correlation of the sensory and physicochemical properties of green tea, including phenolic content and color (Adawiyah et al., 2017). In addition, studies on the effect of green tea grade on total polyphenols and steeping color are also relevant in tea quality evaluation (Prawira-Atmaja et al., 2020). The results of this study indicate that Green Dhool Testing plays a role in determining the quality of tea based on its physicochemical and sensory characteristics.

Drying serves to stop enzymatic oxidation and maintain the stability of tea quality, carried out using circulating hot air supported by a steam boiler with an input temperature of 115-120 °C and an output temperature of 95 – 105 °C (Januar et al., 2014). The process is designed to ensure efficiency and compliance with applicable standards. Tea quality is tested by Tea Tester through organoleptic assessment and Green Dhool Test, with results recorded as per standards, including the impact of drying on the color, flavor, and texture of the tea grounds.

Excessive enzymatic oxidation and improper drying can produce undesirable dhool. This test plays a role in ensuring that tea has characteristics that conform to industry standards, including flavor, aroma, and color characteristics. In addition, Greendhool testing can also detect the presence of unwanted additives or contaminants, thus ensuring that the final product is safe for consumption and of high quality (Agung, 2023).

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Besides serving as a confirmation of factory standard, green dhool testing also indicates the status of the tea processing procedure, particularly the oxidation phase. The testing findings for green dhool that are inconsistent suggest a discrepancy in the production process, particularly with the oxidation of tea leaves. These findings are beneficial for the industry to perform maintenance on industrial equipment involved in the oxidation process, and for personnel to meticulously monitor each processing method to produce tea with satisfactory sensory attributes.

Based on the above background, Green Dhool testing in the Enzymatic Oxidation and Drying process is very important to do, considering that the test affects the quality of tea powder quality. So it is necessary to do an "Assessment of Green Dhool Testing of Orthodox Black Tea as a result of enzyme oxidation and drying. The purpose of this study is to determine the results of the Green Dhool test on powdered enzymatic oxidation results and powdered drying results, as well as to determine the causal factors that affect quality assessment on enzymatic oxidation samples and drying. Furthermore, the assessment of tea quality using green dhool testing contributes to enhancing information for maintaining tea quality in the industrial sector and advancing scientific understanding to boost tea production without compromising the quality of the end product. The industry can examine the proper tea processing methods to generate green dhool testing scores in accordance with standards by connecting the oxidation process to the results of green dhool testing.

Research Method

Materials

The materials used in the Green Dhool Testing were four powder samples in each enzymatic oxidation powder and drying powder, such as powder I, II, III and badag. The wet powder sieving process will produce powder I and powder II using a sieve of 7 mesh for 10 minutes, powder III using a sieve of 6 mesh for 10 minutes, and badag is produced from powder that is stuck in the sieving process. While the tea powder is obtained from the drying process using a Fluid Bed Drier (FBD) machine with an input temperature between 115 – 120 °C, and an output temperature between 95 – 105 °C. The drying duration ranges from 15 – 18 minutes. There are two lines of drying process machines, powder I and II will enter the FBD I line, then for powder III and badag will enter the FBD 2 line.

Green Dhool Testing

Green Dhool testing used 10 trained panelists. Green Dhool Testing on enzymatic oxidation and drying samples is carried out at the same stage. However, the difference is the weight of the tea sample used. The weight of the enzymatic oxidation sample required 11 g each while the drying sample required 5 g each. The test step was carried out by pouring boiling water into a 220 cc cup, covered and allowed to stand for 6 minutes. The brewed tea is then poured into a bowl, while the tea dregs are in the cup. The parameters measured from

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the Green Dhool testing are the color and flavor parameters of brewed tea, and the appearance of tea dregs. The Green Dhool parameters tested compared to factory standard (Table 1).

Table 1. Assessment of Green Dhool Test Standards on the Results of Enzyme Oxidation and Drying

	Recipients	Scoring	Terms
brewed tea color (40% score)	A	40	*Bright Red, Colory*
	B	32	*Bright Red*
	C	24	*Fairly bright, Light in cup*
	D	16	*Dark in cup*
	E	8	*Dull*
brewed tea flavor (40% score)	A	40	*Good Strength, Flavory*
	B	32	*Strength, Some Strength, Brisk*
	C	24	*Fair Strength, Brisk*
	D	16	*Bitter, Coarse, soft, Greenish, Less Brisk, Flain, Harsh*
	E	8	*Taited*
Tea Dregs (20% score)	A	20	*Very Bright, Coppery*
	B	16	*Bright, Coppery*
	C	12	*Fairly bright*
	D	8	*Bit Dull, Greenish*
	E	4	*Dull/Dark*
Totally	A	96 – 100	
	B	76 – 95	
	C	56 – 75	
	D	36 – 55	
	E	20 – 35	

Source: SOP tea factory

Results and Discussion

Green Dhool Testing is useful for evaluating the color, flavor, and dregs of brewed black tea. There are four types of tea powder were analyzed, Powder I, II, III, and Badag. Green Dhool testing data of enzymatic oxidation sample can be seen in Table 2. There are four different powder samples identified, powder I, II, III, and Badag. The attributes observed were color and flavor of the brewed tea, and tea dregs. The test results showed variations in the mean value of each sample. The highest score, 88, was achieved on days 4 and 6. On day 4, the color parameter showed the highest score in powder II, 40 (*Bright Red, Colory*). On day 8, all powder samples recorded a color score of 32 (*Bright Red).* In the flavor parameter, on day 4, powder samples I and III each obtained a score of 40 (*Good Strength, Flavory*), while on day 8, all powder samples recorded a score of 40. For the dregs parameter, the Badag sample obtained a score of 20 (*Very Bright, Coppery*) on days 4 and 8. The lowest score was measured on day 1 with an average of 68, where each sample showed a dregs score of 20 (*Very Bright, Coppery*), 24 score for flavor (*Fair Strength, Brisk*), and color of 24 *(Fairly Bright, Light in Cup)*, which contributed to the overall average score. Based on the test of results, all samples met the factory standard.

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Table 2. Green Dhool Testing Data of Enzymatic Oxidation Powder

Day	Sample	Brewed Tea Color	Brewed Tea Flavor	Tea dregs	Total	Average	Note
1	Powder I	24	24	20	68	**68**	C (Accepted)
	Powder II	24	24	20	68		
	Powder III	24	24	20	68		
	Badag	24	24	20	68		
2	Powder I	24	40	20	84	**75**	C (Accepted)
	Powder II	24	32	20	76		
	Powder III	32	24	16	72		
	Badag	24	32	12	68		
3	Powder I	32	24	12	68	**83**	B (Accepted)
	Powder II	40	32	12	84		
	Powder III	40	32	16	88		
	Badag	40	32	20	92		
4	Powder I	32	40	12	84	**88**	B (Accepted)
	Powder II	40	32	16	88		
	Powder III	32	40	16	88		
	Badag	40	32	20	92		
5	Powder I	32	32	16	80	**79**	B (Accepted)
	Powder II	24	32	16	72		
	Powder III	32	32	16	80		
	Badag	32	32	20	84		
6	Powder I	32	40	12	84	**88**	B (Accepted)
	Powder II	32	40	16	88		
	Powder III	32	40	16	88		
	Badag	32	40	20	92		
7	Powder I	32	32	16	80	**81**	B (Accepted)
	Powder II	32	32	16	80		
	Powder II	32	32	16	80		
	Badag	32	32	20	84		
8	Powder I	32	24	16	72	**73**	C (Accepted)
	Powder II	32	24	16	72		
	Powder II	32	24	16	72		
	Badag	32	24	20	76		
9	Powder I	32	32	12	76	**80**	B (Accepted)
	Powder II	32	32	16	80		
	Powder II	32	32	16	80		
	Badag	32	32	20	84		
10	Powder I	32	24	16	72	**73**	C (Accepted)
	Powder II	32	24	16	72		
	Powder II	32	24	16	72		
	Badag	32	24	20	76		

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Figure 1 Illustrates a radar chart that explores the various attributes of Green Dhool Testing, including the color and flavor of brewed tea, as well as the tea dregs. According to the Figure 1, powders II, III, and Badag exhibit the highest scores for the brewed tea color parameter. The Badag variety demonstrates the highest score for the tea drag characteristic in comparison to the other samples. All samples exhibit equivalent levels for the brewed tea flavor parameter.

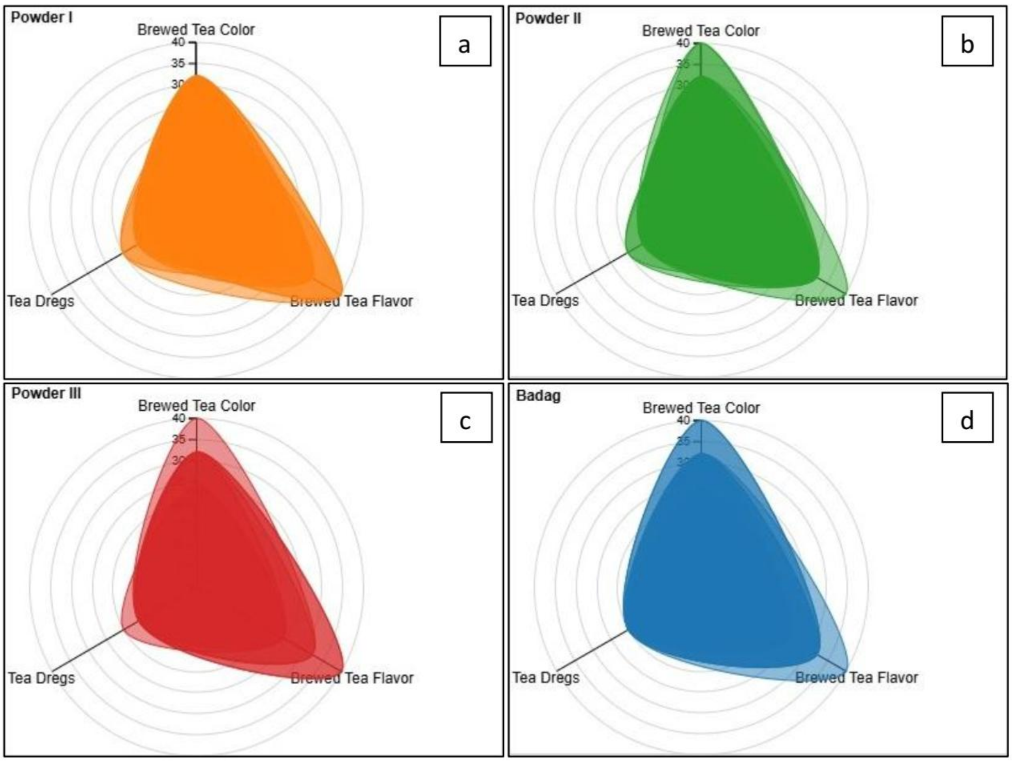

Figure 1. Radar Chart for the Enzymatic Oxidation Powder of Powder I, II, III, and Badag

The tea quality test results showed differences in the standard values set by the company, which is due to the important role of enzymatic oxidation in the formation of theaflavins. Theaflavins give tea its golden yellow color and freshness Shabri & Maulana, (2017), while oxidation converts catechins into theaflavins and thearubigins, which enrich the distinctive flavor of black tea (Teshome, 2019). According to Hamida et al., (2022), the longer the oxidation time, the more thearubigin is formed, so the color of the tea becomes darker. This oxidation process is influenced by temperature, duration, and air humidity.

Pou (2016), showed that the decrease in free amino acids during fermentation indicates that these amino acids are converted into volatile compounds that are important for tea aroma. The flavor intensity scoring test in this study was supported by Uchiyama et al., (2011) who reported that the level of bitterness increases with enzymatic oxidation time. The bitterness of the tea is thought to be related to the caffeine content, following Pou (2016) who stated that the longer the enzymatic oxidation, the higher the caffeine content in the tea. Caffeine is known to contribute to bitter, brisk and creamy flavors.

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According to the Indonesian National Standards (SNI) for Black Tea, the quality of steeping grounds is assessed based on its color and evenness after brewing. ISO 9001:2018 states that good steeping grounds have a very bright color close to copper (very bright & coppery). Obanda. et al., (2001) recommend a temperature of 20 °C for 60 minutes, and humidity above 90% for enzymatic oxidation to produce quality black tea. Asil et al., (2012) showed similar results with 25 °C and 60 minutes. Therefore, optimal tea leaf age and enzymatic oxidation time are required to improve the flavor of black tea.

Table 3. Sample data of Green Dhool Testing on Drying powder

Day	Sample	Brewed Tea Color	Brewed Tea Flavor	Tea Dregs	Total	Average	Note
1	Powder I	40	24	12	76	**78**	B (Accepted)
	Powder II	40	24	12	76		
	Powder III	40	24	12	76		
	Badag	40	24	20	84		
2	Powder I	32	40	16	88	**79**	B (Accepted)
	Powder II	32	24	16	72		
	Powder III	40	24	16	80		
	Badag	32	24	20	76		
3	Powder I	40	40	16	96	**93**	B (Accepted)
	Powder II	40	32	16	88		
	Powder III	40	32	16	88		
	Badag	40	40	20	100		
4	Powder I	32	32	16	80	**89**	B (Accepted)
	Powder II	32	32	16	80		
	Powder III	40	40	16	96		
	Badag	40	40	20	100		
5	Powder I	40	40	16	96	**91**	B (Accepted)
	Powder II	40	40	16	96		
	Powder III	40	32	16	88		
	Badag	32	32	20	84		
6	Powder I	32	40	16	88	**77**	B (Accepted)
	Powder II	32	32	16	80		
	Powder III	24	32	16	72		
	Badag	24	24	20	68		
7	Powder I	40	40	12	92	**86**	B (Accepted)
	Powder II	40	40	16	96		
	Powder III	40	32	16	88		
	Badag	32	16	20	68		
8	Powder I	40	32	16	88	**77**	B (Accepted)
	Powder II	32	32	16	80		
	Powder III	32	24	16	72		
	Badag	24	24	20	68		
9	Powder I	40	40	16	96	**87**	B (Accepted)
	Powder II	40	32	16	88		

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Day	Sample	Brewed Tea Color	Brewed Tea Flavor	Tea Dregs	Total	Average	Note
	Powder III	40	32	16	88		
	Badag	32	24	20	76		
10	Powder I	32	24	12	68	72	C (Accepted)
	Powder II	32	24	16	72		
	Powder III	32	24	16	72		
	Badag	32	24	20	76		

Green Dhool testing data for drying powder tea is shown in Table 3. The attributes observed color and flavor of brewed tea, and the tea dregs. The test results showed that all samples had different average values. The highest value was obtained on day 3 with an average of 93 which had the highest scores for color (40) (Bright Red, Colory) for all the samples, and falvor (40) for Badag type (Good Strength, Flavory), as well as 20 score for Badag dregs (Very Bright, Coppery). While the lowest score was obtained on day 10 with an average of 72 which was influenced by Powder I with a dregs score of 12 (Fairly bright), on the assessment of the flavor of each powder obtained a score of 24 (Fair Strength, Brisk), and on the color of each powder obtained a score of 32 (Bright Red) thus affecting the average value of the sample. Based on the test results, it is still accepted by the factory standard. Figure 2 Illustrates a radar chart that explores the various attributes of Green Dhool Testing of Powder I, II, III, and Badag. According to the Figure 2, all of the samples have high brewed tea color and flavor score, and maximum score for the tea dregs. From that figure, it can be seen that all of the samples in accordance with the factory standard.

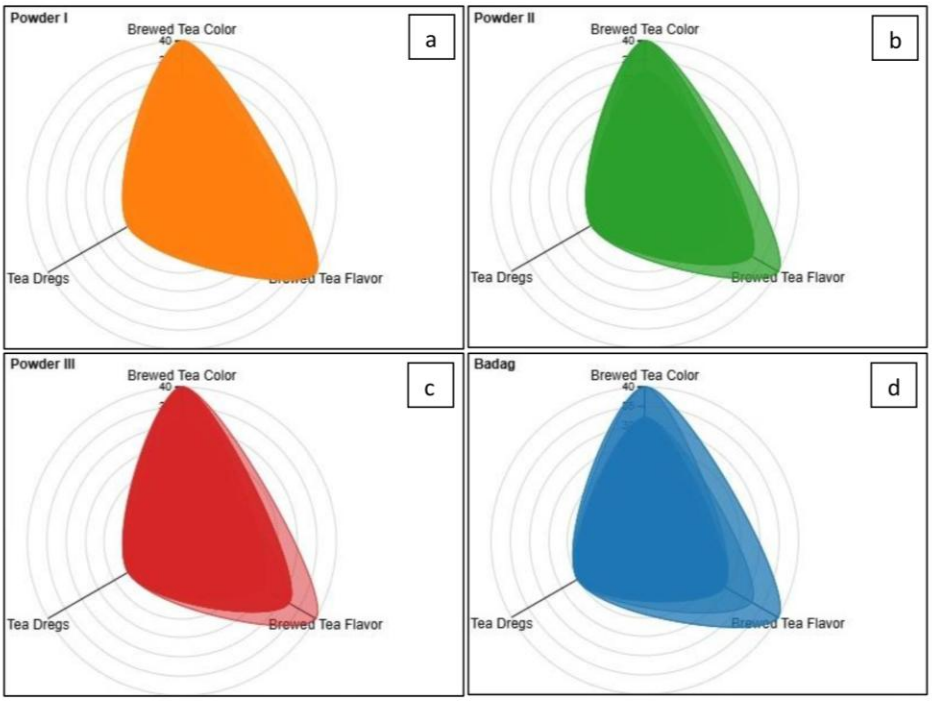

Figure 2. Radar Chart for the Drying Powder of Powder I, II, III, and Badag

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The tea quality test results was affected by the drying tea process. Drying resulting the oxidation of chlorophyll to brown compounds, known as browning, while tannins are oxidized to theaflavins (yellow) and thearubigins (red). An increase in thearubigin concentration during the oxidation process leads to a darker tea color, along with a decrease in polyphenol concentration (Towaha J, 2013). Thearubigin contributes to the aroma, color, flavor strength, and mouthfeel of steeping tea, giving it a brownish-red color (Mitrowihardjo et al., 2025). According to Ulandari et al., (2019) tea aroma-forming compounds mainly consist of volatile oils, producing a fragrant aroma when brewing. Gallic acid in tea will be oxidized to thearubigin during drying, which is also responsible for the aroma of tea (Kim et al., 2011). Purba et al., (2021) stated that the longer the drying, the more volatile components are lost, reducing the aroma of the tea. Research by Adri & Hersoelistyorini, (2013) showed that long drying time can damage aromatic compounds, thus reducing the aroma of tea. According to Etika & Giyatmi, (2020) the longer the drying, the more water evaporates so that the water content decreases and high temperature drying causes tea leaves to scorch, while low temperatures allow fermentation to continue.

The quality of brewed grounds is assessed based on color and uniformity after brewing, where good grounds have a bright coppery color (Very bright & coppery). The enzymatic oxidation process affects the drying powder on the color of the dregs, which is caused by the formation of theaflavins that produce golden yellow pigments, as well as carotenoids that give an orange yellow color (Towaha J, 2013). High drying temperature and duration can fade the color of cocoa leaf green tea, as well as bring out pigments from fruits, changing the color of herbal tea brewing from green to yellow or brownish yellow (Rusnayanti, 2018).

Based on the Green Dhool testing results from enzymatic oxidation and drying powder sample, there are Dhools that have decreased in quality. To find out the cause of the decline in Dhool quality, an analysis was carried out using a fishbone diagram. The fishbone diagram is used to show cause and effect, the fish head contains the problem being analyzed. The bones that lead to the fish head contain the factors of the problem (Anastasya & Yuamita, 2022). The fish bone diagram can be seen in Figure 3.

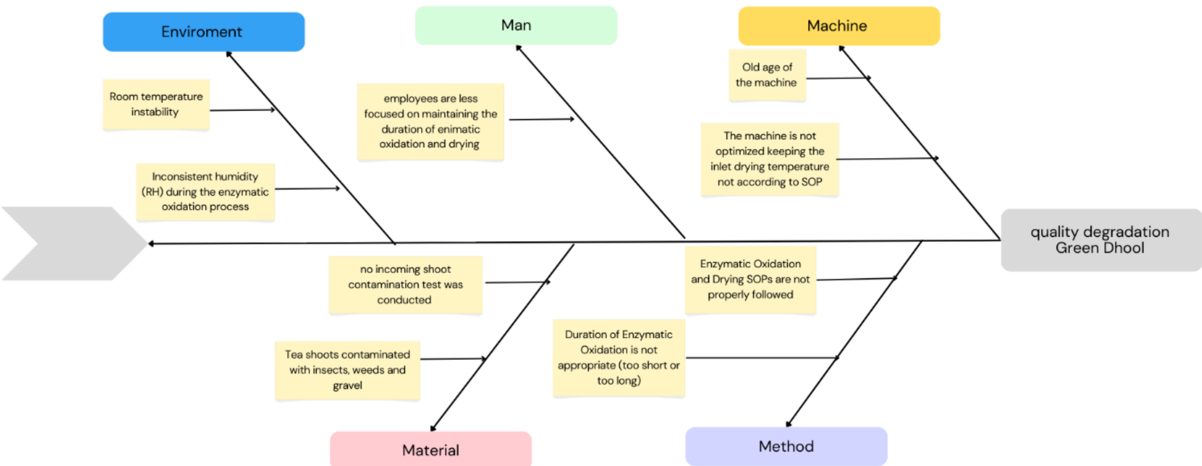

Figure 1. Fishbone Diagram

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Based on Figure 3, it can be seen that there are five factors that affect the decline in the quality of tea powder in the enzymatic oxidation and drying process at the tea factory. The following causal factors and quality improvement proposals are as follows:

1. Material factors:

   A contributing factor is that the absence of contamination tests on incoming tea shoots leads to raw materials that are contaminated by insects, weeds, and gravel, which directly affects the final quality of the tea. Most tea pickers tend to take leaves up to the 4th or 5th leaf, which results in an increase in the number of fibers and stems, so that the resulting product is included in the grade 2 tea category (Maghfiro et al., 2023). Overcoming this problem, the preventive measure is to handle raw materials from the picking process, transportation and up to weathering. As well as sorting raw materials to prevent physical contamination of tea shoots.

2. Machine factors

   The factor causing temperature instability in the drying process is the old age of the FBD machine, so the temperature cannot be operated optimally. Temperatures lower than the SOP standard will affect the quality of the tea. This temperature instability can interfere with the drying process, where temperatures that are too high or too low can cause the product not to dry optimally (Tsaqif et al., 2024). Overcoming these problems, the preventive measure is to schedule routine maintenance of the FBD machine and control the inlet temperature of the FBD machine regularly to maintain consistency in drying. As well as installing automatic temperature sensors for real-time monitoring

3. Method factor

   Factors causing deviations in tea quality include the regulation of the duration of enzymatic oxidation and drying, which are very important. Inappropriate durations in both processes can result in tea with characteristics that do not meet standards, in terms of color, flavor, and dryness. Too high temperatures and long drying durations can cause the product to over-dry on the outside, while the inside remains moist, potentially accelerating mold growth on the product (Sinaga et al., 2023).

   Addressing this issue, a preventive measure is to develop and document clear SOPs for the duration of enzymatic oxidation and drying. The SOPs should include appropriate temperature and time parameters, and provide training to employees on the importance of complying with the SOPs. In addition, implementing a regular temperature and humidity (RH) monitoring system in the oxidation room is also necessary to maintain optimal conditions.

4. Man

   Factors causing deviations in tea quality include the lack of supervision and control of the production process, especially in monitoring temperature and processing duration. Research by Pangaribuan dan

Handayani, (2018) showed that machine errors due to lack of attention contributed to the mismatch of product results with the set standards. Overcoming these problems, preventive measures include organizing regular training for employees on quality control and increasing the number of supervisors in the production area to ensure that all processes are carried out in accordance with established standards.

5. Environment

Temperature instability during the enzymatic oxidation process can hinder the optimal oxidation rate, especially if the temperature is below 27 °C and the relative humidity (RH) does not reach 95%, negatively affecting the tea's flavor and color. In addition, unfresh tea shoots also affect the flavor and color of the tea. Environmental conditions, including climate, play an important role in tea quality and production. A long dry season with low rainfall can result in plant drought, reduce tea shoot production, and reduce the effectiveness of fertilization (Fauziah et al., 2018). To overcome these problems, preventive measures include improving the ventilation system in the oxidation room to keep the temperature and RH stable or using automatic temperature control devices and conducting regular monitoring of environmental conditions, including temperature and humidity, and recording changes for further analysis.

Conclusion

The results shows that all enzymatic oxidation samples have different average values, with the highest value on days 4 and 6 reaching an average of 88, and the lowest value on day 1 with an average of 68. The overall average results show category B and C scores that still meet the factory standards. For the drying samples, the average values also varied, with the highest value on day 3 with an average of 93, and the lowest value on day 10 with an average of 72. The overall scores were also within the B and C categories accepted by the factory. Factors that affect the quality of tea from drying and enzymatic oxidation are the raw materials, temperature and length of time of enzymatic oxidation and drying used. Future research is recommended to develop tighter control methods of production parameters and in-depth understanding of environmental influences on important tea components.

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