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MOISTURE CONTENT ANALYSIS OF ORTHODOX BLACK TEA WITHERING PROCESS AT PT PERKEBUNAN NUSANTARA I REGIONAL 2 KEBUN CIATER SUBANG

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ABSTRACT

PT Perkebunan Nusantara I Regional 2 Ciater Garden is engaged in the black tea commodity using the orthodox system. In the production process, moisture content analysis is an important stage to control quality. Moisture content is the amount of water content that can affect the quality and stability of tea. This study aims to determine the results of the moisture content analysis of the orthodox black tea aging process, then determine the causal factors and impacts if there is a discrepancy in moisture content. The method used in analyzing the moisture content of orthodox black tea is the thermogravimetric method using the Halogen Moisture Analyzer. The test results at PT Perkebunan Nusantara I Regional 2 Ciater Garden showed that there were no deviations in the moisture content of fresh shoots and withered shoots of black tea. Success factors for tea testing include post-harvest management according to SOP, good weather, and appropriate raw materials. A mismatch in moisture content can be fatal. Too low moisture content results in fine tea powder and astringent taste, while too high moisture content results in uneven tea powder and bitter taste. Therefore, it is necessary to closely monitor the moisture content to ensure the quality of the tea produced.

Keywords: *Black tea, Fresh shoots, Moisture content, Orthodox system, Withered shoots.*

Introduction

Indonesia is a country that has a great influence on the needs of the world community including products derived from agriculture, especially industrial crops produced from the plantation subsector. One of Indonesia's main plantation commodities exported to the international market is tea (Purba et al., 2023). Tea produced and consumed globally is divided into proportions of 78% black tea, 20% green tea, and 2% oolong tea. The difference between the three types of tea lies in how the tea leaves are processed after picking. Indonesia produces processed tea in the form of white tea, black tea (enzymatically oxidized), oolong tea (partially enzymatically oxidized) and green tea (not enzymatically oxidized) (Chan et al., 2011).

PT Perkebunan Nusantara VIII Kebun Ciater is a tea commodity company that produces high quality black tea. The company is under the auspices of a State-Owned Enterprise that was established in 1990 and operated in 1991. In early December 2023, there was a merger of the company PT Perkebunan Nusantara I, so that PTPN

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VIII Ciater Garden has changed its entity to PT Perkebunan Nusantara I Regional 2. Ciater tea garden is located at the foot of Mount Tangkuban Perahu, precisely on Jl Raya Ciater-Subang, Subang Regency, West Java. PTPN I Regional 2 Ciater Estate produces orthodox black tea which is produced with an optimal capacity of 30,000 kg wet per day. Marketing of the Ciater factory's production focuses on local (20%) and export markets (80%) which are carried out by PT Agrijaya through the company's contract system. The product is sold as bulk tea and has been named the best tea processing in Indonesia.

PTPN I Regional 2 Ciater Garden uses the main raw material in the processing of orthodox black tea, namely the Camellia sinensis tea type which in the processing process undergoes complete enzymatic oxidation. This process is what gives black tea its distinctive aroma, color and taste. Black tea is the most widely produced type of tea in Indonesia after green tea. Black tea is highly favored by people all over the world because of its less bitter taste and distinctive aroma that creates a fresh impression. The flavor, aroma and nutritional components in tea can be influenced by the quality of the tea. The quality of tea is obtained from the processing of tea starting from the arrival of raw materials to the final tea product (Salgueiro et al., 2010).

There are several types of black tea processing, including orthodox processing and CTC (Crushing tearing curling) processing (Pou et al., 2019). Orthodox black tea processing includes withering for 16 hours, rolling, enzymatic oxidation, drying, sorting, until finished tea is formed (Aaqil et al., 2023). CTC tea is a tea processed by cutting, tearing, and rolling the wet leaves into powder, followed by fermentation, drying, and sorting to form the finished tea (Ahmed & Stepp, 2013). Orthodox and CTC processing have different ways of rolling tea leaves. Orthodox tea processing requires heavy wilting (water content of 52-58%) with lighter rolling properties while CTC processing requires light wilting (water content reaches 67-70%) with hard rolling properties (Ramanda et al., 2021). In addition to the difference in the rolling process, another difference between orthodox black tea and CTC black tea is that orthodox black tea is made from leaves that are selectively chosen using the selection method/picking formula, while CTC black tea is made from less selectively chosen leaves/coarse leaves (Yunitasari, 2015).

The production process is the process of transforming raw materials and additives into a safe and quality final product (Sejati, 2021). Quality control in the production of black tea processing starts from the selection and picking of tea leaves to the process of withering, enzymatic oxidation, drying, and packaging. Quality control plays an important role in ensuring that the black tea produced meets consumer expectations for consistent and high-quality taste, aroma, color, and texture (Kusumo, 2010).

In the process of processing orthodox black tea at the PTPN I Regional 2 Ciater factory, there are several stages of quality control of black tea product quality standards, one of which is the analysis of the moisture content of the withering process. The withering process is an important stage in post-harvest processing of tea leaves that marks the transformation from new leaves to various types of tea, and is very important in black tea processing because it affects the quality and quality of tea (Shao et al., 2022). The purpose of the withering process is to reduce the moisture content of the tea leaves so that the cellular fluid contained in the tea leaf shoots becomes more concentrated, thus facilitating the enzymatic oxidation process and making it flexible for the next processing step (Qiao et al., 2023). In addition, withering enhances the development of certain desirable compounds, including volatile aroma compounds, amino acids, and catechins, all of which contribute to the complex flavor profiles of different types of tea (Sharma et al., 2023). In the orthodox black tea withering process, there are two moisture content analyses, namely fresh shoot moisture content analysis and withered shoot moisture content analysis.

The purpose of this study is to determine the changes in moisture content in fresh shoots and withered shoots of orthodox black tea during the withering process, to determine the results of moisture content quality control analysis, and to determine the impact of changes in moisture content and factors that cause moisture content discrepancies during the withering process. This study uses a control chart or control map where this graph displays the output data and the control limits that have been made. If the data does not show symptoms of deviation and does not go out of the upper or lower control limits, then the process is considered under control. Conversely, if the data goes out of the control limits, the process is considered out of control and improvements must be made to improve the process and prevent product damage (Singgih et al., 2004).

Research Method

This research was conducted in one of the tea processing industries under the auspices of a State-Owned Enterprise (SOE) company, PT Perkebunan Nusantara I Regional 2 Ciater Garden, Subang. The materials used in testing the moisture content of PT Perkebunan Nusantara I Regional 2 Kebun Ciater orthodox black tea during the withering process are fresh tea shoots and withered tea shoots. The method used in analyzing the moisture content of orthodox black tea is the thermogravimetric method using the HG53 Halogen Moisture Analyzer with a testing temperature of 110°C for fresh shoots and 130°C for withered shoots.

This research uses two types of data, namely primary data obtained from various sources such as interviews, surveys, experiments, questionnaires, telephone, and indirect methods such as email and mail (Kabir, 2016). Meanwhile, secondary data is data collected from published sources, which means that the data has been collected by others for other purposes and can be used for other purposes in a study such as the internet, books, and literature (Taherdoost, 2021). For the purposes of this study, the secondary data used includes internal data from the company as well as books and journal articles available online.

The steps in testing the water content of fresh shoots and wilted shoots of orthodox black tea PT Perkebunan Nusantara I regional 2 Ciater Garden are preceded by sampling when the Withering Through of tea shoots has been fully filled or has finished unfolding and withering. Samples of tea shoots are taken randomly, namely from the front, middle and back ends of three grips. Then, the samples are brought to the Quality Control room for moisture content measurement. The samples were placed in a container and mixed until evenly distributed, then taken as much as 100 g, sliced fresh shoots and withered tea shoots into smaller pieces, weighed as much as 5-10 g and put into aluminum foil on the tool, then closed and waited until the measurement results and tea shoots came out automatically. Testing was carried out for 10 days, where one day as many as 2 tests at different times for each sample.

Results and Discussion

The data used in this study are fresh and wilted shoot moisture content test data collected in February 2024. Fresh shoot moisture content data was taken on a daily basis with sample X1 in the first shift at 11:00 am and sample X2 in the second shift at 2:00 pm. Wilted shoot moisture content data was also taken on a daily basis with sample X1 in the first shift at 08.00 WIB and sample X2 in the second shift at 10.00 WIB. The test results can be seen in Table 1. To ensure product quality, the company regulates the quality standards of the products produced. The standard moisture content of fresh shoots is 75-80%, while the standard moisture content of wilted shoots is 55-60%.

Table 1. Sample Data of Fresh Shoot Moisture Content and Wilted Shoot Moisture Content Testing

Day	Fresh Shoot Moisture Content		Water Content of Wilted Shoots	
	X1 (%)	X2 (%)	X1 (%)	X2 (%)
1	79.6	78.5	57.9	57.5
2	78.3	77.1	57.2	56.9
3	75.7	79.1	58	57.6
4	80	78.7	57.6	573
5	80	79.2	57.8	57.6
6	79.1	78.2	57.6	57.2
7	78.7	77.9	58	57.7
8	79.1	77.9	57.3	56.9
9	79.1	75.9	57.5	57.2
10	78.2	76.9	57.7	57.4

Based on the data obtained in testing the moisture content of fresh shoots and withered shoots of PTPN I Regional 2 Ciater Kebun during the implementation of practical work, it is known in Table 2.1 that there is no deviation or discrepancy between the test results and the quality standard of moisture content. The test results show that the moisture content of fresh shoots and withered shoots of black tea produced at PTPN Regional 2 Ciater Kebun is in accordance with the established quality standards. The results of the water content test and the factors causing deviations in the results of the water content of fresh shoots and withered shoots of orthodox black tea will be analyzed using the X and R control charts and the water content discrepancy table.

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Control chart or control map is a graph that serves to measure the variability of the process, either controlled or uncontrolled (Tamjidillah, 2005). The control maps used in this study are X and R control maps. Generally, variable control maps are also called X-R charts. X-bar (average) and R (Range) control maps are used to monitor processes that have continuous dimension characteristics. Each control map has a center line (Control Line) which is denoted by CL, as well as a pair of control limits, namely the upper control limits (UCL) which are above the center line and the lower control limits (Lower Control Limit) which are below the center line (Khikmawati et al., 2021). The steps in making X and R control maps according to (Putri et al., 2021) are as follows:

To create an X control map by finding the average value. The average value which is also the central line is obtained by:

$$\bar{x} = \frac{\sum_{i}^{g}=1^{\bar{x}i}}{g}$$

$$\bar{x} = \frac{783.6}{10} = 78.36$$

The determination of the center line R, which is the average range, is as follows:

$$\bar{R} = \frac{\sum_{i}^{g}=1^{Ri}}{g}$$

$$\bar{R} = \frac{15.2}{10} = 1.52$$

The values A2 = 1.88, D3 = 0, and D4 = 3.269 for subgroup size 2 are obtained from the table of factors A and D forming the control map. The X control limits for March 2024 are:

Center line CL = $\bar{\bar{x}}$

Uper Control Limit

UCL = $\bar{X}$+ (A2 * $\bar{R}$)

= 78.36 + (1.88 * 1.52)

= 78.36 + 2.8576 = 81.2

Lower Control Limit

LCL = $\bar{X}$- (A2 * $\bar{R}$)

= 78.36 - (1.88 * 1.52)

= 78.36 – 2.8576 = 75.5

Calculating the UCL and LCL for the R control map is:

Uper Control Limit

UCL = D4 * $\bar{R}$

= 3.269 * 1.52 = 4.97

Lower Control Limit

LCL = D3 * $\overline{R}$

=0*1.52=0

After following the steps above, the X and R control maps of orthodox black tea fresh shoots were made using Excel. The following is a recapitulation of data on the moisture content of fresh shoots of orthodox black tea can be seen in Table 2., and the x and r control map graphs of wilted shoots of orthodox black tea can be seen in Figures 1. and 2.

Table 2. Recapitulation of the moisture content of fresh shoots of orthodox black tea

Day	Sample (%)		Xbar	R	X			R		
	X1	X2			CL	UCL	LCL	CL	UCL	LCL
1	79.6	78.5	79.05	1.1	78.36	81.2	75.5	1.52	4.97	0
2	78.3	77.1	77.7	1.2	78.36	81.2	75.5	1.52	4.97	0
3	75.7	79.1	77.4	3.4	78.36	81.2	75.5	1.52	4.97	0
4	80	78.7	79.35	1.3	78.36	81.2	75.5	1.52	4.97	0
5	80	79.2	79.6	0.8	78.36	81.2	75.5	1.52	4.97	0
6	79.1	78.2	78.65	0.9	78.36	81.2	75.5	1.52	4.97	0
7	78.7	77.9	78.3	0.8	78.36	81.2	75.5	1.52	4.97	0
8	79.1	77.9	78.5	1.2	78.36	81.2	75.5	1.52	4.97	0
9	79.1	75.9	77.5	3.2	78.36	81.2	75.5	1.52	4.97	0
10	78.2	76.9	7755	1.3	78.36	81.2	75.5	1.52	4.97	0
	Total		783.6	15.2						
	Average		78.36	1.52						

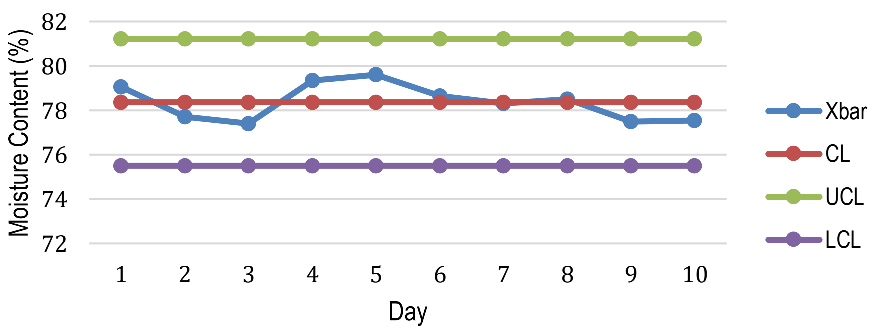

Figure 1. X Control Map Graph of Fresh Shoot Water Content of Orthodox Black Tea

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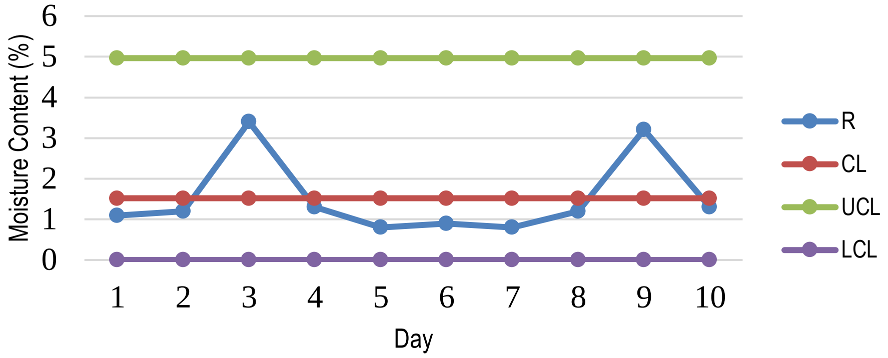

Figure 2. X Control Map Graph of Fresh Shoot Water Content of Orthodox Black Tea

Based on Figures 1 and 2 of the x-r control map of fresh shoots water content above, it shows that on the x-r control map there is no uncontrolled data. The test results obtained an average moisture content of 78.36%. On the x-control map graph, the highest average water content test was in the range of 79% on days 1, 4 and 5, while the lowest water content was in the range of 77% on days 2, 3, 9 and 10. On the r-control map graph, the highest water content test difference was in the range of 3%, while the lowest water content difference was in the range of 0.8%. Both graphs show increases and decreases that do not exceed the specified LCL or UCL limits. This can be interpreted that the data is statistically controlled and can be said to be uniform data and in accordance with company standards. According to the statement of (Ntezimana et al., 2021) factors such as altitude, climate, temperature, humidity, and air circulation greatly affect the moisture content of withering.

After testing and calculating the moisture content of fresh shoots of orthodox black tea, the X and R control maps of wilted shoots of orthodox black tea were made. The following is a recapitulation of the water content of wilted shoots of orthodox black tea can be seen in Table 2, and the x and r control map graphs of wilted shoots of orthodox black tea can be seen in Figures 3 and 4.

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Table 3. Recapitulation of Water Content of Wilted Shoots of Orthodox Black Tea

Day	Sample (%)		Xbar	R	X			R		
	X1	X2			CL	UCL	LCL	CL	UCL	LCL
1	57.9	57.5	57.7	0.4	57.5	58.12	56.87	0.33	1.08	0
2	57.2	56.9	57.05	0.3	57.5	58.12	56.87	0.33	1.08	0
3	58	57.6	57.8	0.4	57.5	58.12	56.87	0.33	1.08	0
4	57.6	57.3	57.45	0.3	57.5	58.12	56.87	0.33	1.08	0
5	57.8	57.6	57.7	0.2	57.5	58.12	56.87	0.33	1.08	0
6	57.6	57.2	57.4	0.4	57.5	58.12	56.87	0.33	1.08	0
7	58	57.7	57.85	0.3	57.5	58.12	56.87	0.33	1.08	0
8	57.3	56.9	57.1	0.4	57.5	58.12	56.87	0.33	1.08	0
9	57.5	57.2	57.35	0.3	57.5	58.12	56.87	0.33	1.08	0
10	57.7	57.4	57.55	0.3	57.5	58.12	5687	0.33	1.08	0
	Total		574.95	3.3						
	Average		57.495	0.33						

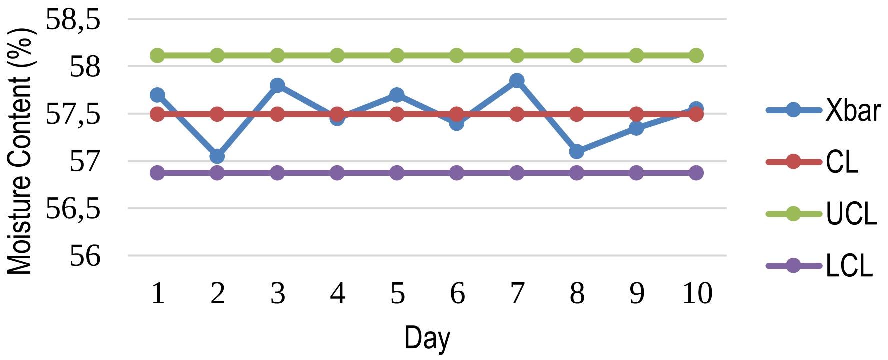

Figure 3. X Control Map Graph of Water Content of Wilted Shoots of Orthodox Black Tea

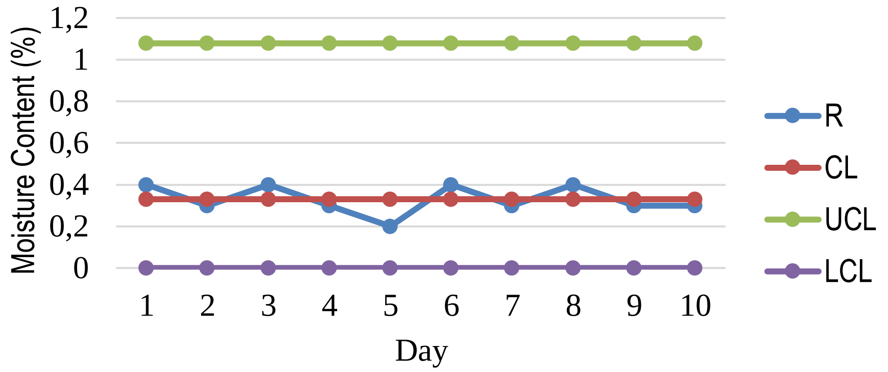

Figure 4. X Control Map Graph of Water Content of Wilted Shoots of Orthodox Black Tea

Based on Figures 3 and 4, the x-r control map of wilted shoot water content does not show any uncontrolled data. The test results for the moisture content of wilted shoots obtained an average of 57.495. On the x-control map graph, the average test result for the moisture content of wilted shoots for 10 days is in the range of 57%. On the r control map graph, the highest difference in moisture content testing was in the range of 0.4% on days 1, 3, 6 and 8, while the lowest difference in moisture content was in the range of 0.2% on day 5. Both graphs show several increases and decreases that do not exceed the specified LCL or UCL limits. It can be concluded that the data is statistically controlled and can be said to be uniform data and in accordance with company standards. According to (Andamdewi, 2018) several factors that support the success of water content testing are processing procedures according to operational standards, controlled conditions of factory buildings / processing sites, and control of raw materials and machines that are appropriate.

Thus, it can be concluded that the X and R control maps are statistically controlled or it can be said that the data is uniform. According to the statement of (Deb & Jolvis Pou, 2016) in their research, during the aging process the shoots will lose some moisture with the moisture level dropping from about 70-80% to 60-0% (wet basis), and the turgid shoots become mushy. Meanwhile, in this study, the moisture content of fresh shoots was found to be 78.36% and decreased during the aging process to 57.49%. This is in accordance with the standard moisture content of fresh shoots and withered shoots set by the company, namely the moisture content of fresh shoots is 75-80%, while the standard moisture content of withered shoots is 55-60%. To facilitate the achievement of good quality wilted tea leaves, several things can be done, such as ensuring that the tea shoots do not stick to the unfolding process, adjusting the thickness of the leaf shoots so that they are evenly distributed, observing air temperature and humidity, and adjusting hot air flow according to air humidity (Rosida & Amalia, 2015).

Although the current production process is statistically under control, it is important to keep in mind the possible causes and effects in the event of moisture content discrepancies in both tea shoots in the future. The following causes and effects of discrepancies in the moisture content of fresh shoots and withered shoots can be seen in Tables 4. and 5.

Table 4. Causes and Consequences of Discrepancies in Fresh Shoot Water Content of Orthodox Black Tea

Causes	Consequences
1. Weather conditions at harvest time. 2. The harvested shoots are old tea leaves.	1. If the moisture content of fresh tea shoots is too high, it may result in excessive withering and undesirable end results, such as an overly bitter taste.

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3. Poor post-harvest management such as tea shoots that are not processed quickly after harvest. 4. Air humidity, altitude and genetic variation of tea plants.	2. If the moisture content is too low, the withering process may be hindered, resulting in poor quality tea and an underdeveloped (astringent) flavor.

Table 5. Causes and Consequences of Water Content Discrepancy of Wilted Shoots of Orthodox Black Tea

Causes	Consequences
1. Less than optimal weathering time. 2. The process of reversing aging is uneven. 3. The harvested shoots are old tea leaves. 4. Poor post-harvest management such as tea shoots that are not processed quickly after harvest. 5. The machine used for weathering is old or not good enough.	1. Grinding process If the moisture content in the withered tea shoots is too high, the milling process will be more difficult and take a longer time, which may result in an uneven finish of the tea powder. Whereas, if the moisture content in the withered tea shoots is too low, the tea shoots may become more fragile and susceptible to damage during the milling process resulting in tea powder with a non-uniform texture or grains that are too fine.
	2. Enzymatic oxidation process If the moisture content is too high, it results in a bitter tea flavor. Whereas, if the moisture content is too low, it results in a astringent tea flavor.
	3. Drying process If the moisture content in the withered tea shoots exceeds the standard, the drying process will take longer and if not dried properly, the tea may become susceptible to spoilage. Conversely, if the moisture

	content in the withered tea shoots is low, the drying process may be faster, but it may cause damage to the tea shoots, such as them becoming over-dried and more brittle, and prone to cracking or breaking during the drying process.
	4. Sorting process If the moisture content in the withered tea shoots is too high, the tea powder may become softer and prone to damage during the dry sorting process. Conversely, if the moisture content in withered tea shoots is too low, the tea may become more brittle and easily crushed during the dry sorting process.

The processing of black tea involves fermentation or oxidation, where the polyphenols in the leaves are oxidized by the endogenous polyphenol oxidase enzyme. Before rolling, polyphenols and polyphenol oxidase separate inside the cells. Once mixed with oxygen, a chemical change occurs that oxidizes the polyphenols to orthoquinones. These compounds then condense to form black tea pigments, such as teaflavin and tearubigin, which have less active hydroxyl groups. This causes the polyphenol content of black tea to decrease (Kumar et al., 2013). Teaflavin and tearubigin are highly influential on the quality of black tea, where teaflavin has an important association with steeping water characteristics such as brightness, freshness and strength. In contrast, tearubigin is related to appearance such as color, strength, and taste (Yuwono & Faustina, 2019).

According to (Hicks, 2021), the main ingredients of tea include caffeine, essential oils, tannins and some B-complex vitamins in moderate amounts. Caffeine provides a refreshing taste and improves heart function, and is safe if consumed in amounts not exceeding 300 mg per day. Tannins are a source of energy derived from the tea juice and give the tea its astringency and color. Essential oils, on the other hand, provide a fragrant taste and smell that affects the value of each cup of tea sold or traded.

Based on Tables 4. and 5. above, it shows that moisture content affects the flavor of the tea. If the moisture content is high, the drying process will be longer, making the color of the tea darker and producing a bitter taste, while if the moisture content is low, it will make the final taste of the tea astringent. The flavor of black tea is also influenced by the content of polyphenols, caffeine, essential oils and amino acids (Teshome, 2019). According

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to (Xu et al., 2018) catechin compounds are reported to be the main contibutors of the bitter and astringent flavors in tea brewing. The bitter and astringent taste of tea is also influenced by other compounds such as caffeine, amino acids, and flavonol glycosides (Yu et al., 2014). This is also supported by the statement (Sari et al., 2022) which says that the tannin content in tea can be used as a quality indicator, because tannin gives a distinctive and unique taste to the tea, which is a slightly astringent taste. In addition to tannins, other compounds that also give a astringent taste to tea are catechins, which are derivatives of tannins. Catechins belong to the category of polyphenolic compounds and are generally found in peko shoots and young tea leaves. The older the tea leaves are, the less catechins they contain.

Conclusion

The conclusion from testing the moisture content of fresh shoots and withered shoots of orthodox black tea is that fresh tea shoots have a high moisture content, around 70-80%, when picked. During the withering process, fresh tea leaves undergo drying/evaporation to reduce the moisture content. Drying can be done in the open air or using machines, resulting in a reduction of moisture content to 50-60%. Analysis of the moisture content of fresh shoots and withered shoots of orthodox black tea at PTPN I Regional 2 Ciater Kebun shows that fresh shoots have an average moisture content of 78.36%, while withered shoots have an average moisture content of 57.4%. These results are in accordance with company standards and show no deviation. The impact if the moisture content is below the standard can accelerate grinding and drying, produce tea powder that is not uniform, brittle, and prone to breakage, and taste astringent tea. Meanwhile, if the moisture content is too high, it can make the grinding and drying process difficult and time-consuming, produce tea powder that is uneven and prone to breakage, and taste bitter tea. Factors that cause moisture content discrepancies in the aging process of orthodox black tea at PTPN I Regional 2 Ciater Kebun include weather conditions during harvesting, old tea leaves, air humidity, altitude, genetic variation of tea plants, less than optimal aging time, old or poor aging machines, and poor post-harvest management.

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