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Analysis of the Effect of Conveyor Speed in Cryo-Grinding System on Matcha Product Quality

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Abstract. In a cryo-grinding system, a conveyor is one of the important components. On the conveyor, the time of stay of raw materials can be varied, allowing for differences in product quality resulting from different cryo-grinding conveyor speeds. The purpose of this study is to determine the best level of conveyor speed treatment in the cryo-grinding system to produce matcha products with the best color, water content, and water activity. In this study, the variations of conveyor speed on the cryo-grinding system used were 20 rpm, 30 rpm, 40 rpm, and 50 rpm. The matcha samples obtained were tested for color quality (L*, a*, b*) using a chromameter, moisture content value using a moisture analyzer, and water activity using an AW meter. The data were analyzed using one-way ANOVA and if significantly different, it was continued with Duncan's test. To determine the best treatment level, the effectiveness index calculation was used. Based on the research and discussion that has been done, the calculation results using the effectiveness index show that the best level of conveyor speed treatment in the cryo-grinding system is at a speed of 40 rpm. At 40 rpm conveyor speed, the test results of L notation color were 53.21, a* notation color was -7.54, b* notation color was 28.11, water content value was 9.29%, and water activity value was 0.69.
Keywords: cryo-grinding, matcha, speed of conveyor.

1 Introduction

Tea is one of the potential agricultural commodities in Indonesia. Based on data from the Biro Kemenko Perekonomian Indonesia (2022), as one of the tea production countries, Indonesia has a contribution of 2% to the total world tea production. Based on data from the Badan Pusat Statistik (BPS) (2022), national tea production in 2021 was 94.1 tons.

PT Pagilaran is one of the tea production industries in Indonesia. PT Pagilaran is currently developing a new product known as matcha. Matcha is a type of Japanese green tea powder (*Camelia sinesis*) of the Tencha variety that is processed by stone grinding. PT Pagilaran's matcha business development can be a good business opportunity. This is caused by the market demand for matcha products that keep growing, both in the local market and the global market. In 2021, the global matcha market size amounted to USD 2.75 billion and is expected to grow at a CAGR of 10.9% from 2021-2030 [1].

Product quality is a major factor in improving the competitiveness of Indonesian tea products [11]. But the matcha produced by PT Pagilaran is not yet optimal, one of the reasons is that the color of the matcha produced is still yellowish green. Matcha has standards that have been regulated through SNI 01-4453-1998, of which one states that the appropriate matcha is blackish green color. In addition, the moisture content of green tea powder also significantly affects the quality and shelf life of the product [10]. Based on SNI 03- 3836- 2012 testing standards, the maximum moisture content of green tea powder is 8%. Determination of water activity in food is also very important because water activity affects the quality and shelf life of a product. Powdered food products are generally stable against chemical reactions if they have a water activity value between 0.20 to 0.40 during the packaging and storage period. The quality of matcha produced by PT Pagilaran, especially in the parameters of color, moisture content, and water activity, still has discrepancies in product quality. Color discrepancies in the products produced by PT Pagilaran are caused by excessive oxidation and excessive heat in the stone milling process. Therefore, to achieve good business, quality control is needed before trading to fulfill food safety requirements and satisfy consumer criteria.

One of the solutions taken by the industry to produce matcha quality in accordance with SNI is to freeze-dry using cryo-grinding. The cryo-grinding process is a process of grinding materials using liquid nitrogen. Liquid nitrogen serves to freeze the material before the material grinding process which aims to reduce the amount of heat in the raw material before entering the grinding process [4]. The main components of this cryo-grinding are the precooler and grinder. The precooler consists of a hopper, belt conveyor assembly, compressor, liquid nitrogen, and power transmission unit. The cryo-grinding machine performs the grinding process by putting the material into the container (hopper) and then it will be dropped into the prechilled. Liquid nitrogen will be sprayed and mixed with the material directly. During the process of moving the material on the conveyor, liquid nitrogen from the storage container will be sprayed onto the screw conveyor and the residence time of the material on the conveyor can be maintained by varying the speed of the drive, namely the conveyor drive[6]. With the variation of conveyor speed, it certainly causes the temperature of the tea raw materials to be ground to have different temperatures. The longer the residence time of the material on the conveyor causes the temperature of the tea to be lower. That way, there may be differences in the quality of the matcha products produced. Therefore, it is necessary to conduct research on the effect of cryo-grinding conveyor speed on the quality of matcha products so that the best cryo-grinding conveyor speed can be known. In this study, matcha produced from four different conveyor speeds in the cryo-grinding system was tested. The quality parameters used in this study are color, water content, and water activity.

The purpose of this study is to analyze the effect of conveyor speed in the cryo-grinding system on the color, moisture content, and water activity of PT Pagilaran's matcha products so that the best conveyor speed in the cryo-grinding system can be determined. This study is expected to identify the best conveyor speed in the cryo-grinding system for processing green tea leaves into matcha so that the matcha products produced by PT Pagilaran have good quality and in accordance with consumer expectations. Therefore, PT Pagilaran's matcha product business target can be achieved.

2 Material and method

In the process of making matcha, when the drying process is carried out using a bed dryer with a capacity of up to 60 kg of wet leaves, then during the leaf crushing process, a tresher is used to crush the leaves into smaller sizes. Then in the freeze grinding process using a cryo-grinding system, the tool components used are hoppers, conveyor belts, and stone milling. While the tools used in the data collection process of this research are Chromameter, Moisture Analyzer, AW Meter. The materials used in this research are green tea leaves and matcha samples from PT Pagilaran.

The color of green tea powder was analyzed using a Chromameter (CR 4000; Kronica Minolta). The working principle of the Chromameter is to obtain the color based on the reflectivity of the "Matcha" product against the light provided by the chromameter. The color system used is CIELAB. The CIELAB system is a color model designed to resemble human visual perception using three components, namely L* as luminance and a* and b* as opposite color dimensions. The values of L*, a*, b*. have scale intervals that indicate the color level of the material being tested. The L* notation expresses the brightness parameter with a value range from 0-100 indicating from dark (black) to light (white), while a* and b* represent chromaticity without a specific numerical limit. A negative a* notation corresponds to green and a positive a* notation corresponds to red. Negative b* notation corresponds to blue and positive b* notation corresponds to yellow.

Analysis of water content in this study using a moisture analyzer. Moisture analyzer is used to measure water content using the thermogravimetric method. This measurement is done in order to determine the amount of water contained in the matcha sample. The large amount of water will cause the growth of mold and microorganisms so that the material becomes damaged and has a short life. Moisture analyzer consists of weighing and heating (infrared) units.

The working principle of the moisture analyzer is based on thermo-gravimetry/Loss on Drying (LOD) where the sample is heated at a certain temperature so that the moisture content in it will evaporate. The evaporation will cause the mass of the sample to decrease until the evaporation process is complete which is characterized by no change in mass. The heat source generated by this tool comes from a halogen lamp, so that the heating process can take place in a relatively short time. The halogen heater is equipped with an analytical balance attached to it, so that the weighing process occurs automatically.

Analysis of water activity in this study using the AW meter tool. AW meters are used to measure water activity. Water activity is free water that microbes can use for growth. This tool uses a retronichygropalm device that will measure water activity. The way this tool works is by inserting the material to be measured into the sample cup and the device will measure the water activity in the material so that the measurement results will be displayed on the screen automatically.

3 Result and Discussion

In the cryo-grinding system installed in PT Pagilaran Gudang Usaha Samigaluh, the variables that can be varied are the speed of the conveyor belt, the height of the feeding hopper, and the amount of liquid nitrogen to be used. The cryo-grinding system has a variety of conveyor belt speeds from 20 rpm to 500 rpm. For the height of the feeding hopper on the cryo-grinding system has a maximum height of 2 cm, while the amount of liquid nitrogen can be adjusted with an angle opening of 45o to 180o. However, in the implementation of this research, the influence variable used is only the conveyor speed in the cryo-grinding system.

The samples used in this study were matcha processed with four different cryo-grinding conveyor speeds. In the matcha sampling process, the raw material used is dark green tea leaves. The selection of dark green tea leaves in the manufacture of PT Pagilaran matcha is to produce a bright green matcha color and avoid a pale green color in the matcha produced. In the color measurement, the control sample used is a matcha sample from one of the pure matcha products which is the strongest competitor of PT Pagilaran's matcha. The brand is the best-selling pure matcha product and is in demand by consumers in Indonesia. The color measurement results of the control sample obtained an average L* value of 59.53, an a* value of -8.34, and a b* value of 24.17.

In the treatment before the cryo-grinding process, the dark green tea leaves that have been sorted manually will then be dried using a bed dryer for approximately 30 minutes using medium heat with a temperature of approximately 80oC. The value of the moisture content of green tea leaves dried using a bed dryer for approximately 30 minutes before processing using a cryo-grinding system ranges from 10%-12%. After drying, the green tea leaves will go through a size reduction stage. In this size reduction stage, there are two ways of size reduction, namely using a thresher and manual size reduction. After size reduction, the tea will be sieved and start processing using the cryo-grinding system.

In the cryo-grinding process, the tap on the liquid nitrogen cylinder is set at 180o pressure for the initial 10 minutes. After 10 minutes, the tap on the liquid nitrogen cylinder is reduced to a 90° opening for 5 minutes. After 5 minutes, the opening on the liquid nitrogen cylinder is reduced again to a 45° opening in order to produce a smaller pressure. After 15 minutes of liquid nitrogen adjustment and when the pressure in the liquid nitrogen has stabilized, the crushed green tea raw material will be put into the hopper and the feeding in the hopper is set with a thickness of 0.25 cm. The tea will go directly to the cryo-grinding conveyor. The speed of the cryo-grinding conveyor is set at 20 rpm, 30 rpm, 40 rpm and 50 rpm. While on the conveyor, liquid nitrogen will be sprayed directly on the green tea that has been crushed and separated from the leaf stems and stalks will be ground using stone milling. After stone milling, the matcha samples from PT Pagilaran will then be screened using a 200 mesh fabric sieve to produce a uniform size of green tea powder. The cryo-grinding system installed at PT Pagilaran Gudang Usaha Samigaluh can be seen in figure 1.

Fig 1. Cryo-Grinding System

3.1 Color Measurement

Color testing carried out in this study uses a tool in the form of a chromameter. The color system used is CIELAB. L*, a*, b* values have scale intervals that indicate the color level of the material being teste [5]. The image of the color difference in the four research samples can be seen in Figure 6. The color measurement results on each sample refer to the control sample that has been tested. So that the best color value in this study is the color value that has a value close to the control value. The color measurement results of the control sample obtained an average L* value of 59.53, an a* value of -8.34, and a b* value of 24.17.

In addition, to compare the color measurement results of matcha samples produced from variations in the conveyor speed of the cryo-grinding system, L*, a*, b* color measurements were carried out on matcha samples processed without the cryo-grinding process. The following are the results of the L*, a*, b* notations obtained from this research:

3.1.1 L Value*

The results of the L* value color test on matcha can be seen in table 1.

Table 1. Color Testing Result (L*)

Parameter	Color Testing Result (L*)					
	20 rpm	30 rpm	40 rpm	50 rpm	Control sample	Non-cryo-grinding sample
Color (L*)	50,33 ± $0,18^{a}$	52,86 ± $0,04^{b}$	53,21 ± $0,27^{bc}$	53,57 ± $0,19^{c}$	59,53 ± 0,40	50,19 ± 0,08

*Numbers followed by different letter notations indicate significant differences with 5% significance.

Table 1 shows that the highest L* value was obtained from the control sample with an L* value of 59.53 followed by the conveyor speed variation of 50 rpm with a value of 53.57, while the lowest L* value was obtained from the non-cryo-grinding matcha sample with a value of 50.19 followed by the conveyor speed variation of 20 rpm with a value of 50.33. The results of matcha research using conveyor speed variations in the cryo-grinding system show that the slower the conveyor speed in the cryo-grinding system, the lower the brightness of the color and vice versa. The results showed that the use of a cryo-grinding system in the matcha processing process can increase the brightness value of the matcha produced so that the results of the L* color test in this study are in accordance with previous research. This is due to the use of liquid nitrogen which can reduce the heat temperature of the food before the grinding process because the higher the grinding temperature can reduce the brightness of the food. Cryogenically milled foodstuffs have a more attractive color compared to other milling methods, even untrained panelists are able to detect color differences in these powdered products [9]. The results of measuring the color brightness of the control sample in this study obtained an average L* value of 59.53. This value is used as a reference value in determining the best matcha brightness value. Therefore, in this study, the highest brightness value is the value of the best treatment level in determining the speed of the cryo-grinding conveyor. So that the best treatment level in the L* value color test in this study is matcha processed using a conveyor on a cryo-grinding system with a speed of 50 rpm which produces the highest average brightness value of 53.57. The L* value resulting from the conveyor speed variation in the cryo-grinding system has a darker value than the control sample used.

3.1.2 a Value*

In this study, the lowest a* value is the best greenish value. This is because the lower the a* value indicates that the color of the matcha sample has a higher greenish color. The difference in green color is associated with differences in the amount of chlorophyll in tea leaves [7]. The results of the a* value color test on PT Pagilaran Samigaluh matcha can be seen in Table 2.

Table 2. Color Testing Result (a*)

Parameter	Color Testing Result (a*)					
	20 rpm	30 rpm	40 rpm	50 rpm	Control sample	Non-cryo-grinding sample
Color (a*)	-6,28 ± 0,05[a]	-7,47 ± 0,06[b]	-7,54 ± 0,05[b]	-7,22 ± 0,04[c]	-8,34 ± 0,11	-2,74 ± 0,10

*Numbers followed by different letter notations indicate significant differences with 5% significance.

Based on Table 2, it can be seen that the best a* value test was obtained in the control sample with a value of -8.34 followed by a conveyor speed variation of 40 rpm. The sample with a speed of 40 rpm has the highest negative a* value compared to other speed variations. In a study conducted by [12] on matcha at PT Pagilaran with non-cryo-grinding processing, the highest a* (greenness) value was obtained at -6.60. The greenness value of matcha produced from the use of a cryo-grinding system in matcha production at PT Pagilaran is higher than non-cryo-grinding matcha. This is because the use of a cryo-grinding system can reduce heat during the grinding process using stone milling, so that the use of a cryo-grinding system can minimize the loss of greenish color in the leaves processed as matcha making materials.

3.1.3 b Value*

The b* notation indicates the degree of yellowness, which indicates the color from blue to yellow. In this study, the lowest b* value is the best yellowish color value to minimize yellowish color in matcha products. The results of the b* value color test on PT Pagilaran Samigaluh matcha can be seen in Table 3.

Table 3. Color Testing Result (b*)

Parameter	Color Testing Result (b*)					
	20 rpm	30 rpm	40 rpm	50 rpm	Control sample	Non-cryo-grinding sample
Color (b*)	26,86 ± 0,11[a]	27,62 ± 0,12[b]	28,11 ± 0,21[c]	27,72 ± 0,04[b]	24,17 ± 0,51	22,22 ± 0,12

*Numbers followed by different letter notations indicate significant differences with 5% significance.

Table 3 shows that the highest b* (yellowness) value was obtained from the conveyor speed variation of 40 rpm with a value of 28.11, while the lowest b* value was obtained from the non-cryo-grinding matcha sample with a value of 22.22 followed by matcha with a conveyor speed variation of 20 rpm with a value of 26.86. In this study, the best treatment level in the b* color test was obtained from the lowest b* value to minimize the yellowish color of the matcha produced. That is, to minimize the yellowish color of matcha, the best cryo-grinding speed used in this study is at the longest speed of 20 rpm. At a speed of 20 rpm, liquid nitrogen is able to reduce heat best compared to other conveyor speeds. Testing the level of yellowish color in this study is still higher when compared to research conducted by [12] on matcha without cryo-grinding process which resulted in a yellowish value of 24.74. The yellowness value of matcha processed using cryo-grinding is also higher than the control sample and the matcha sample processed without the cryo-grinding process. This could be due to other factors beyond the use of the cryo-grinding system ¸ such as differences in the way matcha is processed and cultivated.

3.2 Moisture Content Measurement

Table 4. Moisture Content Testing Result (%)

Parameter	Moisture Content Testing Result (%)					
	Pra *Cryo-grinding*	20 rpm	30 rpm	40 rpm	50 rpm	Non-cryo-grinding sample
Moisture Content (%)	10-12	10,38 ± 0,33[a]	9,67 ± 0,12[b]	9,29 ± 0,21[b]	8,67 ± 0,15[c]	7,21 ± 0,17

*Numbers followed by different letter notations indicate significant differences with 5% significance.

Table 4 shows that the highest moisture content value was obtained from tea samples before the cryo-grinding process with a moisture content value ranging from 10% to 12% followed by matcha with a conveyor speed variation of 20 rpm with a value of 10.38%, while the lowest moisture content value was obtained from matcha samples processed without the cryo-grinding process with a moisture content value of 7.21%, followed by matcha with a conveyor speed variation of 50 rpm, which obtained a moisture content value of 8.67%. According to SNI 01-4453-1998 regarding the quality requirements of green tea powder which states that the maximum moisture content requirement is 8%. From all levels of conveyor speed treatment on the cryo-grinding system carried out on PT Pagilaran matcha samples, the moisture content exceeds the SNI. In testing matcha from PT Pagilaran with non-cryo-grinding matcha processing conducted by [12], it was found that matcha from PT Pagilaran had a moisture content ranging from 7% to 8%. The results of testing the moisture content of matcha using the cryo-grinding system have a higher value compared to non-cryo-grinding matcha processing, which ranges from 8% to 10%.

3.3 Water Activity Measurement

Water activity can be used as a parameter to explain food preservation and microbial growth rate. Water activity values can range from 0 to 1. Materials with a water activity value of 0, then the material is absolute dry, while materials with water activity 1 are pure water [13]. Water activity testing was carried out using an AW Meter. In measuring the value of water activity, the water activity value was measured on matcha samples that were processed without the cryo-grinding process. The results of the water content test on PT Pagilaran matcha samples using the cryo-grinding system with four different treatment levels can be seen in Table 5.

Table 5. Water Activity Testing Result

Parameter	Water Activity Testing Result				
	20 rpm	30 rpm	40 rpm	50 rpm	Non-cryo-grinding sample
Water Activity	0,75 ± 0,1[a]	0,71 ± 0,1[b]	0,69 ± 0,02[bc]	0,68 ± 0,1[c]	0,56 ± 0,01

*Numbers followed by different letter notations indicate significant differences with 5% significance.

Table 5 shows that the highest water activity value is obtained from the conveyor speed variation of 20 rpm with a value of 0.75, while the lowest water activity value is obtained from the measurement of matcha samples without cryo-grinding process with a water content value of 0.56 followed by matcha samples with a conveyor speed variation of 50 rpm which is 0.68. The greater the water activity value, the smaller the durability of the food product, and vice versa, the smaller the water activity value of the food product, the longer the shelf life of the food product [8]. In this study, the speed level that has the best water activity value is at the 50 rpm treatment level with a water activity value of 0.68.

3.4 Determination of Conveyor Speed in the Best Cryo-grinding System by Effectiveness Index Method

Table 6 is the result of the calculation in determining the best treatment level using the effectiveness index method in this study. In Table 6, it can be seen that in this study the best treatment level is obtained from the total value of the calculation of the largest effectiveness index of each treatment level. The total value of the results at a conveyor speed of 20 rpm is 0.501, at a conveyor speed of 30 rpm it is 0.451, at a conveyor speed of 40 rpm it is 0.526, and at a conveyor speed of 50 rpm it is 0.504. So that the order of the best treatment level of conveyor speed in the cryo-grinding system is 40 rpm speed, 50 rpm speed, 30 rpm speed, and 20 rpm speed.

Table 6. Effectiveness Value Calculation Result

Parameter	Weight	Weight Value (BN)	Effectiveness Value (NE) Treatment Level				Treatment Level Result (Weight Value × NE)			
			20 rpm	30 rpm	40 rpm	50 rpm	20 rpm	30 rpm	40 rpm	50 rpm
Color (L* value)	0.80	0.235	0.54	0.42	0.33	0.52	0.13	0.10	0.08	0.12
Color (a* value)	0.40	0.118	0.53	0.39	0.47	0.48	0.06	0.05	0.06	0.06
Color (b* value)	0.50	0.147	0.60	0.48	0.66	0.58	0.09	0.07	0.10	0.09
Moisture Content	0.90	0.265	0.40	0.45	0.62	0.46	0.11	0.12	0.16	0.12
Water Activity	0.80	0.235	0.50	0.500	0.560	0.500	0.12	0.12	0.13	0.12
Total	3.40	1					0.501	0.451	0.526	0.504

4 Conclusions

Based on the calculation of the level of conveyor speed treatment in the cryo-grinding system, the results show that the best conveyor speed is at 40 rpm. At a conveyor speed of 40 rpm, the results of the L notation color test were 53.21, a* notation color of -7.54, b* notation color of 28.11, water content value of 9.29%, and water activity value of 0.69. Conveyor speed in the cryo-grinding system affects the color, moisture content, and water activity of matcha products at PT Pagilaran. The cryo-grinding system can produce better matcha brightness (L*) and greenness (a*) than matcha produced without cryo-grinding. However, in the measurement of yellowish color level (b*), water content value, and water activity value, the cryo-grinding system is still not able to produce matcha as expected, so further research needs to be done regarding the use of the cryo-grinding system on matcha PT Pagilaran.

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