The use of oven as a device to temper molten Dark Chocolate

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Abstract. Tempering is one of the most important processes in chocolate making. Tempering is needed to ensure that chocolate has correct melting point, hardness, snap and gloss. After tempering, cocoa butter crystallises in polymorphic form beta V, resulting in chocolate with melting point in the range of 33-34°C. This work investigated the impact of crystal maturation duration and holding time of tempering process on hardness and appearance of dark chocolate. Five durations of crystal maturation, namely 1, 3, 5, and 7 days and five holding time namely 3, 6, 9, 12, 15 and minutes were used as variables. The results showed that hardness of chocolate had propensity to increase as the maturation duration was prolonged. Similar trend was also observed as the holding time increased. With regard to the colour, the L*, a* and b* values tended to decrease as the duration of crystal maturation increased. The use oven method, thus, seemed to have potential for small-scale production of dark chocolate.

1. Introduction
Conventionally, chocolate is processed using a sequence of mixing, refining, and conching [1-4]. After the conching process is completely done, the following process that must be carried out is tempering. Tempering is a thermo-mechanical treatment of chocolate paste to create highly stable and homogenously dispersed cocoa butter crystals in the correct type and size. The cocoa butter crystals formed during tempering process act as crystal seeds which then grow during maturation period [5]. Well-tempered chocolate has desired characteristics, for example having good contractions (easily removed from the mould), gloss and snap, and optimal stability under normal storage conditions [5-7].

Tempering process is divided into three stages. The first stage is heating process of chocolate paste until it reaches a temperature of 50° C. This stage intends to totally melt the fat crystals. In the second stage, the chocolate is then cooled up to 32° C, followed by further temperature decrease up to 27° C. The last stage is carried out by increasing the temperature up to 32° C. Due to a simple triacylglycerol composition, cocoa butter can crystallize in a number of polymorphic forms, with each polymorphic form having a specific melting point and crystal structure [8]. The most stable polymorphic form of chocolate is beta V with a melting point around 33,8° C [9,10].

Conventionally, tempering is conducted manually on a marble table. This process is suitable for small capacity. However, this process requires skilled and suitable workers to do so. Automatic tempering machines are more often used in industrial scale [1]. The small-scale tempering process that has been
carried out so far still needs large capital because of the expensive marble materials. This condition results in a limitation for small industries and relatively low-income cocoa farmers. Furthermore, the disadvantage of the tempering process using marble table is that this process is still lack of control because it is still done based on feeling. Therefore, a standardised method which is easily applied in small scale chocolate industry is highly needed. This research was conducted to study the use of oven as a tempering device. The research variables used were holding time and the duration of crystal maturation. The chocolate characteristics studied were hardness and colour.

2. Methodology
This research was conducted at the Cocoa and Chocolate Sub-Laboratory, Postharvest and Food Engineering Laboratory, Faculty of Agricultural Technology, Universitas Gadjah Mada. The materials used were cocoa mass, cocoa butter and cocoa powder obtained from the Indonesian Coffee and Cocoa Research Institute, (Jember, East Java), as well as sugar (Gulaku) purchased in Supermarket in Yogyakarta.

2.1. Sample preparation
Dark chocolate was made with a total fat content of 32.16% according to the following formulation: 45% sugar, 5.8% cocoa mass, 27.8% cocoa powder, and 21.4% cocoa butter. The processing of raw materials into a chocolate paste was performed using a melanger (Santha) for 10 hours. The tempering process of molten chocolate was then carried out using an oven. At the beginning, dark chocolate was heated up to 50°C. Afterwards, the temperature of the molten chocolate was maintained with a holding time variation of 3, 6, 9, 12 and 15 minutes. Subsequently, the natural cooling process was done by putting the molten chocolate at room temperature and stirring it at the same time until the temperature reached 27°C. At this point, the temperature was maintained for 3, 6, 9, 12 and 15 minutes. In the end, the temperature of the molten chocolate was raised to 32°C. The tempering temperature profile used can be seen in Figure 1. After tempering, molten chocolate was moulded and stored in a thermostatic cabinet at temperature of 15°C.

![Figure 1. Scheme of tempering temperature](image)

2.2. Analytical method
2.2.1. Particle size. The measurement of chocolate microparticles was conducted using a microscope (Olympus CX23LEDRF) equipped with an Optilab camera (Advance Plus). A 0.5-gram of chocolate was diluted with 10 ml of vegetable oil and put into the oven at temperature of 55°C for 1 hour. Afterwards, the diluted chocolate was vigorously shaken prior to the measurement. The microstructural image was observed using an OptiLab Microscope A drop of diluted chocolate was put on the glass slide. A cover slip was then placed on the sample. Particles size was measured using the application of Image Raster 3.
2.2.2. Hardness. Hardness of chocolate was determined using a texture analyzer (Brookfield). Probe (TA39) used in this test had a diameter of 2 mm. The chocolate samples tested had a thickness of ± 1 cm. The hardness of chocolate bar was measured on the 1st, 3rd, 5th, and 7th day of maturation process.

2.2.3. Colour. Colour of the chocolate was measured using a chromameter (Minolta CR-400). System of CIE \(L^*\) \(a^*\) \(b^*\) was used. \(L^*\) shows the brightness level, ranging from 0 (black) to 100 (white). \(a^*\) indicates the level of green to red, and \(b^*\) indicates the level of blue to yellow. Measurements were performed triplicates.

2.2.4. Data analysis. Data analysis was performed using IBM Statistics SPSS version 21.0 software. One-way analysis of variance (ANOVA) was used to test the differences in color and hardness with a significance level of 5%. Before the ANOVA test was carried out, the homogeneity test was conducted using the Levene’s test. Moreover, when the conditions of homogeneity are met, the Tukey test was used to determine the differences between samples. The principal component analysis (PCA) was used to visualize the relationships between samples and parameters.

3. Results and Discussion

![PCA loading plot of hardness and colour of chocolates](image)

**Figure 2.** PCA loading plot of hardness and colour of chocolates
In this study, Principal Component Analysis (PCA) was used to show the relationship between hardness and colour of chocolates tempered using an oven. Aside from this, chocolate samples were also plotted in PCA graph. It can be seen in Figure 2 that there were two principal components that explained more than 83% of the variance, namely PC 1: 55.36% and PC 2: 29.80%. The value of a* and b*, as well as hardness, were dominantly influenced by PC1. L value was dominantly influenced by PC 2. Based on PC 1, it can be seen that colour and hardness was inversely correlated. Furthermore, it can be seen from figure 2 and figure 3 that the distinction between holding time could be observed along PC 1, while the distinction between duration of crystal maturation could be observed along PC 2.

3.1. Particle size
Particle size has direct influence related to the grittiness of chocolate. Moreover, particle size is also an important factor that affects hardness and colour of chocolate [11,12]. The smoothness of chocolate is directly influenced by the size of the particles that can be felt during chocolate consumption. A low level of grittiness (particle size < 30µm) gives the effect of creaminess to the chocolate, while high level of grittiness (particle size > 30µm) results in a chocolate with gritty sensation [11,13]. In association with the hardness, the smaller the particle size, the higher the interaction among particles. In this condition, chocolates with high particle interactions tend to have a high level of hardness (Saputro, quality attribute). With regard to the colour, Afoakwa (2010) stated that chocolate with small particle size exhibits high particle interactions [1]. This condition results in chocolate with bright colour. Based on Figure 4, it can be seen that all the chocolates exhibited comparable particle size in the range of 14-24 µm. Hence, the different hardness and colour of the tempered chocolates were not influenced by particle size.
3.2. Hardness
It can be seen in figure 5 (a) that regardless of the duration of crystal maturation, the hardness of chocolate had propensity to increase as the holding time increased. This phenomenon occurred because at a shorter holding time, it was possible that the expected heating temperature (50 °C) and cooling temperature (27 °C) could not be homogeneously reached by molten chocolate. Thus, since incorrect tempering process occurred, resulting in unsuccessful formation of beta V, the expected hardness of chocolate could not be achieved. As discussed in introduction section, that the desired polymorphic form of tempered chocolate is beta V [1][2].

Moreover, generally, the hardness of chocolate increased as the duration of crystal maturation increased, except in the chocolate tempered with 3 minutes holding time (figure 5b). This showed that crystal maturation is imperative in creating well-tempered chocolate. Windhab (2009) stated that maturation of the cocoa butter crystals for a certain period of time is sometimes needed, particularly for chocolate with cocoa butter content. Chocolate tempered with 3 minutes holding time exhibited a decrease in the hardness. It seemed that 3 minutes was not enough for chocolate to reach targeted temperatures.

![Figure 4. Microstructural Image of solid particles in chocolate](image)

![Figure 5. Hardness of chocolates as influenced by holding time (a) duration of crystal maturation (b)](image)
3.3. Colour
Appearance of chocolate is highly determined by its glossiness and colour [14]. The glossiness is mainly influenced by the occurrence of fat and/or sugar bloom, while the colour, similar to the hardness, is influenced by the particle size and fat content which further influence the particle-particle interaction in the chocolate matrix [15][16]. It can be seen in Table 1 that the values of $L^*$, $a^*$, and $b^*$ tended to decrease along with increasing duration of crystal maturation. This showed that the change in a polymorphic form characterized by the increased hardness of chocolate resulting in decreased in chocolate colour.

Table 1. Colour of dark chocolates as influenced by duration of crystal maturation

| Colour parameters | 1st day     | 3rd day     | 4th day     | 7th day     |
|-------------------|-------------|-------------|-------------|-------------|
| $L^*$             | 26.67±1.09$^{ab}$ | 25.36±0.96$^{ab}$ | 25.43±0.94$^{ab}$ | 23.97±1.03$^a$ |
| $a^*$             | 9.74±0.8$^a$ | 9.71±0.58$^a$ | 9.25±0.16$^a$ | 9.57±0.44$^a$ |
| $b^*$             | 9.93±0.84$^a$ | 8.52±0.54$^a$ | 8.39±0.17$^a$ | 8.4±0.51$^a$ |

4. Conclusion
Holding time and duration of crystal maturation influenced the hardness and colour of chocolates. The longer duration of holding time and crystal maturation, the higher the hardness and the lower the $L^*$, $a^*$, $b^*$ were observed. The use of oven as a device for tempering seemed suitable to be used in small scale chocolate industry as easy-to-use tempering method.

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