Investigating the impact of Palm Sap Sugar proportion and fat content on heat stability of Milk Chocolate

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Abstract. Chocolate is characterised by its solid texture at relatively low temperature. However, it will easily melt as the temperature increase. This phenomenon contributes to the low level of chocolate quality in tropical countries. In order to cope with this problem, an innovation in producing thermostable chocolate is highly required. This work investigated the impact of fat content and palm sap sugar proportion on the heat stability of milk chocolate. Hardness of chocolate was used as a parameter to evaluate the chocolate stability against storage temperature.

In this study, three levels of fat content, namely 30%, 32%, 34% and five palm sap sugar levels, namely 0%, 25%, 50%, 75%, 100% were used. The results showed that fat content, palm sap sugar proportion and their interaction significantly influenced the hardness of milk chocolate. Due to its moisture content, the hardness of chocolate increased as the proportion of palm sap sugar was increased. In contrast, at the same level of palm sap sugar proportion, the increase of fat content decreased the hardness of milk chocolate.

1. Introduction
Chocolate is one of the food products preferred by the community because of its typical nature. Chocolate is classified into three types, namely dark chocolate, white chocolate, and milk chocolate [1, 2]. Milk chocolate has the highest consumption level (40%) compared to the other types of chocolates [3]. However, milk chocolate has a melting point between the temperatures of 33-37ºC [4] so that it is not suitable for the temperature in Indonesia. As a tropical country, Indonesia has a fairly high temperature. Based on the Indonesia Berau of Statistics data in 2015, the maximum temperature can reach an average of 35ºC. At this temperature, it is possible that chocolate can melt either partially or completely.

The development of heat resistant chocolate can be done by replacing cocoa butter with other equivalent and substituent vegetable fats [5], resulting in a higher melting point [6]. However, replacing cocoa butter with vegetable fat can reduce the quality of chocolate. Furthermore, some countries also limit the amount of fat that is non-cocoa vegetable fat (NCVF), which can be added to chocolate. India does not allow NCVF to be added to chocolate products whereas in Europe, it is permissible for levels of 5 - 12% [7]. Besides replacing cocoa butter with vegetables fat, increasing the melting point of
chocolate can also be done by increasing the moisture content of chocolate. Increasing the moisture content can be done by replacing sugar/sucrose with other amorphous and moist sugars. The use of amorphous sugar which has high moisture content may create sugar network and microstructural bonds [7, 8].

One type of sugar that has high moisture content and amorphous part is palm sap sugar [9, 10]. The use of palm sap sugar in food creates food products with a distinctive colour and aroma. Furthermore, it also has advantage of having low glycaemic index [11] so that it is better for health than the common sugar [12]. Indonesia is one of the exporters of palm sugar in the world. However, the use of this sugar as a substitute for sugar in chocolate products is still not widely developed.

This study aimed to examine the effect of proportion of palm sap sugar and fat level to the physical characteristics of milk chocolate. Moreover, this study also investigated the potential palm sap sugar sweetened milk chocolate as heat resistant chocolate. In this study, milk chocolate was produced using a melanger. Melanger is a device that can be used to replace ball mill in a household scale. The advantage of this device is that it has a low loss compared to ball mill [13].

2. Materials and Methods
This research was conducted at Postharvest and Food Engineering Laboratory, Faculty of Agricultural Technology, Universitas Gadjah Mada. The ingredients used were cocoa liquor, cocoa butter, and cocoa mass provided by Indonesian Coffee and Cocoa Research Institute (Jember, East Java). Coarse sucrose (Gulaku), coarse palm sugar (Nazan Food), skim milk (Lactona) were purchased in Yogyakarta. The characteristics of the ingredients used in this study can be seen in Table 1.

Table 1. Fat and moisture content of chocolate ingredients

| Ingredients   | Fat Content (%) | Moisture Content (%) |
|---------------|-----------------|----------------------|
| Cocoa mass    | 52.42           | 2.61                 |
| Cocoa powder  | 27.76           | 3.67                 |
| Cocoa butter  | 100             | -                    |
| Coarse sugar  | -               | 0.07                 |
| Palm sap sugar| -               | 3.05                 |
| Skim milk     | -               | 5.75                 |

2.1. Sample preparation
Milk chocolate with fat content of 30%, 32%, and 34% were prepared from cocoa powder, cocoa mass, sugar and skim milk powder. Coarse palm sugar (PS) and coarse sucrose (S) were mixed in 5 different PS:S ratios, namely 100:0, 75:25, 50:50, 25:75 and 0:100 (wt%) coded as PS100, PS75, PS50, PS25 and PS0, respectively. Therefore, there were 3 x 5 type of chocolates were produced (Table 2).

Table 2. Name of milk chocolates produced in this study

| Fat content | Sugar   |
|-------------|---------|
|             | PS 0    | PS 25  | PS 50  | PS 75  | PS 100 |
| 30%         | 30 PS 0 | 30 PS 25 | 30 PS 50 | 30 PS 75 | 30 PS 100 |
| 32%         | 32 PS 0 | 32 PS 25 | 32 PS 50 | 32 PS 75 | 32 PS 100 |
| 34%         | 34 PS 0 | 34 PS 25 | 34 PS 50 | 34 PS 75 | 34 PS 100 |

2.2. Chocolate processing
Chocolate was produced using a melanger (Wonder Premier Grinder). The production of chocolate was carried out for 10 hours at temperatures between 60-80ºC. All ingredients were mixed at the beginning of the process. After becoming a chocolate paste, the molten chocolate was then tempered to form stable chocolate crystals. Afterwards, the milk chocolates were stored in the showcase for seven days at 15ºC prior to the measurements.
2.3. Analytical methods

2.3.1. Moisture content. Moisture content was determined using thermogravimetric method. Chocolate samples were heated in the oven with a temperature of 105°C for 24 hours. The moisture content of the chocolates (wb) was formulated with equation 1.

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\text{Moisture content (wb)} = \frac{\text{Mass of water}}{\text{Mass of water} + \text{Mass of solid part}} \times 100\% \tag{1}
\]

2.3.2. Hardness. Measurement of chocolates hardness was carried out at room temperature of 20°C. Brookfield Texture Analyzer with probe No. 39, which had a diameter of 2 mm was used. The probe speed was 0.5 mm/second with a pressing target of 3 mm.

2.4 Data Analysis

Data analysis was performed using IBM SPSS version 22.0 software. One way and two way analysis of variance (ANOVA) were used to test the differences between the physical properties of milk chocolate with a significance level of 5%. Before the ANOVA test was carried out, the homogeneity test was carried out by Levene’s test. Furthermore, when the conditions of homogeneity are fulfilled, the Duncan Multiple Range Test (DMRT) test was used to determine the difference between samples.

3. Results and discussion

Cocoa butter and sugar are ingredients highly influencing the characteristics of chocolate bar. The cocoa butter affects the melting point of chocolate. Chocolate is solid at room temperature and begins to melt at 28-30°C and entirely melts at temperatures below body temperature [14]. In addition, the proportion of cocoa butter also affects the rheological properties of chocolate. When cocoa butter is added, it covers the surface of particles resulting in a lower viscosity [2]. The sugar does not only act as sweetener, but also as bulking agent. Thus, its high portion in chocolate determines the textural and rheological properties. In this study, palm sap sugar was used as milk chocolate sweetener. In general, it can be seen in Table 3 that fat content influenced the hardness of chocolate, while palm sap sugar influenced the moisture content and hardness of chocolate. Nevertheless, their combination only influenced the moisture content of chocolate.

| Table 3. Impact of fat content, palm sap sugar proportion and their combination on moisture content and hardness of milk chocolate produced using melanger |
|---------------------------------|------------------|-----------------|
| Parameters                     | Moisture content (%) | Hardness (N/mm²) |
| Fat                            | *                 |                 |
| Palm sap sugar                 | *                 | *               |
| Fat*Palm sugar                 | *                 |                 |

3.1. Moisture content

Moisture content has a considerable influence on the quality of chocolate, especially on the rheology [15] and hardness [1]. If the moisture content is higher than 2%, it highly affects the rheological behaviour and hardness of chocolate [2]. Moreover, high moisture content also affects the microstructural characteristic and colour. Chocolate with high moisture content exhibit high agglomerates found in the chocolate [8, 16].

The ingredients used to make chocolate plays an important role in the presence of moisture content in chocolate. Sucrose as the most common sugar used in chocolate is a material that has low moisture
content and hygroscopic properties, while palm sugar has relatively high moisture content and hygroscopic properties. Thus the use of palm sap sugar may increase the moisture content of chocolate.

Giving palm sap sugar and fat with various proportions affected the total moisture content of milk chocolates. The effect of fat content and the proportion of palm sap sugar on milk chocolate can be seen in Figure 1. It can be observed in Figure 1 (a) that moisture content of milk chocolate was not influenced by fat content. However Figure 1(b) showed that regardless of the fat content, the moisture content of milk chocolate had propensity to increase with the increase in the proportion of palm sap sugar. This phenomena is similar to the results obtained by Saputro et al (2017) in the making of dark chocolate sweetened with palm sap sugar [17]. Saputro et al (2017) found that chocolate sweetened with a higher portion of palm sap sugar, exhibited a higher level of moisture. With regard to the values, it can be seen in Figure 1 that moisture content of the milk chocolates were approximately in the range of 2.5%-3%. These values were quite high for chocolate.

Different superscripts in each group of milk chocolates indicate significant differences (p < 0.05) among samples

**Figure 1.** Impact of fat content (a) and palm sap sugar (b) on the moisture content of milk chocolate

3.2. **Hardness**

Hardness is a parameter that influences the quality of chocolate. Hardness is determined by moisture content, fat content, particle size of chocolate and degree of tempering [1, 18, 19]. Palm sap sugar is a sugar which contains high moisture [20-23] and hygroscopic materials [9]. Therefore, the incorporation of palm sap sugar into chocolate can affect the hardness of chocolate [9]. As previously discussed, as predicted, the moisture content of milk chocolates produced were relatively high.

To cope with this, the addition of a higher level of fat can be an option to decrease the value of hardness. It can be seen in Figure 2 (a) that regardless of the palm sap sugar proportion, the hardness of chocolates tended to decrease as the fat content increased. In addition, it can be clearly observed in Figure 2 (b) that regardless of fat content, the hardness of milk chocolates increased as the proportion of palm sap sugar increased. From these 2 figures, it can be concluded that the use of a higher level of fat resulted in a milk chocolate sweetened palm sap sugar with a lower hardness. This could happen because at high fat levels, the chocolate particles, mainly palm sap sugar particles, could be well covered by the fat. This led to the reduced interactions among the sugar particles, resulting in a lower level of sugar network formed. This phenomenon was in line with the statement of Afoakwa (2010) that the addition of fat causes a decrease in the hardness of chocolate.
Different superscripts per parameter indicate significant differences (p < 0.05) among samples

Figure 2. Impact of fat content (a) and palm sap sugar (b) on the hardness of milk chocolate

3.3. The potential of palm sap sugar to create heat resistant chocolate

From the above-mentioned phenomena, it can be observed that the milk chocolate hardness increases as the proportion of palm sap sugar is increased. The sugar network which might be formed in the chocolate matrix may act as beam for the chocolate. Hence, once the temperature increases and the cocoa butter crystals are about to melt, the sugar network may support the chocolate matrix, keeping the shape of the chocolate. Therefore, it seems that heat resistant chocolate can be created by fine tuning the proportion of palm sap sugar and fat content. Nevertheless, a thorough investigation is still needed. Several analyses, such as melting profile test, storage test at elevated temperature, sugar bloom test and microstructural characterisation, should be conducted.

4. Conclusion

Based on this research, it can be concluded that the addition of palm sap sugar in milk chocolate affects the hardness of chocolate. The increased hardness of chocolate is caused by the increased moisture content and hygroscopic materials. By fine tuning the portion of fat and palm sap sugar, heat resistant chocolate, to some extent, can be developed.

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