Physical properties of red velvet compound chocolates sweetened with stevia and inulin as alternative sweeteners

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Abstract. Chocolate is one of food products made from cocoa beans (Theobroma cacao L). The ingredients of chocolate in general are cocoa butter, sugar, and cocoa powder/cocoa mass. However, in this study, cocoa butter substitute (CBS) instead of cocoa butter was used to increase the value of melting point. In addition, stevia and inulin were used to reduce the calorie of chocolate and red velvet was added as flavoring agent. The purpose of this study was to examine the physical properties of red velvet compound chocolate sweetened with stevia and inulin. The proportion of stevia used were 15%, 30%, and 45%. The physical properties measured were water content, particle size, color (L*, a*, b*), hardness, and melting point. The result showed that the proportion of stevia significantly affected the characteristics of red velvet compound chocolate. The highest proportion of stevia produced chocolate with the lowest moisture content. Chocolate sample had moisture content in the range of 0.93-1.5%. Particle size was inversely proportional to the water content, ranging from 75.01 to 86.64 µm. Color of chocolates was affected by color of the ingredients. The hardness and melting point of red velvet chocolates were influenced by the proportion of stevia.

1. Introduction

Chocolate is a product that is considered unique for its consumers because chocolate is solid at room temperature, but can completely melt at body temperature [1]. Basic ingredients of chocolate in general are cocoa butter, sugar, and cocoa powder/cocoa mass. Chocolate that used cocoa butter is considered to have a lower melting point.

Increasing the melting point can be done by replacing cocoa butter with Cocoa Butter Alternatives (CBA). CBA were divided into three types, namely Cocoa Butter Substitute (CBS), Cocoa Butter Replacer (CBR), and Cocoa Butter Equivalent (CBE) [2]. Chocolate made from these types of fat are known as compound chocolate. In this study, CBS was used.

Sucrose is the most common sugar used in confectionery industry [3]. The composition of sucrose in chocolate is about 40-50% (depending on type) and this confers multiple functional properties on chocolate including sweetness, particle size distribution (PSD, mouthfeel (texture) [4], and rheological properties [5,6]. Nowadays, many consumers are concern about the high sugar content, calories, and
cariogenic effect in sweet products. This encourage consumer to find products with healthier sweetener [7,8]. The replacement of sugar in chocolate was hard to implement due to the difficulty in finding substitutes for sucrose that provide similar taste, texture, and other characteristics [4].

Aroma of chocolate is very important, affecting the assessment of the chocolate by consumer. The aroma of chocolate is influenced by cocoa bean [9] and sugar or sweetener used [10]. However, nowadays, chocolates with different aroma, especially white chocolate, is highly demanded by consumer. Due to its taste and aroma, currently, red velvet powder is widely used in various products and favored by public. In this study, red velvet was used because it has unique taste and aroma similar to the taste of chocolate that leaves a different impression on the tongue.

The main objective of this research was to study the physical characteristics of red velvet compound chocolate made from CBS as a substitute for cocoa butter. Moreover, the influence of the use of alternatives sweeteners such as stevia and inulin in specific proportions was also investigated. The making of compound chocolate in this study used an alternative method which can be done by using ball mill [11] or melanger [12]. However, melanger was chosen in this study to minimize losses.

2. Materials and methods
This research was conducted at Sub-Laboratory of Cocoa and Chocolate, Laboratory of Food and Postharvest Engineering, Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada. The ingredients used were Cocoa Butter Substitute (CBS) provided by Wilmar Group Indonesia. Stevia, inulin and red velvet powder were purchased at supermarket in Yogyakarta.

2.1. Sample preparation
Compound chocolate with 34% of CBS was prepared. Stevia (S) and inulin (I) were mixed in 3 different S:I ratios, namely 15:85, 30:70, and 45:55 (wt%) coded as S15, S30, and S45, respectively. Therefore, there were 1 x 3 type of chocolates produced (Table 1).

| Red velvet | CBS | Stevia          |
|------------|-----|----------------|
| 26%        | 34% | S15 S30 S45    |

2.2. Chocolate processing
Chocolate was made in a melanger (Wonder Premier Grinder) with grinding time of 5 hours. Afterwards, the molten chocolate was directly molded since chocolate with CBS does not need to be tempered. To remove air bubbles, chocolate was placed on vibrating table for +3 minutes and then stored in the refrigerator at ±15°C for 13 days.

2.3. Analytical methods
2.3.1 Moisture content. Moisture content of the chocolate was measured using thermogravimetric method. The chocolate sample was placed in the oven for 24 hours at 105°C. The moisture content of the chocolate sample was calculated using equation 1.

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\text{Moisture content} = \frac{\text{Mass of water}}{\text{Mass of water + Mass of solid part}} \times 100\%
\]

2.3.2 Particle size. Particle size measurement and its visualization were carried out following a method developed by Nafingah et al [13], Kurniasari et al [14], and Cahyani et al [15], using a light microscope. 0.5 grams of molten chocolate were dispersed in 10 ml of cooking oil. Prior to the measurement, the dispersion was heated in an oven with a temperature of 55°C for 1 hour. A drop of sample was put on
glass slide for further observation using an OptiLab Microscope. Then image was captured and measured using Image Raster 3 Software.

2.3.3 Color. Color of chocolate was determined using Chroma meter. There are three parameters measured, namely L* (lightness), a* (redness), and b* (yellowness). L* (lightness) with a range of 0-100 indicates black to white, a* (redness) ranges from -60 (green) to +60 (red), while b* (yellowness) ranges from -60 (blue) to +60 (yellow) [7,16].

2.3.4 Hardness. Hardness of chocolate was measured following a method developed by Nafingah et al [13], Kurniasari et al [14], and Cahyani et al [15], using a Brookfield Texture Analyzer. This device was equipped with a TA39 probe that has 2 mm of diameter. The probe was set with speed of 0.5 mm/s with a target press of 3 mm.

2.3.5 Melting point. Melting point measurement was manually done following a method developed by Nafingah et al [13], Kurniasari et al [14] and Cahyani et al [15]. Chocolate with the size of 1 x 1 cm was put on a plastic spoon and immersed in a water bath (Advantec 27DA) that was filled with water. The initial temperature of the water bath was set at 28°C. The temperature was periodically increased with the heating rate was 1°C/min. The process was conducted until the chocolate was perfectly melted.

2.3.6 Data analysis. The results was analyzed using IBM SPSS version 26.0 software application. To test the physical differences between chocolate samples, a one-way Analysis of Variance (ANOVA) test was performed with a significance level of 5%. Prior to the ANOVA test, the homogeneity of data was tested using the Levene’s Test model. Afterwards, the Tukey test was used to see the effect of the proportion of stevia and inulin on the moisture content, color, hardness, melting point, and particle size of chocolate. Principal Component Analysis (PCA) was used to visualize the relationship between chocolate samples and their characteristics.

3. Results and discussion

3.1. Characteristics of ingredients
Characterization of the ingredients was a part of preliminary research that aimed to determine the properties of the ingredients. The data can be used to predict and discuss phenomena occur during the production and testing process. The characteristics of the ingredients used in this study can be seen in Table 2.

| Ingredients     | Moisture content (%) | Fineness modulus | Diameter (mm) | L        | a*      | b*     |
|-----------------|----------------------|------------------|---------------|----------|---------|--------|
| Stevia          | 0.56±0.03            | 4.06±0.00        | 1.74±0.00     | 95.25±0.30 | 1.73±0.04 | 1.36±0.04 |
| Inulin          | 2.07±0.23            | 0.19±0.05        | 0.12±0.00     | 96.08±0.36 | 0.91±0.05 | 6.28±0.10 |
| Red velvet      | 1.86±0.03            | 2.96±0.08        | 0.81±0.05     | 56.05±0.59 | 11.39±0.59 | 15.7±0.30 |

Moisture content influenced the hardness and flow properties of chocolate [17]. Fineness modulus testing was carried out to determine the particle size of the raw materials. By knowing this, the duration of chocolate grinding can be estimated.

3.2. The influence of stevia proportion and fat content
The use of stevia and inulin as an alternative sweeteners and CBS as a substitute for cocoa butter affects the characteristics of the red velvet compound chocolate produced. Principal Component Analysis (PCA) shows the relationship between all the characteristic parameters of chocolate in general (Figure 1). From the PCA analysis, two components explained more than 93.96%, namely PC 1: 48.36% and
PC 2: 45.6%. It can be seen in Figure 1, that particle size, melting point, hardness value, L*, and b* had propensity to be inversely proportional to the redness and moisture content (PC 1) as well as lightness (PC 2). In Figure 2, it can be seen that the chocolate samples with a high proportion of stevia (S4534) tend to have a high particle size, melting point, b* value, and hardness. Chocolate samples with a lower proportion of stevia (S15 34) had a fairly high moisture content and a* value (blue circle).

3.3. Moisture content

Moisture content is a specific factor in making chocolate that is closely related to textural properties such as hardness and rheological properties. Moisture must be kept as low as possible [18,19]. If the water content is too high it causes the particles to stick to each other and cause agglomeration, it will cause an increase in hardness and viscosity value [17].

It can be seen in Figure 3 that the value of moisture content decreased with the addition of stevia and the reduction of inulin. This might be due to the initial moisture content of stevia which was lower than inulin (Table 2). Inulin has high moisture content and hygroscopic properties. So that it can bind chocolate particles and cause agglomeration. Agglomeration can lead to suboptimal evaporation of water content [17].
3.4. Particle size

Particle size is also a specific parameter influencing the characteristic of chocolate such as hardness, grittiness and viscosity [20,21]. Figure 4 and 5 show that there is an increasing of the size of particles with an increasing of stevia proportion and a reduction of inulin. It might happen due to stevia exhibited a large enough particle size so that the increase in the proportion of stevia, resulting in a larger particle size of red velvet compound chocolates.

![Figure 3](image1.png)

**Figure 3.** The effect of the proportion of stevia on the moisture content of red velvet compound chocolate.

![Figure 4](image2.png)

**Figure 4.** The effect of the proportion of stevia on the particle size of red velvet compound chocolates

![Figure 5](image3.png)

**Figure 5.** Particles of chocolate made with stevia proportion of (a) 15%, (b) 30%, and (c) 45%
3.5. Color
Chocolate with good quality has a light brown color, does not change easily, and is shiny [21]. The color of chocolate varies greatly depending on the composition and the process of making chocolate. Changes in the brightness level of the chocolate is mainly influenced by the presence of sugar and/or fat bloom.

In this study, the $L^*$ value increased as the proportion of stevia increased and the proportion of inulin decreased (Figure 6). The inclusion of inulin in chocolate produces chocolate with a darker color [22]. The value of $a^*$ tended to fluctuate (Figure 7) and the value of $b^*$ increased significantly ($p < 0.05$) (Figure 8). The appearance of chocolate with different stevia proportion can be seen in Figure 9.

![Figure 6. L* values of red velvet compound chocolates](image)

![Figure 7. $a^*$ values of red velvet compound chocolates](image)

![Figure 8. $b^*$ values of red velvet compound chocolates](image)

![Figure 9. Appearance of chocolate with stevia proportion of (a) 15% (b) 30%, and (c) 45%](image)

3.6. Hardness
Moisture content and particle size distribution are determinants of hardness [21]. The higher water content value, the higher the hardness of chocolate is [19]. The lower the particle size, the harder the
chocolate is [19]. However, in this study, chocolate with stevia proportion of 15% had a lower hardness than chocolate with a higher proportion of stevia (Figure 10). It seemed that the role of moisture and particle size in determining the hardness of compound chocolate was not as high as the role in determining the hardness of cocoa butter-based chocolate.

![Figure 10. The effect of stevia proportion on the hardness of compound chocolate](image)

3.7. Melting point
Chocolate made from cocoa butter melts perfectly at body temperature (33-34°C). Whereas, chocolate made from CBS has a melting point ranging from 38 to 49°C [23]. It can be seen (Figure 11) that red velvet compound chocolate made with lower proportion of stevia had propensity to exhibit slightly lower melting point than red velvet compound chocolate made with higher proportion of stevia. However, the values were similar (still in the range) to the ones in the literature. Slight differences observed could be due to the manual measurement.

![Figure 11. The effect of the proportion of stevia on the melting point of red velvet compound chocolate](image)

4. Conclusion
Based on the research that has been done, it can be concluded that the use of alternative sweeteners in the form of stevia and inulin affects the characteristics (moisture content, particle size, color, hardness, and melting point) of red velvet compound chocolate to some extent. The substitution of cocoa butter with CBS can also increase the melting point of the chocolate.

References
[1] Lipp M and Anklam E 1998 J. Food Chemistry 62 73–97
[2] Cisse V and Yemiscioglu F 2019 Cukurova J. Agric. Food Sci. 34 37–50
[3] Aidoo R P, Afoakwa E O and Dewettinck K 2015 LWT-Food Science and Technology 62 592–7
[4] Aidoo R P, Depypere F, Afoakwa E O and Dewettinck K 2013 Trends in Food Science & Technology 32 84–96
[5] Jeffery M S 1999 Food Technology 47 141–4
[6] Afoakwa E O, Paterson A, and Fowler M 2007 European Food Research and Technology 226 1259–68
[7] Saputro A D, Walle D V, Aidoo R P, Mensah M A, Delbaere C, Clercq N D, Durme J V and Dewettinck K 2016 Eur Food Res Technol. 177–91
[8] Aidoo R P 2014 Functionality of inulin and polydextrose in stevia or thaumatin sweetened dark chocolate Ph.D Thesis (Belgium: Ghent University Belgium)
[9] Saputro A D, Walle D V, Hinneh M, Durme J V and Dewettinck K 2017 European Food Research and Technology 244 1281–92
[10] Saputro A D, Walle D V and Dewettinck K 2019 Sugar Tech. 21 862–7
[11] Saputro A D, Walle D V, Caiquo B A, Hinneh M, Kluczykoff M and Dewettinck K 2019 Food Science and Technology 100 10–9
[12] Hinneh M, Walle D V, Haeck J, Abotsi E E, Winne A D, Saputro A D, Messens K, Durme J V, Afoakwa E O, Cooman L D and Dewettinck K 2019 J. Food Engineering 253 59–71
[13] Nafingah R, Kurniasari J, Cahyani A, Harmayani E and Saputro A D 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012043
[14] Kurniasari J, Cahyani A, Nafingah R, Rahayoe S, Harmayani E and Saputro A D 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012042
[15] Cahyani A, Kurniasari J, Nafingah R, Rahayoe S, Harmayani E and Saputro A D 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012041
[16] Kortei N K, Odamtten G T, Obodai M, Appiah V, Akonor P T and Ae B 2015 Journal of Food Science, Biotechnology and Nutrition 10 66–71
[17] Beckett S T 2009 Industrial chocolate manufacture and use (York, UK: Wiley–Blackwell)
[18] Aidoo R P, Afoakwa E O and Dewettinck K 2014 J. Food Eng. 126 35–42
[19] Saputro A D, Walle D V, Kadivar S, Sintang M D, Meeren P V and Dewettinck K 2017 Eur Food Res Technol. 243 1729–38
[20] Beckett S T 2000 The Science of Chocolate (London: Royal Society of Chemistry Paperbacks)
[21] Afoakwa E O 2010 Chocolate Science and Technology 2nd Edition (York, UK: Wiley–Blackwell)
[22] Bolenz S, Amtsberg K and Schape R 2006 J. Food Science and Technology 41 45–55
[23] Isyanti M, Sudibyo A, Suprijatna D and Suherman H 2015 Warta IHP/ J. Agro-Based Industry 32 33–44