Impact of Cocoa Butter Replacer (CBR) proportion on the physical characteristics of compound dark chocolate

N S Syafira¹, A D Saputro¹*, A N Khasanah¹, T Oetama², A D Setiowati³, S Rahayoe¹ and N Bintoro¹

¹Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia
²Wilmar Group Indonesia
³Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia

Corresponding author: arifin_saputro@ugm.ac.id

Abstract. Dark chocolate that is made from 100% cocoa has a melting point in the range of 33-34°C. Because of that, dark chocolate easily melts at room temperature. The melting point of dark chocolate can be increased by adding Cocoa Butter Replacer (CBR). The aim of this study was to examine the impact of CBR on the several characteristics of dark chocolate, including moisture content, particle size, density, color, hardness, and melting point. Proportion of CBR used on this research were 0%, 70%, 75%, 80%, 85%, and 90%, while duration of crystal maturation applied was 12 day. The results showed that the higher amount of CBR added to chocolate was followed by the higher value of hardness, L*, a*, b*, and melting point.

1. Introduction
Chocolate is a candy-like product made from the seeds of the cacao plant (*Theobroma cacao* L). Drinks and foods from chocolate are greatly demanded by the community because of its taste, aroma, and color [1]. There are several types of chocolate, such as dark chocolate and milk chocolate. Dark chocolate is made from sugar, cocoa butter, and cocoa beans while milk chocolate is added with milk powder [2]. The proportion of the ingredients affect the characteristics of chocolate.

Cocoa fat contains triglycerides that are composed of palmitic acid, stearic acid, and oleic acid [3]. Because of that, cocoa butter has a melting point of 33-34 °C [4]. This melting point makes chocolate as a unique food. However, in the tropics this melting point can be a problem. Chocolate can melt before reaching the consumer. In order to cope with it, partial/full replacement of cocoa butter with vegetable fat can be applied.

Several types of fat that can be used to replace cocoa butter are fat fractions derived from vegetable oil i.e, shea and illepe oil [4,5]. Commercially, there is a fat that is often used as a substitute for cocoa butter, namely Cocoa Butter Replacer (CBA). CBA can be divided into Cocoa Butter Replacer (CBR), Cocoa Butter Substitute (CBS), and Cocoa Butter Equivalent (CBE). In this study, CBR was chosen for chocolate making. This study aimed to investigate the impact of partial replacement of cocoa butter with CBR on the physical characteristics of chocolates. Hardness, color, and melting point of chocolates were measured. The chocolate samples was tested at day 12 of crystal maturation.
2. Methodology

2.1. Research location
This research was conducted in the Laboratory of Food and Postharvest Engineering, Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada.

2.2. Materials
The materials used in this study were cocoa mass and cocoa butter from Indonesian Coffee and Cocoa Research Institute, Jember, cocoa powder from Chokless, Yogyakarta, cocoa Butter Replacer (CBR) from Wilmar Group Indonesia, and sucrose (sugar) purchased in the local supermarket. The physical characteristics of the raw materials used can be seen in Table 1.

| Raw material   | Parameter         | Water content (%) | Fat Content (%) | Fineness Modulus |
|----------------|-------------------|-------------------|-----------------|------------------|
| Sugar          |                   | 0.09 ± 0.01       | -               | 2.83 ± 0.06      |
| Cocoa Powder   |                   | 2.60 ± 1.01       | 11              | 0.02 ± 0.01      |
| Cocoa Mass     |                   | -                 | 52.42           | -                |

2.3. Sample preparation
Dark chocolate is made with proportion of fat: 36%, sugar: 40% and cocoa solid particles: 24%. The fat used in the chocolate production is a mixture of cocoa butter and CBR in a certain proportion. The proportion of CBR: Cocoa Butter (CB) ratio used in this study were 70%:30%, 75%:25%, 80%:20%, 85%:15%, and 90%:10%. The proportion of 0%:100% was used as reference. The samples were coded as mentioned in Table 2.

| Total Fat Content | CBR: Cocoa Butter (%) |
|-------------------|-----------------------|
|                   | 0:100                 | 70:30 | 75:25 | 80:20 | 85:15 | 90:10 |
| 36%               | CBR0                  | CBR70 | CBR75 | CBR80 | CBR85 | CBR90 |

(Reference)

2.4. Chocolate processing
Chocolate was produced using an alternative method [6]. An alternative method is normally done using ball mill or melanger. In this study, a melanger was used in order to reduce the losses [6,7]. The ingredients were mixed and grounded in the melanger for 10 hours. During the process, the chocolate mass was periodically (every 1 hour) subjected to hot air for 10 minutes. This heating process aimed to evaporate water and other volatile substances. Afterwards, the molten chocolates containing CBR were directly molded. However, chocolate without CBR was tempered prior to molding process. To remove air bubbles, the chocolate was placed on a vibrating table. Subsequently, the chocolate was stored in the thermostatic cabinet at 15 ℃ for 1 hour. After 1 hour, chocolate was demoulded and stored for 12 days at 15 ℃ for maturation.

2.5. Analytical methods

2.5.1. Moisture content. The moisture content of dark chocolate was measured using thermogravimetric method. Dark chocolate samples were put in the oven at 105 ℃ for 24 hours. The moisture content of dark chocolate can be determined using equation 1.
\[
\text{Moisture content (wb)} = \frac{\text{mass of water}}{\text{mass of water} + \text{mass of solid part}} \times 100\% \tag{1}
\]

2.5.2. Particle size. The measurement of dark chocolate particles was carried out following methods developed by Cahyani et.al [8], Kurniasari et.al [9] and Nafingah et.al [10]. The particle size of the chocolate was measured using a microscope (Olympus CX23LEDRF) equipped with an optilab camera (Advance Plus). To measure chocolate particles, a 0.5 gram of molten chocolate was taken and dissolved in 10 ml of cooking oil. Afterwards, the dark chocolate dispersion was put in the oven at 55°C for 1 hour. One drop of the dispersion was transferred to the object glass for the observation.

2.5.3. Color. Chromameter (Minolta CR-400) was used for color measurement. \(L^*\) value (brightness) ranges from black (0) to white (100), \(a^*\) indicates green (-60) to red (+60) and \(b^*\) indicates blue (-60) to yellow level (+60) [11].

2.5.4. Hardness. The measurement chocolate hardness was conducted using a texture analyzer with a TA39 probe (\(D = 2\) mm). The speed of the probe is 0.5 mm / second with a target press of 3 mm. In this study, hardness measurements were carried out following methods developed by Cahyani et.al [8], Kurniasari et.al [9] and Nafingah et.al [10].

2.5.5. Melting point. The melting point of chocolate was manually measured by placing the chocolate (1x1 cm) into a 250 ml beaker filled with water in a water bath. At the beginning of the measurement, the temperature was set at 27 °C and increased by 1 °C per minute. When the chocolate was completely melted, the temperature was recorded as melting point.

2.5.6. Data analysis. Data analysis in this study was carried out using the IBM Statistics SPSS version 21.0. The significance level used in this analysis was 5%. Before the Analysis of Variance (ANOVA) test was applied, the homogeneity test was performed with Levene’s test. Tukey was used to determine the differences of the samples. Aside from ANOVA, Principal Component Analysis (PCA) was used to determine the relationships among parameters.

3. Results and discussion

3.1. The relationship among quality parameters of dark chocolate

The proportion of CBR and CB in this study affected the final characteristics of chocolate bar. Principal Component Analysis explained more than 96.26% variance in the first two factors, namely PC1: 53.84% and PC2: 42.42%. In general, the difference in the proportion of CBR:CB can be seen along PC 1. From Figure 1, it can be seen that the moisture content, hardness and brightness were located at the same cluster. The increase in water content was directly proportional to the increase of hardness and brightness. The melting point parameter is located at cluster 2, where the value was inversely correlated to the parameters in cluster 1. The higher the melting point of dark chocolate, the lower the moisture content, hardness, and brightness of chocolate.

From Figure 2, it can be seen that reference chocolate (chocolate without CBR) was located at the same place as cluster 1 (Figure 1). Because of that, the reference sample exhibited the highest moisture content, hardness, and brightness values among chocolate samples. However, the melting point of the reference was the lowest. For other samples, the higher the proportion of CBR added, the location tended to be to the left. This showed that the higher the CBR, the higher the melting point.
3.2. Moisture content

High moisture in chocolate causes the particles to coalesce into lumps so that their viscosity increases [13]. The water content of chocolate more than 2% can affect the rheology and hardness of the chocolate [2]. Therefore, the water content of the raw material should be as low as possible.

Based on the water content value shown in Table 3, it can be seen that chocolate with different proportion of CBR did not show a significant difference (p <0.05). In this study, the highest water content was 1.22%. However this result was still below the maximum water content allowed in chocolate bar products. According to Afoakwa [14], chocolate with a moisture content of 0.5-1.5% does not affect the flow properties of chocolate. Water content of more than 2% chocolate reduces the quality of chocolate due to the formation of sugar bloom.
### Table 3. Results of Measurement of Water Content at Each Variation

| Sample Chocolate | Water content (%) |
|------------------|-------------------|
| Reference        | 1.22 ± 0.07 a     |
| CBR70            | 0.91 ± 0.03 a     |
| CBR75            | 0.87 ± 0.14 a     |
| CBR80            | 0.85 ± 0.39 a     |
| CBR85            | 0.77 ± 0.04 a     |
| CBR90            | 0.77 ± 0.03 a     |

The same superscript letter showed no significant difference (p <0.05).

### 3.3. Particle size

Particle size is one of the parameters that directly affects the quality of chocolate. Good dark chocolate has a particle size lower than 30µm [11]. Large particles create a gritty texture [15]. Moreover, particle size also affects other parameters, such as hardness, flow properties and color.

Based on Figure 3, it can be seen that all chocolates tend to have comparable particle size. Compared to the reference chocolate, samples with CBR had no significant difference (p <0.05). This is due to similar duration of grinding process applied [13, 16].

![Image of particle size](a) 12-20µm  
(b) 16-21µm  
(c) 11-18µm  
(d) 9-25µm
Figure 3. Dark chocolate particle size: Reference CBR0 (a), CBR70 (b), CBR75 (c), CBR80 (d), CBR85 (e), CBR 90 (f)

3.4. Color
One of the physical characteristics of chocolate used to determine the quality of chocolate is appearance. The appearance of chocolate can be assessed by glossiness, surface smoothness and color [11]. In this study the appearance of dark chocolate was evaluated only by color (Figure 4). It can be seen in Table 4 that the brightness (L) among samples was not significantly different (p <0.05). Different results was observed in the a* and b* values. Some of the chocolates exhibited significantly different a* and b* value (p <0.05). However, no clear trend was obtained. This can be due to the different surface roughness of the chocolate. Chocolate with smoother surface had a higher lightness value. This could happen cause the light on the surface of chocolate was more evenly distributed [11,17]. Aside from this, color can be also affected by composition of the raw materials used, the production method, the tempering process, the smoothness of the surface, and the storage time [12,17].

Table 4. Color of dark chocolate

| Chocolate Samples | Color Parameters |   |   |
|-------------------|------------------|---|---|
|                   | L                | a * | b * |
| Reference         | 22.79 ± 1.42 a   | 4.52 ± 0.34 b | 3.17 ± 0.60 a |
| CBR70             | 21.55 ± 0.63 a   | 3.72 ± 0.13 a | 2.30 ± 0.48 a |
| CBR75             | 21.45 ± 1.16 a   | 4.61 ± 0.27 a | 3.39 ± 0.17 a |
| CBR80             | 20.67 ± 0.74 a   | 4.73 ± 0.47 a | 4.72 ± 0.22 b |
| CBR85             | 21.10 ± 1.44 a   | 4.75 ± 0.45 a | 4.29 ± 0.53 b |
| CBR90             | 21.49 ± 0.57 a   | 3.30 ± 0.32 b | 2.43 ± 0.29 a |

*The same superscript letter showed no significant difference (p <0.05).

Figure 4. Example of the appearance of dark chocolate after moulding (a) and on day 12 (b).
3.5. Hardness

Hardness is influenced by several factors, including moisture content, tempering method, particle size and composition [18]. According to Saputro [11], the higher the moisture content of dark chocolate, the higher the hardness value. High amount of fat content can reduce the hardness, this happens because the entire surface of the solid particles can be covered with fat, reducing the interaction among particles. Chocolate with 25% fat content has more particle-particle interactions than chocolate with 30% and 35% fat content [18].

In this study, the total fat content of all chocolates was 36%. Figure 5 showed that chocolate produced without CBR (reference) has the highest hardness compared to chocolate with CBR. This might be due to the tempering process conducted for reference chocolate.

![Figure 5](image)

**Figure 5.** The effect of CBR proportion on the hardness of dark chocolate

3.6. Melting point

Melting point is a parameter that was strongly influenced by the fat used in chocolate making. Figure 5 showed that reference chocolate exhibited the lowest melting point compared to the other chocolate containing CBR. According to Lip & Anklam [4], chocolate produced with fully cocoa butter has a melting point in the range of 33-34 °C. With the addition of CBR, the melting point of chocolate increased up to 39-42 °C (Figure 5). No significant difference (p <0.05) among chocolate containing CBR was observed.

![Figure 6](image)

**Figure 6.** The effect of CBR proportion on the melting point of dark chocolate
4. Conclusion
Dark chocolate without CBR had propensity to have a higher values of hardness, color, and moisture content, but had the lowest melting point compared to dark chocolate containing Cocoa Butter Replacer (CBR). Regardless of the CBR proportion, the particle size among samples were comparable.

References
[1] Saputro A D, Walle D V D, Hinneh M, Durme J V and Dewettinck K 2018 Eur. Food Res. Technol. 244 1281–92
[2] Beckett S T 2009 Industrial chocolate manufacture and use (York: Wiley – Blackwell)
[3] Moreno M T, Torrescana E, Salvado J S and Blanch C 2015 J. Food Chem. 166 125–32
[4] Lipp M and Anklam E 1998 AJ Food Chem. 62 73–97
[5] Oracz J, Zyzelewicz D, Budryn G and Nebesny E 2013 Eur. J. Lipid Sci. Technol. 37 87–105
[6] Hinneh M, Walle D V D, Haek 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 Eng. 253 59–71
[7] Saputro A D, Walle D V D, Caiquo B A, Hinneh M, Kluczykoff M and Dewettinck K 2019 Lwt 100 10–9
[8] Cahyani A, Kurniasari J, Nafingah R, Rahayoe S, Hermayani E and Saputro A D 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012041
[9] Kurniasari J, Cahyani A, Nafingah R, Rahayoe S, Hermayani E and Saputro A D 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012042
[10] Nafingah R, Kurniasari J, Cahyani A, Hermayani E and Saputro AD 2019 IOP Conf. Ser.: Earth Environ. Sci. 355 012043
[11] Saputro A D, Walle D V D, Aidoo R P, Mensah M A, Delbaere C, Clercq N D, Durme J V and Dewettinck K 2017 Eur. Food Res. Technol. 243 177–91
[12] Saputro A D, Walle D V D, Kadivar S, Sintang M D, Meeren P V and Dewettinck K 2017 Eur Food Res Technol. 243 1729–38
[13] Afoakwa E O 2016 Chocolate science and technology 2nd Edition (Oxford: John Wiley and Sons)
[14] Afoakwa E O 2010 Chocolate Science and Technology (York: Wiley-Blackwell)
[15] Do T A L, Hargreaves J M, Wolf B, Hort J and Mitchell J R 2007 Journal of Food Science 72 541–52
[16] Awua P 2002 Cocoa processing and chocolates manufacture in Ghana: The sucess story that demolished a myth (UK: Saffron Walden)
[17] Briones V, Aguilera J M and Brown C 2006 J. Food Eng. 77 776–83
[18] Afoakwa E O, Paterson A, Fowler M and Vieira J 2009 Int. J. Food Sci. Technol. 44 111–9