Physical characteristics of compound chocolate made with various flavouring agents produced using melanger as a small scale chocolate processing device

Z Kusumadevi 1, A D Saputro 1*, A K Dewi 1, F Irmandharu 1, T Oetama 2, A D Setiowati 1, S Rahayoe 1 and N Bintoro 1

1 Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia
2 Wilmar Group Indonesia
3 Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora No. 1, Bulaksumur, Kabupaten Sleman, Yogyakarta, Indonesia

Corresponding author: arifin_saputro@ugm.ac.id

Abstract. Chocolate bars usually use cocoa with or without milk as the ingredients. Innovative chocolate was developed in this study by replacing all cocoa solids with three different powders, namely ginger powder, coffee powder, and fruit flavored powder drinks which was combined with the use of cocoa butter substitute to increase the melting point of chocolate. An alternative processing for chocolate (using a melanger) was used in this study. The evaluated physical characteristics of chocolate were moisture content, color, hardness, melting point and particle size. The results showed that the replacement of all cocoa with or without milk solids with three different powders affected the value of moisture content, color, hardness, melting point, and particle size. Moisture content (0.74-1.3%), particle size (50-65 µm), and the color attributes were directly affected by the original color of the ingredients. The use of CBS as a substitute for cocoa butter increased the melting point of chocolate to 38-39 ºC and the hardness of chocolate to 19-24 N/mm².

1. Introduction

World data revealed that in 2017 the average of chocolate consumption was 0.9 kg per capita per year [1]. The high consumption of chocolate is based on the fact that chocolate has potential to arouse sensory pleasure and positive emotions [2]. Its unique sensorial characteristics are influenced not only by particle size distribution, melting profile, and flow behavior but also by taste and aroma (flavour) [3,4]. The aroma of chocolate is not only influenced by cocoa variety [3], but also the presence of amorphous sugar [5,6]. Due to high consumer demands for new food products, diversification of chocolate products needs to be done. For example, by replacing all cocoa with or without milk solids with other solids that have different physical and chemical properties, such as coffee, ginger, and flavored powder drinks.

Coffee is one of the most widely consumed food ingredients in the world because it has a unique taste and physical stimulant properties [7]. As reported by ICO [8], Indonesia is the second largest coffee consuming country for exporting countries after Brazil. Ginger has great potential as a functional food ingredient, such as high in antioxidants [8], anti inflammatory [9], anticancerous [10], etc. Due to its
high physiological function in the body, ginger consumption tends to increase by 21.9% during 2011-2015 [12]. Flavored powder drink is also consumed by many people because it has many advantages. It is easy to serve (takes a short time) and comes in a variety of flavors [13]. One of them is the taste of mango with a distinctive sweet and sour taste.

Conventional chocolate has several problem such as, chocolates tend to be semi-liquid or even runny under hot temperature, especially in tropical climates [14]. Based on Badan Pusat Statistik in 2015, the average maximum temperature in Indonesia reached 35°C, while chocolate melts at 32-34°C [15]. Many strategies exist to generate heat-resistant chocolate include partially or fully replacing cocoa butter with other vegetable fat which has a higher melting point such as cocoa butter substitutes (CBS) [14,16]. It was reported by Hussain et al [17] that milk chocolate made from CBS has a melting point of 39.38°C. This study aimed to examine the impact of full replacement of solid materials and the use of CBS on the physical properties of chocolate such as moisture content, color, hardness, melting point, and particle size. In this study, the chocolates were produced using melanger as a small scale chocolate processing device [4]. The minimal loss of sample makes the melanger more efficient than ball mill [4,18]

2. Materials and method

This research was conducted at Postharvest and Food Engineering Laboratory, Faculty of Agricultural Technology, Universitas Gadjah Mada. The ingredients used were ginger powder (Flozindo), coffee powder (Kapal Api), mango flavored powder drinks (JPS powder), coarse sucrose (Gulaku), and CBS provided by PT Wilmar Cahaya Indonesia. The characteristics of the ingredients used in this study can be seen in Table 1. The initial moisture content of ginger powder and mango flavored powder drinks were quite high, namely 11.56% and 3.54%. Ginger powder and mango flavored powder drinks was dried using an air-circulated dryer oven at 80 °C for 8–12 hours.

Table 1. The characteristics of chocolate ingredients

| Ingredients                  | Moisture Content (%) | Fineness modulus | Particle Diameter (mm) | L*       | a*       | b*       |
|------------------------------|----------------------|------------------|------------------------|----------|----------|----------|
| Ginger Powder                | 3.28 ± 0.03<sup>d</sup> | 4.00 ± 0.29<sup>b</sup> | 1.86 ± 0.33<sup>b</sup> | 76.4 ± 0.1<sup>c</sup> | 4.0 ± 0.1<sup>c</sup> | 23.5 ± 0.2<sup>b</sup> |
| Coffee Powder                | 1.40 ± 0.01<sup>b</sup> | 5.13 ± 0.28<sup>c</sup> | 3.69 ± 0.75<sup>c</sup> | 26.9 ± 0.0<sup>g</sup> | 13.7 ± 0.3<sup>d</sup> | 23.2 ± 0.2<sup>b</sup> |
| Mango Powder Drinks          | 1.71 ± 0.00<sup>c</sup> | 1.46 ± 0.12<sup>a</sup> | 0.29 ± 0.02<sup>a</sup> | 91.0 ± 0.2<sup>d</sup> | 3.4 ± 0.1<sup>b</sup> | 7.7 ± 0.1<sup>e</sup> |
| Coarse Sugar                 | 0.07 ± 0.00<sup>a</sup> | 5.73 ± 0.11<sup>c</sup> | 5.55 ± 0.41<sup>d</sup> | 73.8 ± 0.5<sup>b</sup> | 0.9 ± 0.1<sup>c</sup> | 7.2 ± 0.6<sup>e</sup> |

Different superscripts in the same column indicate significant differences (p<0.05) among samples

2.1. Chocolate processing

Ginger Chocolate (CJ), Coffee Chocolate (CK), and Manggo Chocolate (CM) (800 grams) were made with fat content of 34% and sugar (sucrose) content of 40%. Chocolate was produced using melanger (Wonder Premier Grinder) for 5 hours at temperatures between 60-70°C. The finished product was promptly poured into molds and shaked for approximately 2–3 min by vibrating table. Afterwards, chocolates were stored in the showcase for 13 days at 15°C prior to the measurements.

2.2. Analytical methods

2.2.1. Moisture content. Moisture content was measured by thermogravimetric method using oven (Memmert ULM400). Approximately 3 g of chocolate was heated at 105 °C for 24 hours. The moisture content of the chocolates (wb) was formulated with equation (1). Measurements were done in triplicate.

\[
\text{Moisture content (wb)} = \frac{\text{mass of water}}{\text{mass of water + mass of solid part}} \times 100\% \tag{1}
\]
2.2.2. **Hardness.** The hardness (N/mm\(^2\)) of the chocolate was evaluated with Brookfield Texture Analyzer equipped with probe TA39 (D=2mm). Measurement was carried out at room temperature of 20 °C. The probe was set with speed of 0.5 mm/s and penetrated 3 mm into the bars [19,20]. Measurements were done in triplicate.

2.2.3. **Melting point.** The melting point of the chocolate was determined using a waterbath (Advantec model TBX272DA). The chocolate (1x1 cm) was put into a plastic spoon in a 250 ml beaker filled with water (150 ml) and heated in a waterbath. The initial temperature of the water bath was conditioned at 28 °C. After the temperature of water in the beaker was reached 27 °C followed by heating at a rate of 1°C/min until the sample melted completely. The temperature at thermocouple was recorded as the melting point of the chocolate.

2.2.4. **Color.** Color of the chocolate was measured using a chromameter (Minolta CR-400). The machine was calibrated with a white reference standard before the determinations. Color parameters were expressed in CIE L* a* b* system. The color space parameters L* (lightness, ranging from zero (black) to 100 (white), a* (ranging from +60 (red) to -60 (green) and b* (ranging from +60 (yellow) to –60 (blue) were measured in triplicate [21]. Measurement was carried out at room temperature of 20°C.

2.2.5. **Particle size.** Approximately 0.5 g of chocolate was dissolved in 10 ml of cooking oil and heated in an oven at 55 °C for 1 hour. After heating, the diluted chocolate was shaken vigorously. A drop of diluted chocolate was put on the object glass. The particle size of chocolate was observed using a microscope (Olympus CX23LEDRF) connected to an Optilab camera (Advance Plus). Afterwards, the observations was captured and particle size was measured using the Image Raster 3 application. The representing value was selected as the particle size of the chocolate [19,20,22].

2.2.6. **Data analysis.** Statistical analysis was performed using SPSS 26.0 Software. One-way analysis of variance (ANOVA) was used to test differences in the physical properties of ginger chocolate, coffee chocolate, and mango chocolate with 5% significance level. Testing for homogenity of variances was performed with Levene Test. After the conditions for homogenity of variances were fulfilled, Tukey test was used to determine the differences between samples. Principal component analysis (PCA) was used to visualise the relationships between chocolate samples

3. **Results and discussion**

3.1. **Effect of solid particles on the characteristics of compound chocolate**

Full replacement of fat and solid material affected the physical characteristics of chocolate bars. The physical characteristics of chocolate evaluated were moisture content, color, hardness, melting point and particle size. PCA plot in Figure 1 give a general overview of the relationship between parameters. It can be seen that PCA explained more than 96,01% variance in the first two factors, namely PC1:50,89% and PC2:45.12%. It can be seen in Figure 1 that there are two groups of quality parameters and three groups of chocolate. The first group (CM) characterized by high positive values in PC2, showed high melting point, particle size, and L* values. The second group (CJ) with high positive values in PC1, exhibited high values of hardness, a*, b*, and moisture content. The third group (CK) characterized by high negative values in PC1 and PC2 showed low value of chocolate quality parameters.

From the Figure 1, it can be seen that hardness tend to be inversely correlated to the moisture content. In the previous study, chocolate with high moisture content also exhibited high value of hardness [5]. In this study, the moisture content did not have a major effect on the hardness. The effect of the sugar network on CBS-based chocolate was not observed. Fatty acids contained in CBS highly influence the hardness and melting point of chocolate. The main fatty acids, namely lauric acid and myristic acid, have melting points of 43°C and 54°C [23].
3.2. Moisture content

Moisture content of 0.5-1.5% does not affect the flow of chocolate. However, high water content (> 2%) creates abnormal rheological behavior in the product [24,25]. The particles in chocolate stick together and cause agglomeration. Further, the presence of agglomeration results in increased viscosity and hardness [24]. It can be observed in Table 2 that chocolate with the same fat content exhibited different moisture content. This showed that moisture content of the chocolate were largely influenced by the ingredients used.

| Chocolate sample | Moisture content (%) |
|------------------|----------------------|
| CJ               | 1.30 ± 0.02<sup>c</sup> |
| CK               | 0.74 ± 0.03<sup>a</sup> |
| CM               | 0.81 ± 0.03<sup>b</sup> |

Different superscripts indicate significant differences (p<0.05) among samples

3.3. Color

Appearance involves all visual attributes including glossiness, color, shape, roughness, and surface texture [5]. In this study, color were directly affected by the original color of the ingredients. As can be
seen in Table 3, chocolate with coffee solids has smaller \( L^* \), \( a^* \), and \( b^* \) values compared to the other two chocolates. This suggested that, the characteristics of the raw material such as particle size, density, internal structure, color, and taste have the potential to influence the processing conditions required to make chocolate, the physical properties of the chocolate, and/or the sensory characteristics of the final product [26].

**Table 3. Impact of full replacement of cocoa solids with ginger, coffee, and mango powder on color parameters**

| Chocolate | \( L^* \) | \( a^* \) | \( b^* \) |
|-----------|-----------|-----------|-----------|
| CJ        | 42.79 ± 0.10\(^b\) | 8.62 ± 0.13\(^c\) | 26.9 ± 0.15\(^c\) |
| CK        | 20.00 ± 0.12\(^a\) | 5.18 ± 0.10\(^b\) | 6.2 ± 0.21\(^a\) |
| CM        | 81.83 ± 0.10\(^c\) | 7.58 ± 0.13\(^b\) | 13.84 ± 0.13\(^b\) |

Different superscripts in the same column indicate significant differences (\( p<0.05 \)) among samples.

**Figure 2.** Appearance of (a) ginger chocolate, (b) coffee chocolate, and (c) mango chocolate

The appearance of chocolate can also be seen from the glossiness of chocolate. The results showed that (Figure 2) all types of chocolate had similar level of glossiness. The chocolates did not show any fat or sugar blooms after 13 days of storage. According to Wang et al. [27], Chocolate produced from hydrogenated palm kernel oil (CBS) has a slower bloom rate than chocolate produced from completely cocoa butter.

3.4. **Hardness**

The fatty acid composition largely determines the melting point of chocolate and the hardness of chocolate [28]. The use of CBS as a substitute for cocoa butter is known to increase the hardness of chocolate [16]. In addition, the particle size and moisture content also influence the hardness of chocolate [24,25]. Based on Figure 3, the source of solid particles influenced the hardness of chocolates. Chocolate with mango flavored powder drink and ginger solids shows a higher hardness than chocolate with coffee. This can be due to the composition of powdered drinks containing stabilizers which have strong binding properties making chocolate a higher hardness [29].
3.5. Melting point

The melting point of chocolate bars is highly influenced by fat content. Moreover, the melting point of fat is highly dependent on the fatty acids contained in the fat [30]. Based on the results reported by Hussain et al. [17] milk chocolate made from CBS has a melting point of 39.38 °C. Figure 4 shows that all chocolates exhibited higher melting point (in the range of 38-39.5 °C) than the conventional chocolate. Chocolate with cocoa butter melts at 32-35 °C [15]. It can be seen that the moisture content did not have a major effect on the hardness and melting point of chocolate with CBS. The effect of the sugar network on CBS-based chocolate was less visible. Slight differences in the hardness can be due to the manual measurement used.

3.6. Particle size

Particle size determines consumer perception when chocolate is in the mouth. A large particle size (> 30 µm) produces coarse or gritty (sandy) texture [31,32]. Solid materials had a large influence on the particle size of chocolate. Figure 5 shows that at the same fat content, chocolate showed a significantly different particle size (p <0.05). Coffee chocolate had a smaller particle size than ginger and mango chocolate. It can be seen in Figure 6 that all types of chocolate exhibited particle size in the range of 50 to 65 µm.

Compared to the initial particle diameter of the coffee powder, the others two powders had a smaller particle size. However, the particle size of the chocolate made with coffee powder is the smallest. This suggested that the characteristics of the raw material such as brittleness, density, internal structure highly influenced the grinding process.
Figure 5. Impact of full replacement of cocoa with ginger, coffee, and mango powder on particle size

Figure 6. Particle size of (a) ginger chocolate, (b) coffee chocolate and (c) mango chocolate in 10x magnification

4. Conclusion
The results showed that replacement of cocoa solids with or without milk solids with three different powders affected the value of moisture content, color attributes, hardness, melting point, and particle size. The use of CBS resulted in chocolate with melting point of 38 to 39 °C

References
[1] CBI 2019 What is the demand for cocoa on the European market?.cbi [cited 6 August 2020] Available from https://www.cbi.eu
[2] Macht M and Dettmer D 2006 Appetite 46 332–6
[3] Saputro A D, Walle D V D, Hinneh M, Durme J V and Dewettinck K 2018 *Eur. Food Res. Technol.* **244** 1281–92

[4] Hinneh M, Walle D V D, Haeck J, Enorkplim E, Winne A D, Messens K, Durme J V, Ohene E, Cooman L D and Dewettinck K 2019 *Journal of Food Engineering* **253** 59–71

[5] 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

[6] Saputro A D, Walle D V D, Kadivar S, Mensah M M, Durme J V and Dewettinck K 2017 *Eur. Food Res. Technol.* **243** 955–67

[7] Huang M and Zhang M 2013 *Handbook of Food Powders: Processes and Properties* ed Bhandari B R, Bansal N, Zhang M, Schuck P (UK: Woodhead Publishing) 513–31

[8] International Coffee Organization 2020 World coffee consumption. *ico* [cited 31 Mei 2020] Available from: http://www.ico.org

[9] Si W, Ping Y, Zhang J, Chen Z and Yin H 2018 *Food Chem.* **239** 1117–25

[10] Grzanna R, Lindmark L and Frondoza C G 2005 *J. Med. Food* **8** 125–32

[11] Habib S H M, Makpol S, Hamid N A, Das S, Ngah W Z W and Yusof Y M 2008 *Clinics (Sao Paulo)* **63** 807–13

[12] Salim Z and Munadi E 2017 *Info Komoditi Tanaman Obat* (Jakarta: Badan Pengkajian dan Pengembangan Perdagangan Kementerian Perdagangan Republik Indonesia)

[13] Permata D A and Sayuti K 2016 *Jurnal Teknologi Pertanian Andalas* **20** 44–9

[14] Stortz T A and Marangoni A G 2011 *Trends Food Sci. Technol.* **22** 201–14

[15] Lai O M, Lo S K and Akoh C C 2012 *Palm oil: Production, processing, characterization and uses* ed Lai O M, Tan C P and Akoh C C (Urbana: AOCS Press) 527–43

[16] Rector D 2000 *The Manufacture of Confectionary* **80** 63–70

[17] Hussain N, Aya B, Agus P, Nur S, Abdul F and Sa H 2018 *MOJ Food Processing & Technology* **6** 292–6

[18] Saputro A D, Walle D V D, Antan B, Hinneh M, Kluczyko M and Dewettinck K 2019 *LWT - Food Science and Technology* **100** 10–9

[19] Kurniasari J, Cahyani A, Nafingrah R, Rahayoe S, Harmayani E and Saputro A D 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **355** 012042

[20] Nafingrah R, Kurniasari J, Cahyani A, Harmayani E and Saputro A D 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **355** 012043

[21] Kortei N K, Odamten G T, Mary O, Appiah V and Akonor P T 2015 *Croatian Journal of Food Technology, Biotechnology and Nutrition* **10** 66–71

[22] Cahyani A, Kurniasari J, Nafingrah R, Rahayoe S, Harmayani E and Saputro A D 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **355** 012041

[23] Timberlake K C 2016 *General, organic, and biological chemistry: Structures of Life* vol 5 (US: Pearson)

[24] Afoakwa E O, Paterson A and Fowler M 2007 *Trends Food Sci. Technol.* **18** 290–8

[25] Beckett S T 2008 *The Science of Chocolate* (Cambridge: RSC Publishing)

[26] Liang B and Hartel R W 2004 *Journal Dairy Science* **87** 20–31

[27] Wang F, Liu Y, Shan L, Jin Q, Wang X and Li L 2010 *J Am Oil Chem Soc* **87** 1137–43

[28] Ramlah S and Lullung S A 2018 *Jurnal Industri Hasil Perkebunan* **13** 117–28

[29] Tranggono S, Haryadi, Suparmo A, Murdiati S, Sudarmadji K, Rahayu S, Naruki and Astuti M 1991 Bahan Tambahan Makanan (Food Additives) *PAU Pangan dan Gizi* (Yogyakarta: Universitas Gadjah Mada)

[30] Asmawit 2012 *Biopropal Industri* **3** 17–21

[31] Afoakwa E O 2010 *Chocolate Science and Technology* 2nd Edition (York: Wiley-Blackwell)

[32] Do T A L, Hargreaves J M, Wolf B, Hort J and Mitchell J R 2007 *Food Engineering and Physical Properties* **72** 541–52