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Characteristics of dark chocolate produced using tengkawang (*Shorea sumatrana*) fat in various substitution levels

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Abstract

Dark chocolate is a variant of chocolate products made by emulsifying a mixture of sugar, vanilla, milk, and cocoa powder into cocoa butter (CB) with the addition of lecithin as an emulsifier. Substitution of CB with other fats such as fat from tengkawang (*Shorea sumatrana*) seeds (TF) is possible in making dark chocolate because both have almost the same characteristics. This study aimed to determine the effect of TF as a CB substituent on the physical and organoleptic properties of dark chocolate and to determine the optimal percentage of substitution to produce dark chocolate with characteristics that are not different from those without substitution. The study was arranged in a completely randomized design with six levels of CB/TF ratio (P) treatment which was repeated 3 times. The six treatment levels included were: P0 = 100/0, P1 = 90/10, P2 = 80/20, P3 = 70/30, P4 = 60/40 and P5 = 50/50. The substitution of CB with TF significantly affected the physical and organoleptic properties of dark chocolate, especially on the melting point, fat blooming and its acceptance level on odor and taste. Based on the level of panelist acceptance, the percentage limit for CB substitution with TF should not be more than 20% to produce a chocolate taste with high preference.

1. Introduction

Cocoa butter is not always available and therefore at certain times, it becomes very expensive. Replacing some of the butter with other vegetable oils can reduce chocolate production costs (Budianto and Kusmardini, 2021). Several types of vegetable oils that can be used to substitute CB include TF (also known as illipe nut fat or shorea fat), mango seed fat, bambangan kernel fat, shea butter, kokum butter, sunflower stearin and palm oil mid fraction (Norazlina *et al*., 2021; Ornla-ied *et al*., 2022). Cocoa butter and its fat substituents act as a dispersing matrix for solid particles in the dough which is generally a mixture of cocoa powder, sugar, vanilla and milk (Ramlah *et al*., 2019; You *et al*., 2023). Care must be taken to ensure that the substitute does not negatively impact the taste or texture of the chocolate. Cocoa butter possesses unique melting properties that play a crucial role in determining the texture, mouthfeel, and overall sensory experience of chocolate. These properties are influenced by the composition of CB, which contains a mixture of different types of triglycerides (Cooney *et al*., 2023).

Making chocolate using CB blended with equivalent fat has been widely carried out such as using coconut oil, coconut cream, and coconut milk for increasing oxidative stability (Divya *et al*., 2017), mango seed kernel fat to improve shelf-life (Naeem *et al*., 2019), CB substitute from coconut oil to increase the stability of chocolate against bloom formation (Halim et al., 2019), xanthan gum and guar gum blends to increase the melting point (Amir *et al*., 2013), blend's components of xanthan gum, corn starch, and glycerin to increasing the viscosity and yield stress of chocolate (Syafiq *et al*., 2014).

Tengkawang seed fat is a fat that contains medium chain fatty acids which are easily digested and oxidized by the body, has almost the same chemical properties as CB, such as palmitic acid content (19.65 %), stearic (44.58%), oleic (32.34%) and linoleic (0.55%) (Maharani *et al*., 2016). Tengkawang seed fat is considered to be a CB equivalent; it has similar physical and chemical properties that can be directly blended with CB in unlimited quantities (Aumpai *et al*., 2022; Darmawan *et al*., 2022). Tengkawang seed fat has

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widely used in making lipstick or lotions (Warnida *et al*., 2020; Darmawan *et al*., 2021; Butar-Butar *et al*., 2021; Desnita *et al*., 2022) and also used in making chocolate (Bahari and Akoh, 2018; Mursalin and Yernisa, 2021; Budianto and Kusmardini, 2021; Podchong *et al*., 2023). So far, research on substituting CB with TF in making chocolate has very rarely been published. In fact, this is important as information for the development of processed chocolate products at low prices in the future.

This research aimed to determine the effect of TF level substituted for CB on the physical and organoleptic properties of dark chocolate and the maximum addition of TF can still produce dark chocolate with high acceptability.

2. Materials and methods

2.1 Materials and equipment

This research was carried out in July-November 2022. The materials used in this research were TF, CB, cocoa powder, refined sugar, lecithin, and vanilla. The equipment used were a grinder, roaster, mixer (Miyako HM0620, Japan), stainless steel container, rattan tray, 60 mesh sieve, measuring cups, analytical scales, glassware, and plastic zip locks. The instruments used for analysis were color reader, capillary tube, Erlenmeyer flask, thermometer, magnetic stirrer, and stopwatch.

2.2 Methods

The research was done in a completely randomized design with 6 treatments of CB and TF comparison (100/0; 90/10; 80/20; 70/30; 60/40; and 50/50). Ingredients and formulations of dark chocolate formula were as follows. In 500 g of the formula consists of 100 g cocoa powder (20%), 150 g powdered sugar (30%), 10 g vanilla (2%), 24 g lecithin (4.8%), and fat (a mixture of CB and TF) 216 g (43.2%). The process of making dark chocolate was followed according to the method developed by Beckett's Industrial Chocolate Manufacture and Use (Beckett *et al*., 2017). The ingredients were first weighed according to the formulation, the cocoa butter was melted, and all the ingredients apart from the fat were mixed separately. Finally, all the ingredients were mixed together until a smooth dough was formed. The blend of Cb and TF was melted by heating at 50°C using a water bath. The mixture of cocoa powder, sugar and vanilla was called dough 1. To make the whole dough, dough 1 plus 1/3 of the lecithin was added to the liquid CB blended while stirring at 97 rpm for 10 mins. After that, the conching process was carried out at a stirring speed of 60 rpm at 45°C for 8 hrs. An hr before the end of the conching process, another 2/3 of the lecithin was added to the dough. Tempering was done to stabilize the dough after conching, it was carried out by heating the dough successively at 50°C, 28°C; and 32°C for 10 mins. Finally, to give an attractive shape and appearance, dark chocolate was then put into a mold and cooled at 4°C for 24 hrs.

2.3 Parameters

The parameters observed in this research were the melting point, color, fat blooming, and level of acceptance of the dark chocolate produced. The melting point was determined based on the temperature of frozen chocolate pieces in a capillary tube heated at a rate of 1°C/min (Amir *et al*., 2013). Color was analysed using the CIE-lab method (León *et al*., 2006), carried out by placing the sample in the middle of 50×50×50 cm box with 4 neon lights and photographing it using Canon EOS 1200D Kit camera which has 18MP resolution and a CMOS sensor, ISO 100-12800, shutter speed 30-1/4000 seconds. The photos were cropped and analyzed for L* (lightness), a* (redness), and b* (yellowness) values using Adobe Photoshop CS5. Color description based on L*, a*, and b* values. L value from 0 (black) to 100 (white), +a (positive) value from 0-100 for red, –a (negative) value from 0-(-80) for green, +b (positive) value from 0-70 for yellow, and a -b (negative) value from 0-(-70) for blue. Fat blooming was measured based on the increase of the whiteness index of chocolate during 30 days of storage at room temperature (Hasibuan *et al*., 2015). The level of acceptance of taste, texture, and aroma was determined based on hedonic tests using 25 semi-trained panelists (Setyaningsih *et al*., 2019). The data obtained were analyzed for variance (ANOVA) and continued with Duncan's New Multiple Range Test (DNMRT) at a 95% confidence level.

3. Results and discussion

3.1 Melting point

The melting point of dark chocolate increases with increasing TF concentration (Table 1). Increasing TF substituents has a significant effect on the melting point of dark chocolate. The more CB substituted with TF, the higher the melting point of the chocolate produced.

Increasing the amount of TF in the formulation increases the melting point of the chocolate produced, this occurs because TF has a high melting point. The melting point of CB used in the research was 32°C while TF was 38°C. CB-TF blended produced chocolate with a melting point ranging 35.0-37.6°C (Table 1). Increasing the melting point can increase the stability of chocolate, it makes the chocolate not melt easily at room temperature, which is known as a heat-resistant chocolate (Bangun *et al*., 2022). Good chocolate is indicated by its properties such as perfectly melting inside the mouth instead of melting at room temperature

(Jahurul *et al*., 2013). However, chocolate is expected to melt completely at oral temperature (37°C) while releasing a pleasant distinctive flavor (Suri and Basu, 2021). Consequently, the melting point limit for chocolate is 37°C. Thus, based on Table 1, it is known that the permitted substitution limit for CB with TF is 40%, which produces chocolate with a melting point of 36.5°C.

Table 1. Melting point of dark chocolate at various levels of CB substitution.

CB/TF	Melting point (°C)
100/0	34.0^{a}
90/10	35.0^{ab}
80/20	35.3^{ab}
70/30	36.0^{abc}
60/40	36.5^{bc}
50/50	37.6^{c}

Values with different superscripts are statistically significantly different at the 5% level according to the DMNRT test.

The increase in the melting point of chocolate due to the addition of TF is thought to be because TF is better able to increase the binding of chocolate powder, thereby forming a stronger agglomeration system. This causes the chocolate to become more stable and melt at higher temperatures. Meanwhile, TF can also play a role in inhibiting the migration of cocoa oil in chocolate, making it have a higher melting point than regular chocolate (Suri and Basu, 2021).

3.2 Color

Substitution of CB with TF has no significant effect on the L*, a* and b* values. The L*, a*, b* values and description of the dark chocolate color can be seen in Table 2. The L* value of chocolate is 38.67-39.6 (less bright) with a* being positive 8.0-8.6 (leading to red) and b* also positive 19.3-19.7 (leading to yellow). Thus, this chocolate is described as a very dark desaturated orange.

Table 2. Color description of dark chocolate at various levels of TF substitution.

CB/TF	L*	a*	b*	Color Description
100/0	39.60	8.60	19.60	Very Dark Desaturated Orange
90/10	39.30	8.60	19.60	Very Dark Desaturated
80/20	39.00	8.70	19.70	Very Dark Desaturated
70/30	39.30	8.30	19.30	Very Dark Desaturated
60/40	39.00	8.00	19.30	Very Dark Desaturated
50/50	38.67	8.00	19.30	Very Dark Desaturated Orange

Based on Table 2, it is known that substitution with TF up to 50% does not cause a significant change in chocolate color, so the color parameter cannot be used as a benchmark for determining the limit of CB substitution. However, the CIE Lab values for dark chocolate are typically L*: 20-40 (dark brown), a*: 0-10 (red may be weaker or almost neutral), and b*: -10 to 5 (indicates blue to neutral color) (Hernández-Ortega et al., 2022). Based on these limitations, chocolate produced from CB substitution with TF is indicated to have a slightly different color from chocolate without CB substitution. The chocolate has colour with lack of blue elements (the b value is close to 20, far from the standard range of -10 to 5).

3.3 Fat bloom

The addition of TF as a substitute for CB in certain formulations can improve the anti-blooming properties of chocolate (Table 3). During storage, the saturation index (L* value) of chocolate will increase due to the transformation of the white tinge on the surface of the chocolate into spots. The whiteness index of chocolate is determined by the magnitude of the increase in the L* value. For example, for chocolate without the addition of TF, on day 27 it has an L* of 40.29 while on day 0 it is 39.10; This means that the whiteness index of the chocolate was calculated at 1.74% on day 27 (Table 3).

Table 3 shows the blooming of chocolate (marked by a whiteness index of more than 2,00) began to appear at day 30 (week 4) and tended to decrease in line with increasing of TF in the formulation. The presence of TF

Table 3. Percentage of chocolate whiteness index in various of CB/TF formulation.

CB/TF	Whiteness index of chocolate (%) after storage (days)										
	0	3	6	9	12	15	18	21	24	27	30
100/0	0.00	0.00	0.03	0.10	0.25	0.33	0.48	0.56	0.90	1.74	2.30
90/10	0.00	0.03	0.00	0.13	0.20	0.27	0.41	0.47	0.81	1.65	2.14
80/20	0.00	0.00	0.04	0.08	0.12	0.17	0.29	0.33	0.67	1.51	1.95
70/30	0.00	0.03	0.03	0.06	0.10	0.14	0.25	0.29	0.62	1.45	1.86
60/40	0.00	0.00	0.02	0.10	0.09	0.13	0.24	0.28	0.60	1.44	1.82
50/50	0.00	0.00	0.03	0.06	0.10	0.14	0.26	0.30	0.64	1.50	1.89

Whiteness index more than 2% indicates that chocolate is detected to be blooming.

in the formulation tends to prevent the mobility of cocoa oil in chocolate. It means that TF has a positive contribution in preventing fat blooming. This is in line with Bahari and Akoh finding, that chocolate formulations containing the illipe butter can help prevent dark chocolate fat blooms (Bahari and Akoh, 2018). Based on fat blooming, the higher the level of substitution, the more stable the chocolate produced. This means that substitutions can be made up to 50%.

In chocolate, there are micropores that facilitate the migration of some of the cocoa oil that melts due to being at high temperatures. When this melt turns back into a solid it will form a whitish tinge which will fade the color of the chocolate, this is called blooming (Briones and Aguilera, 2005). Chocolate which has a lower density and wider micropores turns out to bloom faster (Ekantari *et al*., 2019). Different compositions in chocolate formulations have an effect on the formation of chocolate microstructure which greatly determines its bloom properties (Afoakwa, 2016).

3.4 Level of acceptance

Panelists' preferences for dark chocolate in this study were measured based on 3 indicators, namely aroma, texture and taste. Of the three indicators, only texture was not affected by the substitution of CB for TF. The more TF in the formulation, the panelists' preference levels tended to decrease for all sensory attributes of chocolate (Table 4). The more TF replacing CB tends to produce chocolate with a decreasing level of preference.

3.5 Aroma

Tengkawang fat is often integrated into food or cosmetic product formulations because it has a neutral to slightly distinctive aroma that is not dominant. The aroma of tengkawang fat varies depending on the type of Shorea and the extraction method used. Some types of tengkawang have a distinctive sharp aroma while others do not have any striking characteristics that could interfere with the aroma of the final product. In several regions in Southeast Asia, the distinctive aroma of tengkawang fat is often used as a special attraction in their traditional culinary delights (Gusti and Waluyo, 2016). In this research, TF was extracted from *Shorea sumatrana* seeds which grow widely in Sarolangun Regency, Jambi, Indonesia. Determining the type of shorea is based on the similarity in appearance of the fruit, leaves and stems of the same type studied by previous researchers (Fahmi *et al*., 2018; Riski *et al*., 2020).

Based on Table 4, 20% substitution is the highest limit to obtain chocolate with an aroma that is no significant difference from the control (without substitution). This is indicated the DNMRT test with an acceptance score of 2.8-3.2 (somewhat like). Substitution of CB with TF above 20% reduces the level of panelists' preference for odor chocolate. The use of TF above 20% masks the original aroma of cocoa butter and produces chocolate with a favorability score interval of 2.4-2.7 (like less to somewhat like).

3.6 Texture

Cocoa butter substitution with TF in making dark chocolate had no significant effect on its texture (Table 4). The texture assessment of dark chocolate is based on the smoothness of the product when enters the mouth. The highest score indicates the chocolate has the best texture that impresses the panelist and vice versa. The soft and stiff texture of chocolate is determined more by the conching process; namely a homogenization process combined with particle size reduction to produce chocolate with a smooth texture (Bahari and Akoh, 2018). So, even though the composition of the solid dispersing fat is not pure CB (substituted with TF), the texture will not be affected by this.

Table 4. Preference for odor, texture, taste and aftertaste of chocolate at various levels of CB substitution.

CB/TF	Odor	Texture	Taste
100/0	3.2^{b}	3.08	4.00^{c}
90/10	2.9^{ab}	3.04	3.56^{b}
80/20	2.8^{ab}	3.12	3.32^{ab}
70/30	2.7^{a}	3.24	3.12^{a}
60/40	2.6^{a}	3.28	3.04^{a}
50/50	2.4^{a}	3.12	3.00^{a}

Values with different superscripts are statistically significantly different at the 5% level according to the DMNRT test.

Acceptance score for the texture of dark chocolate ranges from 3.04-3.28 (somewhat like to like), has not produced a texture with an acceptance score of like to like very much (4-5), meaning that the conching process applied is not perfect yet and need to be improved.

A good chocolate texture is smooth and buttery which can melt gently in the mouth without leaving an unpleasant taste, this is not directly influenced by the fat used. Fat in chocolate is used to homogenize the mixed ingredients and increase the density. Apart from that, cocoa powder also plays a role in forming texture as a dispersed phase in fat (Stewart *et al*., 2018). Based on this, it was concluded that the texture of chocolate is determined more by the proportion of cocoa powder with its dispersing fat, regardless of whether the fat is pure CB or mixed with other compatible fats.

3.7 Taste

The presence of TF in chocolate dough significantly affects the taste of dark chocolate. The panelists' preference score for the chocolate taste without the addition of TF was 4 (like). The greater the concentration of TF in the formulation, the lower the panelists' preference scores (Table 4). The addition of TF at concentrations of 10 and 20% produces a chocolate taste with scores that are no different, namely 3.32-3.56 (somewhat like to like). Using TF more than 20% is no longer recommended because it will produce chocolate with an undesirable taste. This result is quite satisfactory because the substitution of 20% TF has saved a lot of chocolate production costs.

Chocolate does have a unique natural bitter taste, which arises from the presence of alkaloid components such as theobromine and caffeine, phenol and polyphenol components, several types of special peptides and free amino acids, and tannins derived from cocoa powder (Gunaratne *et al*., 2019; Dey, 2022). The natural bitter taste of cocoa combined with the sweet taste of sugar and the aroma of vanilla is a combination of taste and flavor in chocolate that consumers want when eating it. This taste sensation will be more triggered when pure CB is used as a dispersant for these components. Thus, replacing CB with other compatible fats (including TF) will certainly reduce the strong unique taste of chocolate, which will ultimately reduce the level of consumer preference.

Tengkawang seed fat has a different flavor profile than CB. TF tends to have a soft and slightly sweet taste, while CB has a strong and distinctive chocolate taste (Engeseth and Ac Pangan, 2018; Aumpai *et al*., 2022). Partial replacement of CB with TF can reduce the intensity of the chocolate flavor desired by many people. Panelists who are used to the distinctive taste of chocolate from cocoa butter may feel dissatisfied with chocolate products that have a change in taste due to the mixture of tengkawang fat. People are often accustomed to certain flavors and have strong preferences for them.

However, adding TF up to 20% only reduced the panelists' acceptance score by 11-17%, even for adding TF up to 50% the decrease was only 22-25% and was still in the somewhat favorable taste category. This means that every 10% increase in CB substitution by TF reduces the panelist preference score by 0.19 or 4.74%.

4. Conclusion

In conclusion, we found a percentage limit for the substitution of CB by TF based on its influence on the melting point, fat blooming, and acceptability of the dark chocolate produced. Based on the melting point, the permitted substitution limit for CB with TF is 40%, which produces heat resistance chocolate with a melting point of 36.5°C (meets the melting requirements right at the temperature in the mouth, namely ≤ 37°C). Based on fat blooming, the higher the level of substitution the more stable the chocolate produced, this means that substitutions can be made up to 50%. Based on the panelists' level of acceptance, the substitution percentage limit should not be more than 20% because it will produce a chcolate taste with low preference. These findings support the validity of the system for determining the amount of CB substitution in making chocolate in tropical countries, that the substitution limit must not exceed 20%. Chocolate can be produced with a substitution level of up to 20% TF with physical and sensory properties that are no different from those without substitution. These findings highlight the importance of regulating the percentage of cocoa butter equivalent that can be substituted in chocolate making, especially in tropical countries that have higher room temperatures.

Conflict of interest

The authors declare that no conflict of interest.

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