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Original Research Article

The Influence of Granulated Sugar and Cocoa Butter Substitute on The Physical Properties of Milk Chocolate Couverture: Preliminary Study

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Abstract: Milk chocolate was produced by incorporating granulated sugar and cocoa butter substitute into chocolate formulations. Modification of recipes by the addition of 5% of cocoa butter substitute and granulated sugar in the formulation to replace cocoa butter and icing sugar produced cost-effective milk chocolate. Reformulation of the chocolate recipe will reduce the amount of cocoa butter and help to reduce cost. Currently, the price of cocoa butter is very high and is exposed to large price and supply fluctuations. Granulated sugar was used in the formulation to replace icing sugar, which is pricier. These chocolates were analysed for melting profile using a differential scanning calorimeter (DSC), solid fat content (SFC) using a pulsed-nuclear magnetic resonance (p-NMR) spectrometer, particle size distribution using Malvern Master Sizer and sensory evaluation using trained panellists. The addition of 5% cocoa butter substitute and the incorporation of granulated sugar in the chocolate formulations affect the melting properties and solid fat content of the milk chocolate couverture component. The addition 5% of cocoa butter substitute in the icing sugar chocolate formulation increases the particle size of the chocolate. However, the addition of 5% cocoa butter substitute in the granulated sugar chocolate formulation decreases the particle size of the chocolate component. Sensory attributes show no significant difference (p>0.05) among all the samples.

Keywords: milk chocolate couverture; cocoa butter substitute; granulated sugar, physical properties

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1. Introduction

The five cost factors that are typically considered when pricing chocolate products for market sales are labour costs, ingredient and packaging costs, sales and marketing costs, overhead costs, and profit. The pricing strategy of chocolate manufacturers has been significantly impacted by the increasing cost of raw materials. The most affected by the rising cost of ingredients are generally cocoa butter, cocoa liquor, as well as milk powder and sugar (Thomas *et al.*, 2017). Currently, due to the rising cost of dry cocoa beans, which have reached RM18,300 per metric ton in 2025 and about RM40,000 per metric ton in 2024, the cost of cocoa butter and cocoa liquor has also shown a dramatic increase.

To create a uniform milk chocolate mixture, the cocoa butter, cocoa liquor, milk powder and sugar are combined in a refining conch, melangeur or identical equipment for mixing process purposes. Cocoa butter, as the main ingredient of the chocolate component, is pricey when compared among all the vegetable oils/fats due to the increase in market demand and its limited supply (Das *et al.*, 2021; Naik & Kumar, 2014; Wang *et al.*, 2011). Thus, the incorporation of cocoa butter substitutes that have an identical melting profile, but with different chemical composition compared to cocoa butter, is an alternative to reduce the raw material cost (Biswas *et al.*, 2016). According to Biswas *et al.* (2017), European Union Directive 2000/36/EC and Food Standards Agency 2003 limit the use of vegetable fats in chocolates to a 5 g/100 g blend.

In chocolate, the sugar component is mainly used as filler and sweetener, which influences the texture, taste, and flavour of chocolate (Chen *et al.*, 2022). The raw material cost of sugar ingredients can be reduced if fine granulated sugar is used in the production of chocolate. Lees and Jackson (1992) have posited that, in certain chocolate factories, the sugar is still customarily pre-crushed into icing or powder form before being combined with milk powder, cocoa butter, cocoa liquor, and other required ingredients and roller-refined in a single step. One item used in the production of chocolate that can be swapped out for icing sugar is granulated sugar. Based on the size of its crystals and purity, granulated sugar is ranked. All varieties of white granulated sugar have exceptionally high purity. Typically, the sucrose concentration is greater than 99.9% and just marginally less than 99.7% (Kruger, 2017). Some breakdown of granulated sugar will appear during the mixing process, with a slightly smaller effect on the size of the cocoa particles.

2. Materials and Methods

2.1. Materials

Cocoa butter and cocoa liquor were bought from the local grinder, Guan Chong Cocoa Manufacturer Sdn. Bhd., Pasir Gudang, Johor. Cocoa butter substitute Isfat H2100EM from Intercontinental Specialty Fats Sdn. Bhd., Port Klang, Selangor. Icing sugar, granulated sugar and milk powder were purchased from a local shop in the vicinity. All chemicals used were food-grade and obtained from local chemical suppliers.

2.2. Sample Preparation

Table 1 provides the components and quantities used in the creation of milk chocolate couverture chocolate samples. 1 kg of chocolate mass was used for each sample preparation. The melangeur (PG 506, Tamil Nadu, India) utilised in the processing of the samples has a rotational speed of 120 rpm. The melangeur utilises 105 mm diameter roller stones made of high-quality granite. The mixing and refining times of the samples were determined as the moment when the entire mixture started to circulate in the melangeur drum. The cumulative duration of the processing was 12 h. Lecithin and vanillin were introduced to the refining process 2 h before it ended. In the subsequent phase, the chocolate undergoes a tempering procedure. The ideal ambient temperature for chocolate tempering was around 28°C , accompanied by a relative humidity below 50%. This procedure utilises the hand tempering table top method. Once finished, the chocolate was placed into a mould for the moulding process and then chilled to a temperature of 8°C to 12°C for a duration of 1 h to solidify. . Thereafter, the chocolate samples were then carefully demoulded after 1 h and arranged directly onto trays in preparation for the packaging process. It was crucial to ensure that the finished chocolates exhibit a high standard of visual appeal at this stage, as their aesthetic presentation significantly influences consumer perception and product value. The chocolate sample storage area maintains a temperature within the range of 20°C-23°C, accompanied by a relative humidity below 60%.

2.3. Sampling Procedure

Each sample was stored at temperatures 20 ± 2℃ and kept away from heat and light prior to analysis. All the analysis of each sample was accomplished within one month of the sample preparation.

Table 1. The formulations used for the production of chocolate samples (g/100 g)

Ingredients	Icing sugar (control) (Sample A)	Granulated sugar (Sample B)	5% CBS and icing sugar (Sample C)	5% CBS and granulated sugar (Sample B)
Icing sugar	36.9	-	36.9	-
Granulated sugar	-	36.9	-	36.9
Cocoa butter (CB)	23	23	18	18
Cocoa butter substitute (CBS)	-	-	5	5
Cocoa liquor	17			
Milk powder	22.59			
Lecithin	0.5			
Vanillin	0.01			

2.4. Melting Profiles

The melting profile was determined using the differential scanning calorimeter (DSC) 8000. The methodology employed was selected in accordance with the approach proposed by Md Ali and Dimick (1994). The specimens were subjected to a temperature of 50℃ within an enclosed heating chamber. A quantity of sample weighing between 3 and 5 mg was tightly packed in an aluminium pan. The specimen underwent heating at a temperature of 60 ℃ for a duration of 30 min, followed by cooling at 0℃ for 90 min. Subsequently, it was transferred to a DSC chamber and maintained at a temperature of -25℃ for 5 min on the DSC head. The fat's melting profile was determined by measuring its temperature change at a heating rate of 20℃/min, starting from -25℃ and reaching a maximum of 5℃.

2.5. Solid Fat Content

The solid fat content (SFC) of chocolate was determined using a pulsed Nuclear Magnetic Resonance (p-NMR) spectrometer called the Newport analyser Mark 3, manufactured by Newport Parnell in England. Samples measuring 3-4 cm were placed into NMR tubes and heated to 80℃ until they melted. They were then kept at a temperature of 60℃ for approximately 25 min. Subsequently, it was subjected to a cooling process at a temperature of 0℃ for a duration of 90 min. Prior to measuring the SFC, the sample was stabilised for 35 min at each of the following temperatures: 10℃, 15℃, 20℃, 25℃, 30℃, 35℃, and 40℃.

2.6. Particle Size Distribution

The chocolate particle size was determined using the laser diffraction technique using the Master Sizer instrument from Malvern Instruments, UK. The chocolate samples were heated to a temperature of 50℃ in an oven until they melted. A beaker holding 20 mL of sunflower oil was filled with 100 mg of the chocolate sample. Next, the mixture underwent sonication in the master sizer equipment for a duration of 2 min to ensure thorough dispersion of all chocolate particles and prevent any agglomeration. When the obscuration reading reaches 0.0%, and the instrument background remains constant, the sample was then introduced into the small volume sample dispersion unit containing sunflower until the obscuration reading reaches 20%. The equipment proceeds to measure the particle size and provides the value of a distribution of the sample particle size (Malvern, UK).

2.7. Sensory Evaluation

A group of 10 experienced panellists conducted sensory evaluation sessions at the Cocoa Innovation and Technology Centre. The panellists were served with miniature bars of chocolate for evaluation, focusing on several aspects such as cocoa content, total acidity, bitterness, astringency, sweetness, roast level, presence of off-flavours, and overall quality. The method of sensory evaluation was derived from the 'Guide for the assessment of cocoa quality and flavour' (Laliberte *et al.*, 2023)..

2.8. Statistical Analyses

A one-way analysis of variance (ANOVA) and Tukey multiple comparison test were performed using MINITAB version 21 software, with a significance level of 0.05.

3. Results and Discussions

Table 2 shows the melting properties of milk chocolate couverture. The results indicated that there were significant differences in onset temperature, end temperature and delta H. No significant (p>0.05) major changes in peak temperature were detected. Peak onset (T_{onset}) reacts to the temperature at which a specific crystal form starts to melt, while peak maximum (T_{peak}) reacts to the greatest end of melting (T_{end}), and melting rate occurrence shows completion of liquefaction. The addition of cocoa butter substitute (CBS) in icing sugar formulation (Sample C) and additional CBS in granulated sugar formulations (Sample D) caused significant (p<0.05) reductions in T_{end} value from 37.85 °C to 37.91 °C and from 35.39 °C to 35.83 °C, respectively. These interpreted that the additional CBS in milk chocolate couverture leads to a longer melting period than pure milk chocolate that has fully cocoa butter (Wang *et al.*, 2010). The experimental results revealed a statistically significant (p<0.05) reduction in the endpoint melting temperature (T_{end}) of the milk chocolate couverture when icing sugar was replaced with an equivalent amount of granulated sugar. The (T_{end}) values decreased from 37.85°C (Sample A) to 35.39°C (Sample B) and from 37.91°C (Sample D) to 35.38°C (Sample C).

Table 2. Melting properties of milk chocolate couverture component

Samples	T_{Onset} (°C)	T_{Peak} (°C)	T_{End} (°C)	Delta H (J/g)
Sample A	33.03 ± 0.02[a]	34.90 ± 0.50[a]	37.85 ± 0.18[a]	7.65 ± 0.32[a]
Sample B	31.14 ± 0.03[d]	33.89 ± 0.28[a]	35.39 ± 0.21[b]	0.84 ± 0.02[c]
Sample C	31.47± 0.05[c]	34.41 ± 0.29[a]	37.91 ± 0.22[a]	2.00 ± 0.14[b]
Sample D	32.84 ± 0.03[b]	34.83 ± 0.45[a]	35.83 ± 0.16[b]	2.55 ± 0.03[b]

Figure 1 depicts the SFC of the milk chocolate couverture samples. The key attributes of the chocolate component are its melting characteristics, as demonstrated by SFC against temperature graph. This graph revealed significant information about the chocolate's eating characteristics, including flavour release, heat resistance, melting behaviour, and consistency. The results indicated there were significant differences among all samples and observed temperatures. Molten chocolate is a mixture of sugar, cocoa, and milk solids suspended in a continuous phase of fat (Kruger, 2017). The existence of solid particles in the molten stage hinders the SFC measurement in the chocolate from reaching zero. At temperatures ranging from 35℃ to 40℃, the percentage of SFC at the final stage was moderately average and does not have a significant impact on the product. The inclusion of CBS and the addition of granulated sugar in the chocolate formulations impact the melting characteristics and SFC of the milk chocolate couverture component.

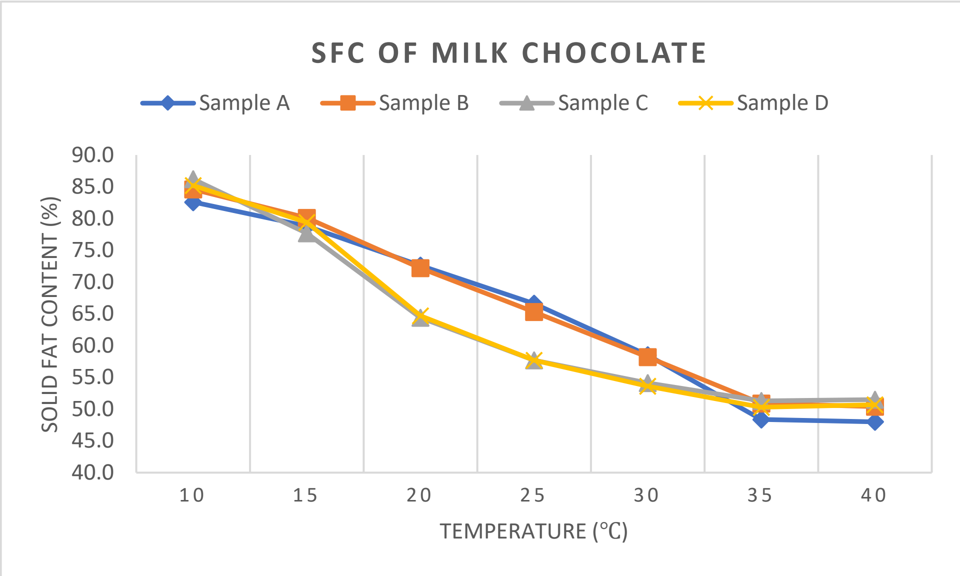


Figure 1. SFC of milk chocolate couverture component

Wide variations in particle size distribution were produced with intervals ranging between 20.78, 26.85, 50.42 and 70.32 µm using D90 (90% finer than this size). Sample D, with a combination of 5% cocoa butter substitute and granulated sugar, exhibited a lower particle size compared to Sample C, with a combination of icing sugar and 5% cocoa butter substitute that had the highest particle size (Figure 2). Chocolate sample A with icing sugar as the ingredient had a fine particle size compared to chocolate sample B with granulated sugar as the ingredient. The results showed that the addition 5% of cocoa butter substitute in the icing sugar chocolate formulation increases the particle size of the chocolate component. However, the addition of 5% cocoa butter substitute in the granulated sugar chocolate formulation decreases the particle size of the chocolate component. As stated by Biswas *et al.* (2017), particle size distribution has a direct influence on textural, rheological, and sensory characteristics. The highest particle size will affect mouth-feel notably, with grittiness, while the lower particle size improves hardness and flow properties. Ziegler and Hogg (2017) have added that the influence of particle size distribution on the flavour of chocolate suggests that deagglomeration occurring during conching may be as important to flavour development as it is to viscosity reduction. Figure 3 shows volume histograms of sample A with a size distribution of 26.85 µm, sample B with a size distribution of 50.42 µm, sample C with a size distribution of 70.32 µm, and sample D with a size distribution of 20.78 µm. Samples A and D showed a single modal distribution, while samples C and D showed a bimodal distribution.

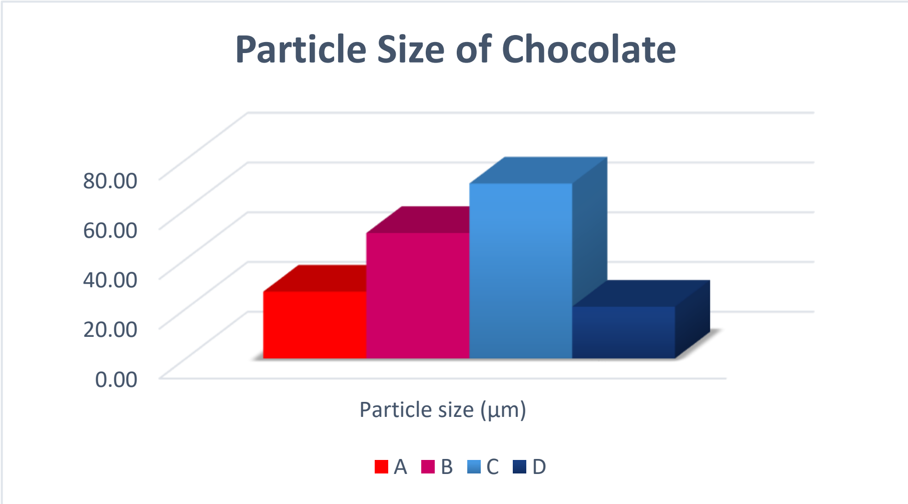
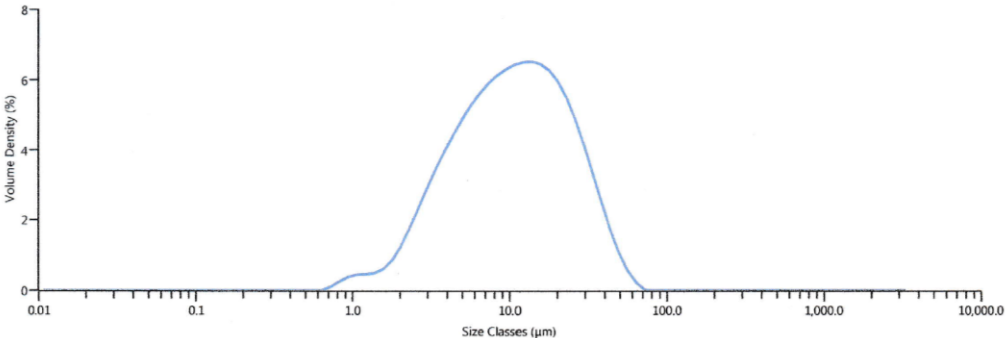
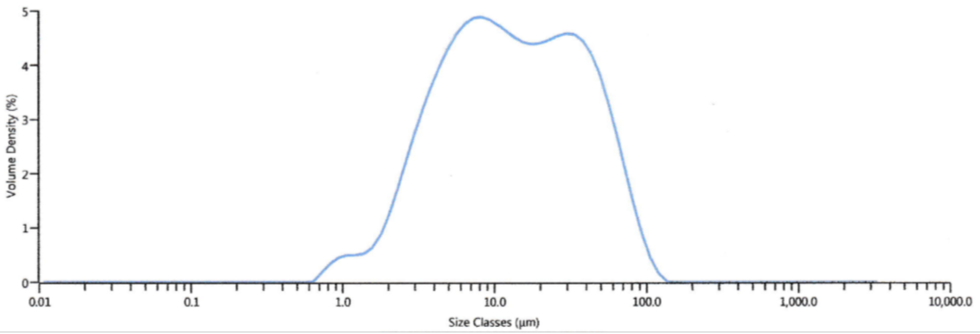


Figure 2. Particle size of milk chocolate couverture component

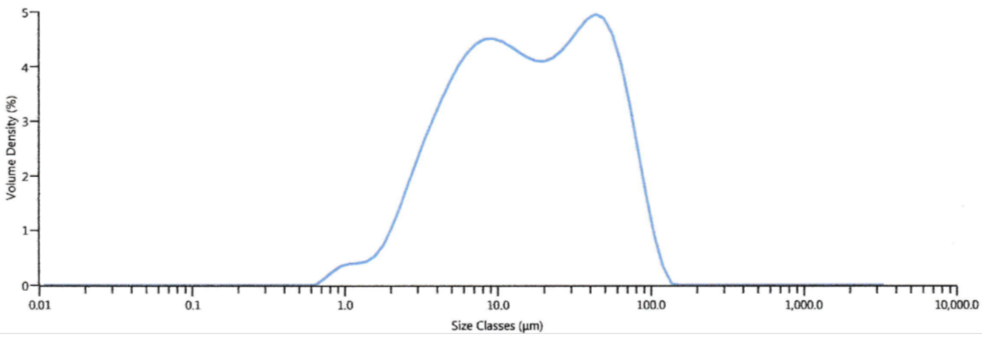
(a)



(b)



(c)



(d)

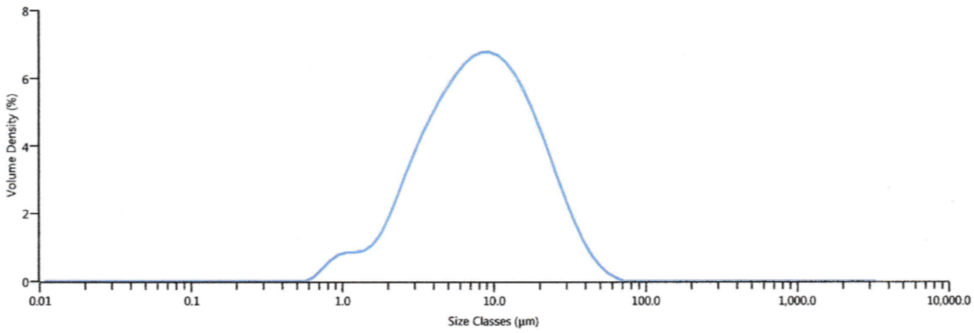


Figure 3. Particle size distribution of dark chocolate with D90 of (a) 26.85 µm, (b) 50.42 µm, (c) 70.32 µm, (d) 20.78 µm

The flavour profile of milk chocolate was determined by the quantitative descriptive (QDA) method. The chocolate sample tested was described with a scale from zero, the lowest point or intensity, to ten, the highest point or intensity. The flavour profile of the milk chocolate is tabulated in Table 3. The results indicated that there was no significant difference (*p*>0.05) among all the samples. On the other hand, there were significant differences in attributes of each sample. CBS addition in the chocolate recipe led to the texture of the chocolate sample's grittiness. Besides that, the type of sugar used influences the sensorial properties and rheology of chocolates. Granulated sugar contributes a different degree of sweetness, which is sweeter than the icing sugar formulation. The global quality of chocolate formulations with a combination of granulated sugar, 5% CBS, cocoa butter, and another ingredient (Sample D) was the highest among all other samples. Therefore, the formulation of Sample D, which was a more cost-effective milk chocolate coverture with acceptable quality compared to the original milk chocolate coverture (control). Samples B and C indicated the higher particle size. This may be due to variation occurring during the conching process.

Table 3. Sensory profile of milk chocolate couverture component

Sensory Attribute	Sample A	Sample B	Sample C	Sample D
Cocoa	5.1±1.4	5.4±1.6	5.2±1.2	5.4±1.4
Total acidity	0.7±0.9	0.6±1.0	0.5±1.0	0.6±0.8
Bitterness	1.1±1.1	1.2±1.2	1.1±1.1	1.2±1.2
Astringency	0.8±0.9	1.0±1.2	0.8±0.9	0.8±0.9
Sweetness	5.5±2.5	5.7±1.6	6.3±1.3	6.2±1.5
Roast degree	4.8±1.8	4.8±1.8	4.7±1.7	4.8±1.8
Total off-flavours	0.0±0.0	0.3±0.7	0.2±0.4	0.0±0.0
Global quality	6.8±0.9	6.5±0.8	6.3±0.9	6.9±0.7
Overall flavour comments	milky soft smooth waxy sweet	milky soft smooth waxy very sweet	oily soft & gritty coarse waxy average sweet	balance gritty coarse balance sweet

4. Conclusions

The physical properties and sensory attributes are influenced by the type of sugar ingredient and incorporation of CBS in the formulations. Application of 5% CBS and use of granulated sugar can be cost-effective to reduce the cost of production for milk chocolate, although it affects the melting properties and SFC of the milk chocolate. Suitable formulations of milk chocolate may provide the best cost-effective alternatives for the chocolate producer. Further study will be carried out with other CBS to improve the chocolate texture and properties.

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Conflicts of Interest: The authors declare no conflict of interest.

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