

Cocoa butter and replacement in compound coatings and effect on the coating's rheological profile

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Abstract. Cocoa butter is a crucial component in chocolate and compound coatings, significantly influencing their physicochemical properties, which, in turn, affect the viscosity and cooling rate of the coatings. This impact is vital in the formulation and storage of coatings, affecting their flow behavior, texture, and stability. Research has shown that the inclusion of coconut oil as a cocoa butter substitute in chocolate results in a reduction in the chocolate's viscosity. This is attributed to the lower viscosity of coconut oil, primarily due to its lauric acid content. This experiment utilized the Brookfield viscometer to measure the viscosity of chocolate. Three representative types of chocolate were selected: milk chocolate, white chocolate, and dark chocolate, all containing the same ingredient: coconut oil. The analysis of the measurement results allows the determination of the viscosity characteristics of chocolate, providing insights into which type of chocolate exhibits the most significant improvement in viscosity due to the presence of coconut oil. Experimental results indicate that milk chocolate with the addition of 4.5% coconut oil exhibits optimal physical characteristics, including gloss, texture, and overall acceptance by participants. In contrast, dark chocolate with coconut oil has higher viscosity and slower cooling rates, requiring more time to complete the coating or product preparation, which may affect production efficiency. White chocolate with coconut oil typically falls between milk chocolate and dark chocolate in terms of viscosity. This study delves deep into the impact of cocoa butter substitutes on various chocolate coatings, offering valuable insights into the application of coconut oil as a cocoa butter alternative in chocolate production.

Keywords: Chocolate, rheology, compound coatings, coconut oil.

1. Introduction

Compound coatings regularly allude to coatings utilized in the food business, usually applied to chocolate, confections, and rolls. These coatings effectively enhance the outer qualities, including appearance, surface, and flavor, of these food items. One of the principal parts of such coatings is chocolate or chocolate substitutes, for example, cocoa spread and cocoa powder. Cocoa spread has been a basic fixing in chocolate and compound coatings, impacting the usefulness and tactile traits of chocolate items, including hardness, and fragility. This part grants an exceptional cocoa flavor and surface to coatings, and it regularly stays stable at room temperature, limiting issues connected with fat blossoming or different types of unsteadiness [1].

Cocoa spread confers the fundamental perfection, unwavering quality, and enjoyability to coatings, in this manner accomplishing a surface suggestive of certifiable chocolate [2]. This multitude of elements adds to the application and tangible experience of coatings. This report plans to exhaustively investigate the effect of cocoa spread and its substitution in various kinds of chocolate, including milk chocolate, dim chocolate, and white chocolate, given past exploration. Through the examination of key elements, including definition, handling, and rheological qualities, the point is to acquire a more profound comprehension of how the substance of cocoa margarine can improve item improvement and shopper fulfillment in the ceaselessly developing field of food innovation.

2. Literature review

2.1. *The importance of cocoa butter and its role in chocolate production*

Currently, there are both domestic and international research, focused on the physicochemical properties of chocolate itself. The prevailing consensus is that the cocoa butter content significantly impacts its rheological properties, consequently affecting chocolate coatings' viscosity and cooling rate. Cocoa butter, as the principal lipid component of chocolate, primarily comprises cocoa butter triglycerides, and these lipid molecules play a pivotal role in the composition of chocolate.

The simplest approach to investigating various cocoa butter and fat contents in chocolates is to select milk chocolate, dark chocolate, and white chocolate as typical samples. These samples are considered representative of different fat content and types in chocolate products, and their choice is rational based on their widespread availability and extensive research background.

2.2. *Sustainability of cocoa butter*

Cocoa butter, constituting approximately 25%-35% of the overall production cost of chocolate, stands as its most costly ingredient [3]. Nevertheless, a global reduction in cocoa cultivation has resulted in a continual decline in the production of natural cocoa butter, thereby causing sustained price escalations [4]. Consequently, the food industry has initiated a shift toward utilizing alternative cocoa butter substitutes in compound coatings. This transition involves the incorporation of various proportions of cocoa butter with alternative plant-based oils like coconut oil, palm oil, mango seed oil, and others. A prerequisite for these plant-based fats is their compatibility with cocoa butter, ensuring seamless integration into compound coatings.

2.3. *Development and characteristics of cocoa butter substitutes*

Coconut oil fills in as a substitute for cocoa spread. As opposed to plans that need cocoa spread substitutes, those consolidating cocoa margarine substitutes with coconut oil have exhibited the capacity to keep a smoother appearance and a beneficial surface in chocolate items [5]. Characterized as lauric oil, coconut oil boasts a high concentration of medium-chain fatty acids and a low content of unsaturated fatty acids [6]. The substantial presence of lauric acid in coconut oil contributes to a melting point range between 24°C and 29°C [7], a crucial factor determining the suitability of coconut oil for use in food applications [8]. Lauric acid's advantageous impact on the surface gloss of chocolate is noteworthy. Although cocoa butter substitutes and cocoa butter exhibit distinct chemical compositions and properties, the elevated lauric acid content in coconut oil imparts comparable physical characteristics to them. Additionally, the introduction of coconut oil leads to a reduction in chocolate viscosity, attributed to the formation of V-type (β') crystals within coconut oil [7]. The existence of large β' crystals disrupts the intricate crystal network formed during co-crystallization, thereby influencing rheological characteristics and lowering viscosity [9]. Traditional chocolate production typically necessitates tempering to impede or prevent fat blooming and attain the desired crystal structure of V-type (β'). Moreover, Malaysia's abundant cultivation of palm and coconut trees enables their cost-effective processing into cocoa butter substitutes.

2.4. Compound coatings and their applications

The rheological performance of cocoa butter and its substitutes in compound coatings is crucial, as it profoundly impacts their flow behavior, texture, and stability throughout processing and storage. Rheological characteristics, including viscosity, thixotropy, and melting point, play integral roles. Maintaining adequate rheological performance is essential for achieving a seamless flow on the production line, uniform coating application, and the desired visual attributes. These aspects collectively contribute to the practical application and sensory experience associated with coatings.

2.5. Summary review

Research on chocolate and various cocoa butter alternatives has reached a relatively advanced stage within the scholarly domain. Conversely, studies regarding their application as coatings in confectionery, bread, and other food products have been relatively scarce. Furthermore, systematic investigations into the substitution of cocoa butter with coconut oil across different chocolate types have been limited, often due to the predominant focus on the purported health benefits of coconut oil. Although there have been emerging concerns regarding the potential adverse health effects of excessive saturated fat intake from coconut oil, industrial considerations, such as the cost-effectiveness of partially substituting coconut oil for cocoa butter, have maintained the current emphasis on cocoa butter alternatives in production. This experiment aims to produce three different chocolate varieties with varying fat contents, substituting a portion of cocoa butter with coconut oil, and assess the resulting viscosity and solidification time. The objective is to determine the most suitable chocolate coating formulation utilizing coconut oil as a substitute, aligning with the desired sensory characteristics for future product manufacturing.

3. Research Design

3.1. Raw Materials

The chocolates used for production include milk chocolate, dark chocolate, and white chocolate, with their ingredients as shown in the table below.

Table 1. Ingredients of all samples

White Chocolate	Min. cocoa: 28 % sugar, cocoa butter, whole milk powder, emulsifier: lecithins (soya), natural vanilla flavoring
Milk Chocolate	Min. cocoa: 33.6 % - Min. milk solid: 20.8 % sugar, cocoa butter, whole milk powder, cocoa mass emulsifier: lecithin (soya), natural vanilla flavoring
Dark Chocolate	Min. cocoa: 70.5 % coca mass, sugar, fat-reduced cocoa powder, emulsifier: lecithins (soya), natural vanilla flavoring

The same amount of coconut oil was added to these chocolates as a substitute for cocoa butter.

3.2. Viscosity

The experiment is divided into three groups, each corresponding to a type of chocolate with and without coconut oil (milk chocolate, white chocolate, and dark chocolate). Ensure that the quality of chocolate is the same in each group and that the amount of coconut oil they contain is also the same. Viscosity is measured using a Brookfield Viscometer with spindle 64, and the rotational speed is maintained at 60 RPM. Dark chocolate, milk chocolate, and white chocolate should reach 37° C. At these temperatures, the chocolate should be completely melted in the mouth and in a liquid state.

3.3. Texture

Texture can be reflected through hardness. Using the Texture Profile Analyzer (TA XT2) to test the texture of three types of chocolate coatings after cooling. The probe size and temperature of this practical are the same; the temperature was 22 ° C, the probe diameter was 50 mm, the pre-test speed was 10 mm/s, the test speed was 0.1 mm/s, the post-test speed was 20 mm/s, and the strain was 80%.

4. Results



Figure 1. The three samples in this practical

4.1. Viscosity

4.5% of coconut oil was added to the formulations as a cocoa butter substitute. The results indicate that the viscosity of milk chocolate is approximately 300 cp, dark chocolate is approximately 500 cp, and white chocolate is approximately around 250 cp. Compared to the control group without added coconut oil, the impact of coconut oil on the viscosity of milk chocolate and white chocolate is more pronounced, while its effect on dark chocolate is relatively minor. Coconut oil can significantly alter the viscosity of white chocolate, and it also has a noticeable impact on the viscosity of milk chocolate, whereas the change in viscosity for dark chocolate is comparatively smaller.

4.2. Texture

To prepare chocolate coatings, hardness was tested using a TPA (Texture Profile Analyzer) after cooling. By observing the highest points on the stress-strain profiles of these three chocolates, it was found that white chocolate itself is relatively soft at room temperature, and the addition of coconut oil makes it even easier to cut, chew, and melt, thereby reducing its hardness. Milk chocolate, compared to white chocolate, may be slightly firmer at room temperature, but the addition of coconut oil still makes it softer, affecting its hardness. However, the impact of coconut oil on the hardness of dark chocolate is relatively minor.

5. Discussion

5.1. Data analysis

Coconut oil reduces the viscosity of chocolate with minimal impact on coating hardness. When considering taste aside, milk chocolate, among the three chocolate types, is the most suitable for chocolate coatings. In comparison to dark chocolate, milk chocolate typically has a lower viscosity. This means that after the addition of coconut oil, milk chocolate becomes easier to handle and flow, enhancing production efficiency, especially during coating and surface application. As for dark chocolate, the addition of coconut oil increases its smoothness and yields a smoother texture, making it more amenable to coating applications, which can also improve production efficiency. However, white chocolate naturally has a lower viscosity, and the addition of coconut oil has a less pronounced impact on viscosity compared to milk and dark chocolate.

5.2. *Rheological qualities of chocolate with coconut oil*

Chocolate injected with coconut oil shows a non-Newtonian way of behaving and displays low thickness levels. This peculiarity is ascribed to the presence of lauric corrosive in coconut oil, which innately has low thickness. Thus, an expansion in the amount of coconut oil integrated into chocolate creation prompts a diminishing in general consistency levels. Prominently, differing measures of coconut oil used in chocolate creation were found to perceivably affect the by and large rheological qualities, staying inside satisfactory chocolate cutoff points. This declaration is validated by a review [7] researching the rheological properties of chocolates made with coconut oil rather than cocoa spread, which inferred that chocolate planned with 4.5% coconut oil accomplished ideal actual traits, including shininess, taste, and by and large member acknowledgment.

5.3. *Structural properties*

To ensure the optimal taste of chocolate, precise tempering is essential to impart the β -type to cocoa butter, the predominant fat in chocolate. Cocoa butter plays a crucial role in the melting properties of chocolate and the even dispersion of ingredients, exhibiting various crystal structures. Careful tempering during chocolate production is necessary to achieve small, precisely shaped crystals (β -type). Without tempering, cocoa butter tends to crystallize into rough crystals, leading to an undesirable phenomenon known as bloom—a manifestation of large, white fat crystals on the chocolate's surface [10]. Bloom results from fat migration within the chocolate, softening the coating and causing a loss of liquid glycerides [11].

Coconut oil, characterized by a higher melting point, owes its functional properties to the composition of fatty acids and triacylglycerols [12]. With saturated fatty acids, including lauric acid (48.2%) and carboxylic acid (18.5%), constituting its main components, coconut oil remains solid at room temperature, necessitating higher temperatures for liquefaction [13, 14]. Notably, coconut oil has a more limited melting range of about 23 - 26 ° C compared to other fats and oils, influenced by the length and position of the fatty acid carbon chain [15]. Chocolates containing coconut oil are sensitive to temperature variations, given its low melting point of 23 to 26 ° C. Consequently, in warmer climates, these chocolates may liquefy more easily, requiring refrigeration to maintain their form [16]. The addition of coconut oil imparts a distinct texture, characterized by a velvety feel, accelerated mouth melting, and a smoother, silkier sensation. Furthermore, it introduces a coconut flavor, enhancing the overall complexity of the chocolate.

6. Conclusion

This study, through an experimental evaluation of cocoa butter alternatives in chocolate, reveals the significant potential of coconut oil in enhancing the viscosity and texture of chocolate. The experimental results indicate that applying coconut oil notably transforms the texture of milk chocolate, white chocolate, and dark chocolate, reducing hardness and making it more aligned with modern consumers' preferences for improved sensory experiences. While the study examined textural properties such as hardness and viscosity, there was a lack of detailed evaluation regarding the sensory aspects of chocolate. Also, the experimental scale was relatively small, potentially limiting the comprehensive exploration of various conditions and variables. Larger-scale experiments could be more beneficial in determining the effects of substitutes in industrial production and offering more reliable conclusions. As discrepancies may exist between large-scale production and experimental data, further investigations are necessary to ascertain factors like the flow viscosity of chocolate in pipelines. Future research could incorporate more comprehensive sensory assessments to gain a more thorough understanding of how substitutes impact the overall taste and mouthfeel of chocolate.

It is acknowledged that other plant-based oils contribute to cocoa butter substitution, albeit with milder effects compared to coconut oil. The impacts of alternatives such as palm oil and avocado oil may require further in-depth research and refinement to better meet the diverse requirements of different chocolate products. In conclusion, the addition of coconut oil has a multifaceted impact on chocolate coatings, encompassing changes in viscosity, texture, and flavor. While it lowers viscosity and enhances

operability, its influence on texture and flavor should be thoughtfully considered based on specific requirements and consumer preferences. Furthermore, addressing the temperature control needs in chocolate production, especially in warmer climates, is essential.

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