Prodction nd evaluation of olive oil hydroxypropyl methylcellulose based oleogels as saturated fat replacer in chocolate

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Abstract

This study investigated oleogels as a partial replacement for cocoa butter using an olive oil-based emulsion method with hydroxypropyl methylcellulose (HPMC) in chocolate. A ۵۰٪ replacement level of cocoa butter was optimal, as higher replacement levels negatively affected the sensory appearance compared to the control chocolate. Four levels of HPMC (۰٫۲۵٪, ۰٫۵٪, ۰٫۷۵٪, and ۱٪) were considered. The textural and sensory properties of the formulated chocolates were evaluated. Partial replacement of cocoa butter with olive oil-based oleogels and HPMC significantly reduced the hardness of the chocolate. Higher concentrations of HPMC led to an increase in this parameter. The highest concentration of HPMC negatively impacted the sensory properties of the chocolate related to texture and flavor, while formulations with ۰٫۵٪ and ۰٫۷۵٪ HPMC exhibited properties more similar to the control chocolate. Overall, the results demonstrated that olive oil-based oleogels and HPMC are suitable alternatives for reducing cocoa butter in chocolate.

Keywords

Cocoa butter replacer; olive oil; chocolate; oleogel; sensory and physical properties.

Introduction

Chocolate is a multiphase system in which the continuous phase consists of a mixture of various fats (cocoa butter, cocoa butter substitutes, shortening, and other vegetable fats for some formulations), while the dispersed phase is primarily composed of sugar, cocoa powder, and milk powder(Mokbul et al., ٢٠٢٣). Cocoa butter directly influences the texture of chocolate (softness and creaminess) and the release of flavors, and it also contributes to the product's longer shelf life due to its lower moisture content. Additionally, cocoa fat is responsible for the typical melting behavior of chocolate (You et al., ٢٠٢٣). The melting point of cocoa butter is close to the human body temperature and has a narrow melting temperature profile.
The demand for cocoa butter is expected to increase due to the growing trend of chocolate confectionery consumption. However, the high cost of cocoa butter, low yield, and poor wages in cocoa farming led to a shortage in cocoa butter production. Furthermore, chocolate production requires highly precise control. The tempering process of chocolate converts unstable fat crystals into the stable β form, and this process is heavily influenced by the triacylglycerol structure of cocoa butter. If tempering is not done correctly, a gritty mouthfeel due to post-production crystallization can affect the quality of the final product (Alotaibi et al., ٢٠٢٤). Another concern is the fatty acid profile of cocoa butter, which is rich in saturated fatty acids (approximately ٦٠٪). Excessive consumption of saturated fatty acids is associated with a wide range of health issues, such as heart disease, high blood pressure, and insulin resistance (L. Zhang et al., ٢٠٢٥).

When replacing cocoa butter, it is important to note that the melting behavior of the substitute should closely resemble that of cocoa butter to achieve the same mouthfeel. If only a portion of cocoa butter is replaced, the addition of a fat substitute should not significantly affect the crystallization and melting behavior of cocoa butter (Li & Liu, ٢٠٢٣).
In recent years, research into new, healthier alternatives to solid fats while preserving the sensory properties of food has been a highly active area in food science. One approach to producing solid fats with low saturated fatty acid content is the use of oleogels. Oleogels are composed of an edible liquid phase (vegetable oil) entrapped within a structural network, leading to gel formation (Shuai et al., ٢٠٢٣).
There are various methods for producing oleogels. In some methods, the gelling agent is a hydrocolloid. Since hydrocolloids are inherently hydrophilic, these oleogels are produced through indirect methods, such as the emulsion-templated approach. The advantage of hydrocolloid-based oleogels is that they require lower temperatures for production.
Oleogels formulated with other oleogelators can also be used as the fat phase in chocolate. For example, sunflower oil-based oleogels developed using methylcellulose (MC) or hydroxypropyl methylcellulose (HPMC) as structuring agents through the emulsion-templated method have shown promising results in terms of texture and oil-binding capacity (S. Zhang et al., ٢٠٢٥). Olive oil, known for its health-promoting properties, can serve as an excellent substitute for cocoa butter, cocoa butter alternatives, and shortening in chocolate formulations when used to produce oleogels. This research aimed to investigate the production of olive oil-based oleogels with HPMC as partial replacements for cocoa butter in chocolate formulations, to achieve a confectionery product with reduced saturated fat content.

Materials and Methods

٢,١. Materials

The materials required for preparing the oleogels included: olive oil from Tooska Company (Mazandaran, Iran), water, and hydroxypropyl methylcellulose (HPMC) (Methocel® F٤M) purchased from Dow Chemical (Bomlitz, Germany). The ingredients used for the chocolate formulation included: soy lecithin, sugar powder, cocoa powder (١٢٪ fat), skim milk powder, and pure cocoa butter (١٠٠٪) obtained from local stores (Mashhad, Iran).

٢,٢. Preparation of Oleogels

The oleogels were prepared using the emulsion-templated method. The initial water-in-oil emulsion composition consisted of ٤٧٪ (w/w) olive oil, cellulose ether (HPMC) at varying concentrations (٠,٢٥٪, ٠,٥٪, ٠,٧٥٪, and ١,٠٪ (w/w)), and water to make up ١٠٠٪ (w/w). To form the emulsion, HPMC was dispersed in the oil under continuous stirring at ٢٨٠ rpm for ٥ minutes. Cold water (T < ١٠°C) was then added to hydrate the HPMC, and the mixture was homogenized using an Ultra-Turrax® to obtain the emulsion. The emulsion was heated at ٦٠°C until the moisture content reached ٠٪. The resulting dried emulsion was ground into a homogeneous mass, which was considered the oleogel.

۲,۳. Preparation of Chocolate

To prepare the chocolate, cocoa butter was melted in a water bath at ۸۰°C. Lecithin was dispersed in the liquid fat, and the remaining ingredients were gradually added while stirring continued to achieve a homogeneous mixture. Finally, the bath temperature was reduced to ٦۰°C, and the oleogel was added to the mixture. The resulting mixture was refrigerated for ۲٤ hours.

۲,٤. Texture Measurement

The texture of the different chocolates was determined using a texture analyzer (TA-XT Plus, UK) equipped with a ۳۰ kg load cell. A penetration test was performed to evaluate the hardness of each sample. The tests were conducted at room temperature using a cylindrical probe (۱۰ mm diameter). Samples were penetrated to a depth of ۸ mm at a speed of ۱ mm/s. For each sample, force-time penetration profiles and maximum force values were recorded as hardness.

۲,٥. Sensory Analysis

The sensory characteristics of five different chocolate formulations were evaluated by ۱٦ panelists. Each panelist assessed the appearance, texture, and flavor of the chocolates and marked the intensity of each attribute on a ۱۰ cm unstructured scale (۱ = "not perceived at all" and ۱۰ = "very strong/intense").

The sensory test was conducted in a standard testing room with individual booths. Each chocolate was randomly labeled with a three-digit code for identification and served at room temperature. Mineral water was also provided to the panelists to rinse their mouths between samples.

۲,٦. Statistical Analysis of Data

The statistical analysis of the data obtained from the texture tests was performed using analysis of variance (ANOVA) and Tukey's test to determine significant differences between the samples (p < ۰,۰٥). Three preparations of each sample were conducted on different days, and each preparation was performed in duplicate.

۳. Results and Discussion

۳,۱. Visual Appearance of the Formulated Chocolates

All chocolates exhibited a hard, cuttable, and homogeneous morphology with a smooth and glossy texture. No significant differences were observed between the control chocolate and the chocolates containing oleogels.

۳,۲. Texture Analysis of the Chocolates

Hardness is an essential quality attribute of chocolate. Excessively hard chocolates are difficult to chew, while low hardness values indicate a bar of sticky chocolate. As shown in Table ۱, a significant difference was observed between the force values of the control chocolate and the chocolates containing cocoa butter/oleogel. The control chocolate exhibited greater resistance to penetration, indicating higher hardness compared to all oleogel-containing chocolates. This difference is attributed to the higher hardness of cocoa fat at room temperature compared to oleogels, which results in a firmer and harder texture, requiring greater force for penetration. The replacement of cocoa butter with structured oleogels likely led to a softer texture in dark chocolate due to the presence of high levels of unsaturated fatty acids in liquid form.

To statistically evaluate the differences in hardness between the samples, the maximum force values were calculated from the force-time curves. The differences obtained between the samples are presented in Table ۱. The maximum force value in the force-time curve represents the force required to penetrate and break the chocolate's structure; thus, a higher peak indicates greater sample hardness. The obtained data confirm that the control chocolate differed from the other samples, showing significantly higher hardness. On the other hand, increasing the concentration of HPMC in the oleogel led to an increase in the hardness of the chocolates. Chocolates made with oleogels containing ۰,۷٥٪ and ۱٪ HPMC concentrations did not show a significant difference from each other but exhibited higher force values compared to chocolates with lower hydrocolloid concentrations (۰,۲٥٪ and ۰,٥٪). Higher percentages of structuring agents likely enable the formation of a more stable and compact cellulose network, making penetration into the chocolates more difficult.

Table ٢. Maximum force values of the control chocolate and cocoa butter/oleogel-based chocolates obtained with oleogel at different concentrations of HPMC.

	Control	HPMC ٠,٢٥٪	HPMC٠. ٥٪	HPMC٠,٧٥٪	HPMC ١٪
Hardness (N)	١٨٩,٣١[a]	٨,٠٧[d]	٢٤,١٥[c]	٤٢,٢٥[b]	٥٠,١١[b]

*Means with different letter indicate significant differences among the samples (p < ٠,٠٥) according to the Tukey test

٣,٣. Sensory Analysis of the Chocolates

In summary, increasing the HPMC content resulted in chocolates associated with negative texture and flavor characteristics. However, using oleogels with the lowest HPMC concentration led to chocolates with more positive attributes shared with the control chocolate, such as "sweet" and "chocolatey" flavor, as well as a "hard" and "homogeneous" texture.

Conclusion

In this study, olive oil-based oleogels with varying concentrations of HPMC, prepared using the emulsion-templated method, were investigated as partial replacements for cocoa butter (٥٠/٥٠) to produce chocolates with reduced saturated fat content (٤٠٪ reduction) and optimized sensory properties. Chocolates with an appearance very similar to the control chocolate containing cocoa butter but with a softer texture were obtained. The concentration of the structuring agent was directly related to the hardness of the chocolate, as higher percentages of HPMC (٠,٧٥٪ and ١٪) enabled the formation of harder samples. Higher HPMC percentages produced harder chocolates, but the chocolate with the best sensory characteristics was the one with ٠,٥٪ HPMC, which shared key attributes with the control chocolate containing cocoa butter. These findings demonstrate that replacing ٥٠٪ of cocoa butter in chocolate with olive oil-based oleogels and HPMC can yield a healthier chocolate with lower fat content, reduced saturated fat, and optimized sensory properties.

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