Vegetable Oils as Fat Enhancers in Processed Cheese: Effects on Texture, Protein Interactions, and Lipid Profile - A Review

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Abstract. Vegetable oil as a fat enhancer in processed cheese formulations is an important strategy for developing healthier, more sustainable, and economical food products. This review was conducted as a narrative literature review based on peer-reviewed publications published between 1984 and 2025, retrieved from major scientific databases. This study aims to review the effect of substituting various vegetable oils on processed cheese characteristics, including texture, protein interactions, and fat profiles, and to identify the potential applications of coconut, canola, corn, and sunflower oils in cheese-based food systems. The results show that the physicochemical characteristics of each oil, such as fatty acid composition, melting point, and polarity, significantly affect the functional performance of processed cheese. Coconut oil enhances thermal stability but tends to produce a denser texture, whereas canola and sunflower oils promote softer textures and more elastic protein structures. Corn oil improves the nutritional fat profile but is more susceptible to lipid oxidation. Protein interactions indicate that unsaturated oils support protein matrix homogeneity, while saturated oils increase aggregation potential. Meanwhile, the fat profile of processed cheese changes significantly depending on the type of oil used, influencing nutritional quality and product stability. This review provides an integrated food science perspective on vegetable oil-based processed cheese formulations and highlights future opportunities for optimizing oil blends and emulsion-based technologies.
Keywords: food science, milk fat, milk protein, milk product, saturated fat, unsaturated fat

1 Introduction

Processed cheese is a product resulting from the recombination of natural cheeses such as Cheddar cheese with the addition of other ingredients such as powdered milk, water, emulsified salts, and other additives, including stabilizers and flavor enhancers, to produce a product with a uniform texture and high shelf stability. This formulation produces a product

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with high shelf stability, processing flexibility, easily controlled melting properties, and a longer shelf life, making processed cheese one of the fastest-growing dairy products globally [1].

In modern formulations, vegetable oil is often added in limited amounts (usually <2%) not to replace total milk fat, but as a fat enhancer that helps optimize fat phase dispersion, improve texture, increase softness, and stabilize the emulsion and melting properties of the cheese. The primary fat in processed cheese still comes from the base cheese, but the addition of vegetable oils offers significant functional and economic benefits [2].

Various vegetable oils, such as coconut, palm, canola, sunflower, corn, and olive oils, have been studied as fat enhancers, with unique characteristics such as different melting points, fatty acid compositions, and bioactive compounds such as tocopherols and phytosterols. PUFA-rich oils such as canola and sunflower are known to improve the nutritional value of cheese, while SFA-rich oils such as coconut and palm oil improve structural stability and heat resistance [3].

Beyond their technofunctional roles, vegetable oils offer economic advantages by reducing reliance on butterfat, which is cost-intensive and subject to price volatility. More importantly, the strategic incorporation of vegetable oils enables formulation flexibility in processed cheese, supporting the use of locally available lipid sources and facilitating the development of more sustainable, plant-integrated dairy systems without compromising product functionality [4].

However, the use of vegetable oils also poses new challenges, such as changes in microstructure, different protein-fat interactions, and influences on rheology and emulsion stability. Several studies have shown that the type and proportion of vegetable oil can affect melting ability, protein network formation, and fat distribution within the cheese matrix. Therefore, proper emulsification techniques and the selection of appropriate oil types are crucial in the formulation of high-quality and competitive cheese products [5].

While numerous studies have examined individual vegetable oils in processed cheese and cheese analogue systems, comparative and integrated evaluations across different oil types remain limited, particularly with respect to their simultaneous effects on texture formation, protein-fat interactions, and lipid profile modulation. Existing literature is largely fragmented, often focusing on single oil types or isolated quality parameters, making it difficult to establish formulation-oriented conclusions. Therefore, this review aims to comparatively evaluate the physicochemical and technofunctional roles of major vegetable oils used as fat enhancers in processed cheese, synthesize current evidence on their effects on texture, protein interactions, and fat profiles, and identify formulation strategies and research gaps relevant to nutritional optimization and sustainable processed cheese development.

2 Materials and methods

This study was conducted as a narrative review designed to synthesize and integrate existing scientific evidence on the effects of vegetable oil substitution in processed cheese systems. This approach was selected to enable a descriptive and mechanistic interpretation of how different vegetable oils influence texture, protein-fat interactions, and lipid profiles, rather than to perform a quantitative or systematic meta-analysis. Literature sources were obtained through searches of reputable scientific databases, including Scopus, ScienceDirect, and Google Scholar. The primary keywords used in the search included “processed cheese,” “vegetable oil,” “fat enhancer,” “texture,” “protein interaction,” “lipid profile,” “coconut oil,” “canola oil,” “corn oil,” and “sunflower oil.”

Inclusion criteria included peer-reviewed publications published between 1984 and 2025, with priority given to studies from the last decade. Eligible articles addressed the

effects of vegetable oil use on processed cheese characteristics and were written in English or Indonesian, and research that explicitly discussed the impact of vegetable oil use on the characteristics of processed cheese, whether in a laboratory, pilot plant, or industrial-scale production context. Articles that were not relevant to the topic of oil substitution or did not present sufficient empirical data or theoretical review were eliminated from the selection process.

All selected articles were qualitatively analyzed to assess the methodological approach, the parameters studied (texture, protein, and fat), and key findings relevant to the study focus. A narrative synthesis approach was used to integrate the diverse study results into a coherent conceptual framework. Furthermore, classification of the types of vegetable oils used and approaches to measuring product characteristics were conducted to identify formulation patterns and existing knowledge gaps in the literature.

3 Results and discussion

Processed cheese is a dairy product formulated using a combination of emulsifying salts, proteins, and fat components, allowing a high degree of formulation flexibility, including the incorporation of vegetable oils. Previous studies have reported the use of coconut oil, canola oil, corn oil, and sunflower oil as functional fat enhancers in processed cheese systems. The literature consistently indicates that the type of vegetable oil influences key product attributes, particularly texture characteristics, protein stability, and the resulting fat profile of the cheese. This section synthesizes findings from published studies that examine how different vegetable oils affect the functional and nutritional properties of processed cheese.

3.1 Processed cheese

Processed cheese is a product resulting from the recombination of melted natural cheese and mixed with additional ingredients such as emulsified salt, powdered milk, whey protein, animal and vegetable fats, water, and other stabilizers and flavor enhancers. This process involves intensive heating at temperatures around 80-95°C with vigorous agitation until homogenization and system stability are achieved, resulting in a product with a uniform texture, controlled functional properties, and a longer shelf life than natural cheese. Processed cheese boasts advantages in terms of heat stability, meltability, and textural consistency, making it a key ingredient in various modern food products such as cheese slices, cheese spreads, processed cheese blocks, and cheese sauces. Each type has a formulation tailored to its application characteristics, such as softness, spreadability, and shelf stability [6].

However, differences in fatty acid composition in vegetable oils can affect the microstructure and emulsion stability, making controlling the fat composition and selecting the emulsion salts crucial for producing cheese with optimal texture and sensory characteristics [7]. Overall, processed cheese is a complex emulsion system in which the interactions between milk proteins, fat, and emulsion salts determine the physical properties, texture, and stability of the product. With increasing attention to sustainability and raw material innovation, the use of vegetable oils and natural proteins as functional enhancers offers opportunities for the development of efficient, economical, and sustainable processed cheese products. The various components of processed cheese are shown in Figure 1.

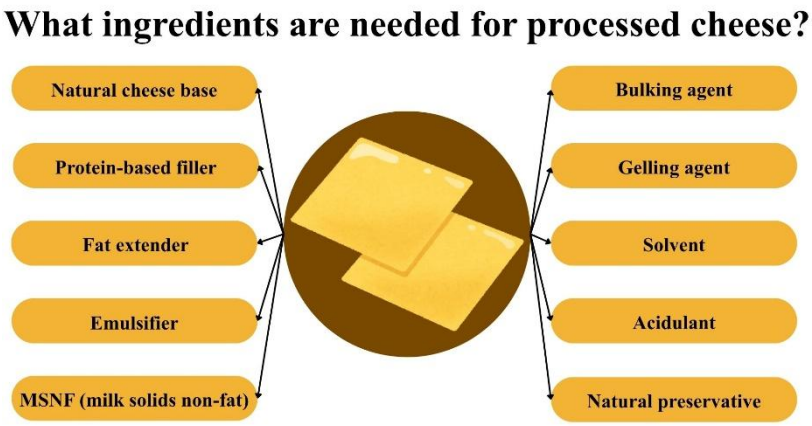

Fig. 1. Main components in processed cheese formulation.

3.2 Vegetable oil

In modern processed cheese formulations, vegetable oils are not used as milk fat replacers, replacing the entire milk fat component, but rather as fat extenders (Figure 2). Their primary role is to partially expand the fat phase without altering the primary characteristics of the milk fat. Generally added in low concentrations (<2%), vegetable oils contribute to improved texture, grittiness, thermal stability, and meltability of the final product.

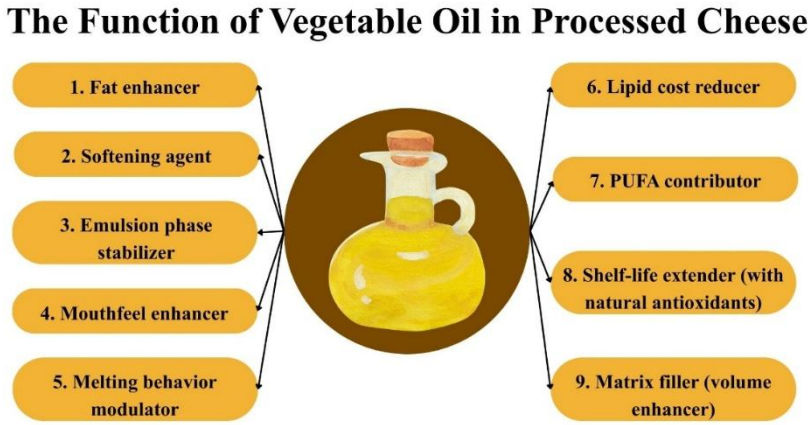

Fig. 2. Function of vegetable oil in processed cheese.

As shown in Figure 2, vegetable oils play a multifunctional role in processed cheese, including as a fat extender, softening agent, emulsion phase stabilizer, melting behavior modulator, and mouthfeel enhancer. Furthermore, vegetable oils contribute PUFAs (polyunsaturated fatty acids), reduce lipid costs, and extend shelf-life thanks to their natural antioxidant content, such as tocopherols and phytosterols. Various types of vegetable oils commonly used include coconut, palm, sunflower, corn, canola, and olive oils (Figure 3). The choice of oil type depends heavily on technofunctional characteristics, such as melting

point, proportion of saturated fats (SFA) and unsaturated fats (MUFA/PUFA), viscosity, and the composition of minor compounds, such as tocopherols and phytosterols, which influence oxidative stability and fat-protein interactions in the cheese matrix [8].

Fig. 3. Diversity of vegetable oil types and their impact on processed cheese

3.7 Effect of vegetable oil on cheese texture

Cheese texture is influenced by the protein matrix and fat phase distribution. Substituting milk fat with vegetable oil does not produce fat globules that interact strongly with the protein network, but instead forms oil droplets that require the addition of an emulsifier to achieve a stable cheese texture. The type of oil used also influences cheese texture, oils high in saturated fatty acids tend to produce a denser structure, while oils rich in unsaturated fatty acids produce a softer texture and melt more easily due to their low melting point and liquid nature at room temperature [9].

The use of coconut oil, rich in saturated fatty acids, produces a denser cheese product due to the formation of a network of fat crystals that strengthen the casein matrix, while sunflower oil, rich in unsaturated fatty acids, produces a softer texture and melts more easily. Oils with a high saturated fatty acid content, such as coconut oil, form solid fat crystals that reinforce the protein matrix, resulting in a harder, denser, and more heat-resistant cheese, but with lower spreadability and meltability. Conversely, unsaturated oils such as canola, sunflower, and corn oil provide a softer, more elastic, and more meltable texture due to their low melting points and good emulsification properties [10].

3.8 Effect of vegetable oil on cheese protein

The protein content of vegetable oils is notably low due to the refining and purification processes, which remove nearly all nitrogenous or protein-phospholipid fractions [11]. Although differences in chemical structure and the physical properties among oil types exert distinct effects on their interactions with proteins within the cheese matrix. Coconut tends to increase protein aggregation and textural firmness. Corn and sunflower oils enhance cheese elasticity and mouthfeel, while canola oil yields the most stable and uniform protein microstructure due to the balance between fatty acid saturation and emulsion stability [9]. Conversely, canola which is rich in unsaturated fatty acids exhibit a tendency to form more

open and elastic protein structures as the higher polarity of unsaturated fatty acids enhances interfacial wettability between fat and protein [12].

Overall, vegetable oils show no direct binding affinity to milk proteins, interacting instead at the emulsion interface modulated by emulsifying agents and process thermal conditions [13]. Highly saturated oils create stronger hydrophobic interactions elevating protein aggregation risk, while highly unsaturated oils promote more uniform and mechanically compliant protein structures [10]. A combination of saturated and unsaturated oils is therefore recommended to achieve an optimal balance of structural stability, meltability and textural softness in the formulation of modern processed cheese [9].

3.9 Effect of vegetable oil on the fat profile of cheese

The utilization of plant-based oils in processed cheese directly modifies the fatty acid composition of the final product. Coconut oil increases the proportion of saturated fatty acids contributing to improved thermal stability and a firmer cheese texture yet reducing cardiovascular nutritional quality [14]. In contrast, canola and corn oils enrich cheese with unsaturated fatty acids such as oleic and linoleic acids, widely recognized for their hypocholesterolemic effects and positive role in heart health [8].

Meanwhile, sunflower oil contains the highest PUFA content among commonly used edible oils (up to 54% linoleic acid) and a high level of α-tocopherol (270-1240 mg/kg), making it an effective natural antioxidant source. Milk fat with sunflower oil in processed cheese formulations results in a softer cheese texture and higher spreadability, although oxidative protection through added antioxidants or blending with saturated oils such as coconut or palm oil is necessary to suppress lipid oxidation [15].

From a food technology perspective, blending saturated and unsaturated oils in a balanced SFA:MUFA:PUFA ratio (e.g., 30:40:30) is considered an effective strategy to achieve simultaneous optimization of thermal stability, textural softness and nutritional value in modern processed cheese [10]. The matrix of study findings and practical recommendations for vegetable oil application in processed cheese systems is presented in Table 1.

Table 1. Matrix of study findings of types of vegetable oil and their application in processed cheese.

Vegetable oil	Dominant Texture Characteristics	Protein-Fat Interaction Characteristics	Lipid Profile and Oxidative Stability	Technofunctional Benefits	Limitations	Recommended Types of Processed Cheese
Coconut Oil	Dense, firm, non-melting, and thermally stable at high temperatures	Strong hydrophobic interactions drive high protein aggregation yielding a dense protein structure.	High SFA content (C12:0, C14:0) with strong oxidative stability	Provides strong structure, high sliceability and heat resistance	Low meltability and limited creamy mouthfeel	Sliced cheese, block cheese, processed cubes, baking cheese
Corn Oil	Soft, spreadable, homogeneous, and	Moderate protein interactions enhance water	High PUFA content (C18:2) with	Promotes a softer texture, improves the nutritional profile and	Lower oxidative stability requiring additional	Spread cheese, low-fat cheese, cheese

	moderate viscosity	retention and product softness	moderate natural antioxidant levels (vitamin E)	facilitates handling during processing	antioxidant incorporation.	sauce, processed dip cheese
Canola Oil	Soft, elastic, creamy, and meltable	Homogeneous protein-fat interactions and fine microstructural uniformity	High MUFA content (C18:1) with tocopherols and canolol stabilizing lipid oxidation	Optimal balance of texture, meltability, and nutritional quality	Slightly more expensive with moderate thermal stability	Spread cheese, cheese dip, cheese sauce, premium processed cheese
Sunflower Oil	Very soft, smooth, easily meltable, and plastic	Open protein structure with a fine emulsion	High PUFA content, rich in α-tocopherol, mildly prone to oxidation	Provides a soft mouthfeel, mild flavor, and high spreadability	Prone to oxidation; requires antioxidant protection	Spread cheese, cheese dip, soft processed cheese, cream cheese analogue

4 Conclusion

This review provides a comprehensive and integrated evaluation of the effects of different vegetable oils on processed cheese characteristics, particularly texture, protein-fat interactions, and fat profile modulation. Unlike previous reviews that primarily focus on individual oil types or isolated quality parameters, this study synthesizes comparative evidence across multiple vegetable oils to clarify their distinct and overlapping functional roles within processed cheese systems. The findings indicate that each vegetable oil exhibits unique physicochemical properties that differentially influence cheese structure and quality. Coconut oil, characterized by high saturated fatty acid content, enhances thermal stability but results in a denser texture. In contrast, canola and sunflower oils improve the nutritional lipid profile and promote softer, more elastic textures, while corn oil offers nutritional benefits but requires careful formulation control to minimize product instability.

Based on protein interactions, unsaturated oils tend to form a more homogeneous and viscoelastic protein structure, while saturated oils tend to increase protein aggregation. Vegetable oil substitution significantly alters the fat profile of processed cheese, which can impact oxidative stability and consumer perceptions of the product's health benefits. The main contribution of this study lies in the integration of literature data to build a deeper understanding of the impact mechanisms of each oil in the context of processed cheese applications. This study opens up opportunities for further exploration related to the optimization of oil blend ratios, the use of natural antioxidants, and formulation approaches based on modern emulsion technology to improve the quality and sustainability of plant-based dairy products.

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