The Application and Potential of Oleogels in the Food Industry

Ziqi Chen *

Faculty of Veterinary & Agricultural Science, University of Melbourne, Melbourne, 3010, Australia

* Corresponding Author Email: ziqchen3@student.unimelb.edu.au

Abstract. This article explores the utilization and potential of oleogels in various food applications, with a specific focus on their incorporation in bread making, meat products, dairy products, and their role in delivering fat-soluble nutrients. In the context of bread production, oleogels successfully alter the properties of the gluten network without impairing its formation, prolonging bread's shelf life and lowering its saturated fatty acid (SFA) content. However, further research is still needed, especially concerning potential changes in texture and flavor. The integration of oleogels in dairy products holds the potential for reformulation to decrease saturated fatty acid content while maintaining the desired texture and nutritional value. Additionally, oleogels are anticipated to revolutionize the delivery of fat-soluble nutrients by enhancing their bioavailability through added protective capabilities. Nevertheless, the full commercialization of oleogels has yet to be realized due to potential alterations in texture, mouthfeel, and flavor, which may impact consumer acceptance. Despite these obstacles, oleogels are widely used, have the ability to lower SFA in food items, and have the capacity to offer critical nutrients. This suggests that integrating oleogels into a variety of food applications is very practical. Continued research is essential to unlock the full potential of oleogels and drive a new era of health-conscious food production.

Keywords: Organogels; oleogels; food Industry.

1. Introduction

Oleogels refer to semi-solid systems formed by constructing liquid oils using suitable reagents. These structuring agents are also referred to as organogels. They include on the one hand non-triacylglycerol oleogels containing emulsions, polymers etc. and on the other hand lipid-based gelling agents. The structuring agents combine with each other to form fibres that construct a three-dimensional network of immobilised liquid oils, mimicking the solid or semi-solid structure of conventional edible fats [1]. Different types of oleogels, such as monoacylglycerols, phytosterols and fatty acid-based oleogels, have their own unique properties and potential applications.

Conventional fats tend to elevate SFA and Trans fatty acid (TFA) intake, increasing low density lipoprotein (LDL) levels in the body and thus having a negative impact on health [2]. However, conventional lipid modification technologies do not lower the SFA concentration in lipid formulations for industrial purposes. Instead, they modify lipids through processes including hydrogenation and ester exchange [3]. As a novel solution, oleogels can be used as a substitute to reduce the TFA and SFA content without changing the processing characteristics and sensory quality.

The use of organogels in food products can produce nutritionally balanced and stable products. Gel properties can be modified by adjusting the proportion of oleogel agent in a synergistic mixture, or by processing conditions, leading to further potential applications in food processing. Oleogels are now employed in a variety of culinary products, such as to improve the fatty acid profile, replace solid fats in the production of chocolate spreads [4]. Improved partial oleogels enable greater reduction of oil oxidation and colour change than conventional fats [5].

This article describes the composition and formation mechanisms of oleogels, describes their application in different food categories (bakery products, meat products, dairy products), discusses application as carriers of fat-soluble nutrients and analyses the possible challenges and opportunities. Based on this, the current research status and development potential of oleogels in the food industry is demonstrated.

2. Oleogels: Mechanisms and Properties

An oleogel is a semi-solid structure formed by the immobilisation of liquid oil by a network of physical interactions triggered by a suitable structuring agent [1]. Through intermolecular attraction, crystallization, or other physical interactions, organogel molecules can organize into a structure that is three-dimensional in the oil phase. The organogel agent is mixed with the liquid oil under specific mechanical conditions and heated above the glass transition temperature of the gelling agent (e.g., waxes, fatty alcohols, monoglycerides) to ensure that a gel can be formed. Through a polymer network stabilized by physical interactions, the organogel retains the liquid oil when the temperature is dropped and produces a semi-solid oleogel [5].

Oleogels possess the ability to mimic fats, more flexible research models and higher nutritional value. Firstly, the rheological behaviour, texture and mouthfeel of oleogels are similar to traditional fats such as butter and lard [6]. This similarity is due to the fact that the structure of oleogels, which capture and immobilise oils, allows them to behave like solid fats at room temperature. Additionally, a study on the polymer ethyl cellulose (EC) shown that mixing and changing various EC viscosities might change the mechanical strength of oleogels. Their physical properties were also influenced by the type of additional surfactant added [5]. The decomposition of surfactants and gelling agents also occurs during heating, which leads to a reduction in gel quality and affects the palatability of the product. Finally, oleogels have lower levels of SFA and TFA compared to conventional fats, which are more beneficial for heart health [2]. Therefore, oleogels have the potential to be a healthier and more promising alternative in a variety of food formulations and also have significant scope for research.

3. The Application of Oleogels in Bakery Products

Oil gels are often used as fat substitutes in biscuits, cakes, bread and so on. The traditional solid fat content affects the stability of the dough bubbles, prevents the gluten bundles from coalescing and helps to form the structure of the final product. At the same time, it can affect sensory properties such as flavour release during baking [2]. Additionally, oil migration and stability against oxidation may be impacted by fat during storage [4]. Patel and Dewettinck's report describe the properties that oleogels impart to baked products [7]. Oleogels help the more minute bubbles in the dough to remain stable, giving the baked product a more homogeneous structure. And oleogel increases and maintains the softness of the final product over time because it disrupts the protein-polysaccharide network in the dough and provides a lubricious protective film for the solid particles during the baking process.

Traditional biscuit processing requires a small amount of water and a large amount of shortening, which provides lubricity and softness to the sample. Most applications of oleogels in biscuit processing use waxes as an organic gelling agent. Waxes have a low polarity and high melting point and can have a high oil binding capacity at very low concentrations, helping liquid oils to crystallise [2]. It was shown that the oleogel could achieve improved texture and mechanical properties, but the solid-like structure formed by the oleogel did not remain stable in response to changes in shear force, depending on the dough mixing conditions [8]. Shortening has a stiffer texture and prepares a more viscous biscuit dough with better rheology than that prepared from oleogels. Further research is needed, for example by partially replacing shortening with oleo-gel or by further optimising the oleo-gel to give better physical properties to the products prepared from oleo-gel.

Cakes have porous structure, with the fat providing a soft, spongy texture during processing. In contrast to conventional fats, the oleogels interact differently with the flour proteins and the texture of the finished cake is slightly denser [1]. Cakes made with camellia oleogels instead of butter achieved a higher sensory evaluation (Fig.1) [9]. The oleogel-based cakes exhibited a more homogeneous crumb structure and were less prone to spoilage than traditional fat cakes, thus potentially extending the shelf life of the cakes [7]. Furthermore, oleogels can be used to gluten-free cake products to lower their greater SFA level. Demirkesen and Mert studied the effect of a concentration gradient of beeswax oleogels on gluten-free aerated products and found that using oleogels reduced the SFA content of the product by almost 35% without affecting the texture characteristics [10]. The addition of oleogels to traditional cake recipes requires modifications to the preparation process and the proportions of other ingredients, which can add complexity to the baking process.

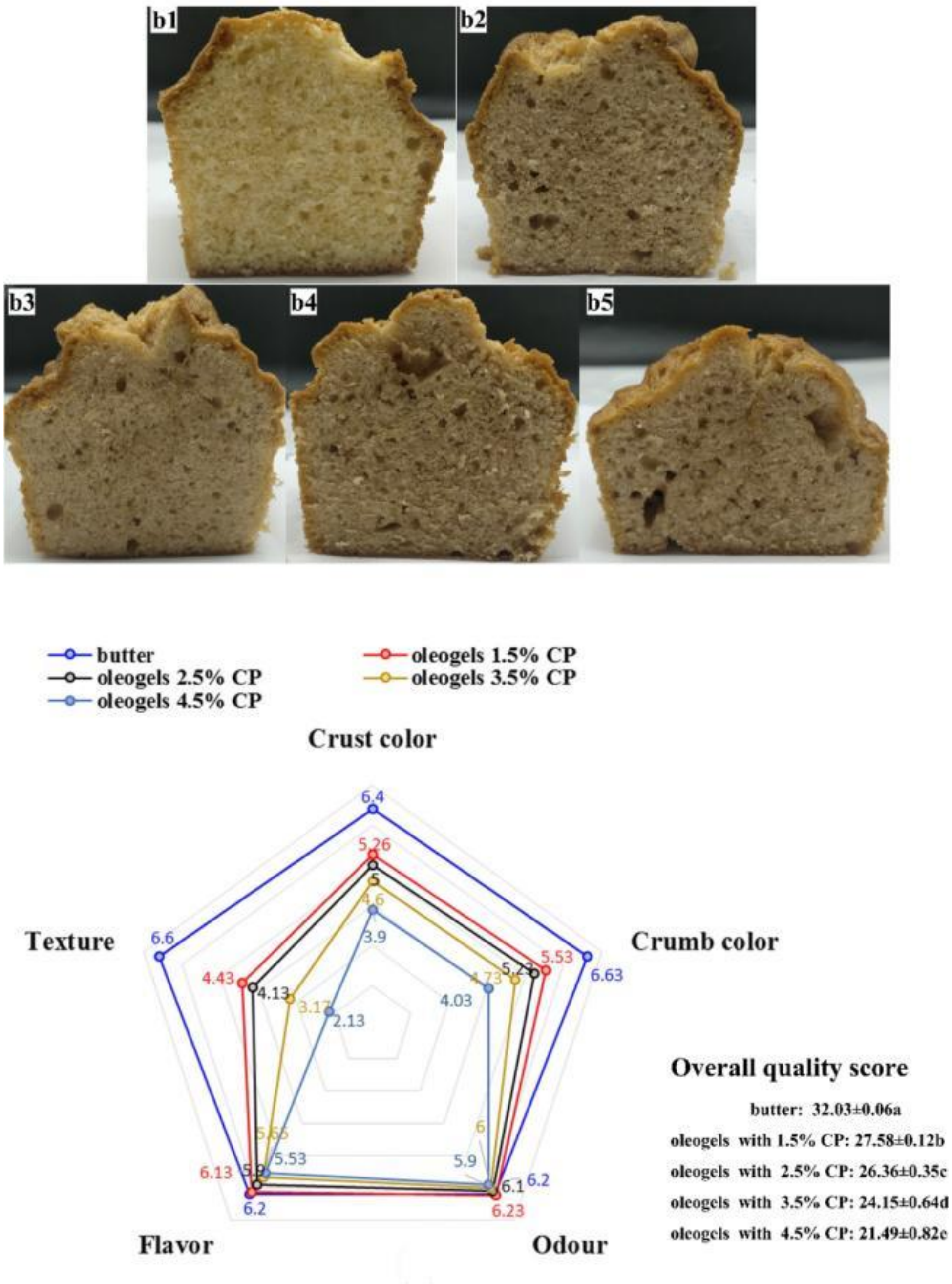

Fig 1. Photos and corresponding sensory parameters of cake products at different oil gel concentrations[9].

In bread making, the formation of complex gluten networks in the dough is critical to the texture and volume, and the fat or alternative chosen needs to help enhance the gas retention capacity of the dough [11]. Available studies have shown that the use of oleogels instead of traditional fats does not inhibit the formation of the gluten network, but does alter its properties [4]. The texture and volume of the bread was slightly altered, but there was no negative impact on overall organoleptic acceptability, and Zhao et al. used oleogels prepared from monoacylglycerol (MAG) or rice bran wax (RBX) to produce bread that yielded similar qualities to shortening-prepared bread, as well as a softer crumb [11]. Similar to cakes, the use of oleogels for bread can also improve shelf life and reduce SFA content, although there are also technical challenges in production.

4. The Use of Oleogels in Meat Products

Potential applications of oleogels include mainly the reduction of total fat content and the improvement of fatty acid profiles. In meat products, fat prevents losses during cooking by binding to water and enriches the juiciness of the food [12]. Oleogels are often used to replace animal fat, maintaining the characteristics of classic meat products [3].

There has been limited research on oleogels in meat products, mainly focusing on chopped meat products (pâté, sausages, etc.) Lupi et al. used monostearic acid glycerides and monopalmitates to construct an oil phase that enhanced the stability of meat suspensions such as pâté [13]. In another study where pork fat was substituted to make pâté, the total SFA of the finished product decreased, but so did the hardness and adhesion (Fig.2) [12]. Furthermore, such oleogelation methods only ensure the stability of the suspension and do not reduce the total fat content. puşcaş et al. prepared oleogels using a mixture of vegetable oil and ethyl cellulose for application in the preparation of frankfurter sausages [4]. These new sausages did not differ significantly in hardness from the frankfurters containing beef fat. Under the same processing conditions and costs, the oleogels produced sausages that were visually and texturally similar to regular sausages, had acceptable organoleptic qualities and a healthier fatty acid profile. However, the high temperatures (140 degrees C) in the gel processing conditions may cause excessive oxidation of the oil resulting in a sour flavour profile of the finished product. Partial replacement of pork fat in dry cured sausages using modified linseed oil gels has been shown to be feasible, but involves process adjustments that add complexity [3].

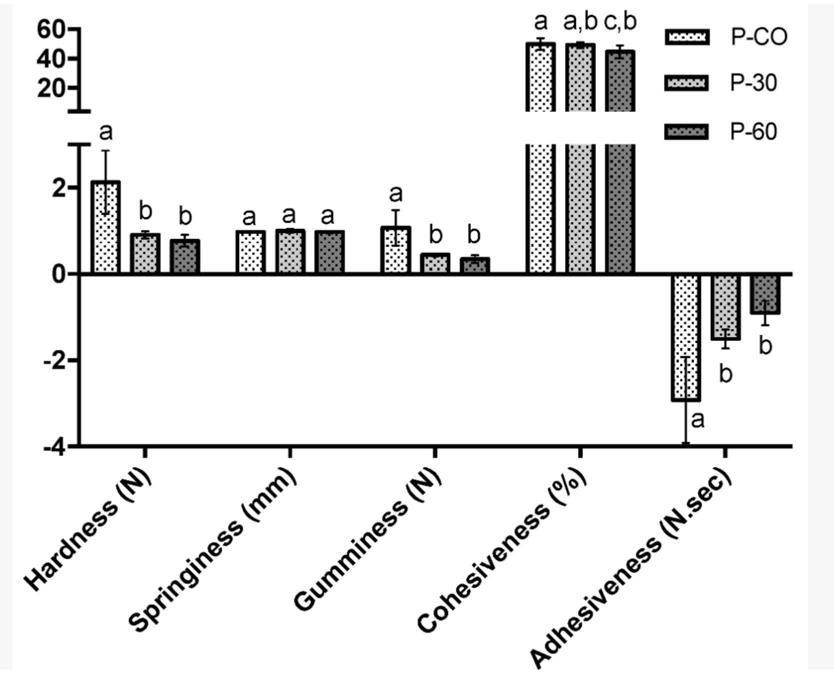

Fig 2. Texture for control sample(P-CO), samples replaced by 30% and 60% pork fat (P-30,P-60) [12].

A relatively new direction of research is using oleogels to partially replace fat in the production of patties. Moghtadaei et al. [14] prepared beef burgers from three different concentrations of (5%, 7.5% and 10%) sesame oil oleogels, in which a quarter and a half of the animal fat was replaced. It was shown that the concentration of beeswax used in the preparation of the gels affected the thermal properties of the final gels as well as the rate of lipid oxidation. The textural properties (e.g., hardness, stickiness) of the burgers prepared with the experimentally obtained gels differed from those of conventional burgers, but were not perceived by the group members. The method was effective in enhancing the colour of the burgers and reducing cooking losses and fat absorption. To further enhance the nutritional properties of the product, future research directions could be to use vegetable oil blends to increase the polyunsaturated fatty acid content of the product.

5. Oleogels in Dairy Products

Oil gels are used in dairy products (creams. Cheese, ice cream, etc.) Show promise for reformulation. Milk contains a large amount of SFA and TFA, but is also rich in nutrients such as vitamins A, D and calcium, making it difficult to replace them with oleogels.

In the manufacture of cream cheese, saturated fat ensures textural properties, a property that cannot be met by replacing it with liquid oil. The use of vegetable oil gels in the manufacture of low saturated fat cream cheeses was investigated by Bemer et al. In this study two organogels, rice bran wax (RBW) or EC, were mixed with vegetable oil to prepare oleogels to compare their effects on the preparation of cream cheese. It was discovered that the various organogels had an impact on the samples' structural characteristics, with cream cheese samples made with RBW having samples with similar hardness, adhesion, and ductility to commercially available samples and samples made with EC having samples with different adhesion and energy storage modulus (G') values [15]. No discernible variations in moisture and fat content were found between the experimental samples and the commercial cream processed cheese in another experiment comparing RBW and sunflower wax (SW) as gelling agents, although the use of oleogels was successful in lowering the SFA concentration [16].

Fats have an important influence on the freezing and melting behaviour of ice cream as well as on the structure formation. In recent years, the use of organogels and phytosterol complexes to replace milk fat in milk ice cream (gelato) has been successfully applied [3]. The addition of oleogels replaces 50% of the fat and reduces the SFA content of the product, while maintaining the sensory qualities necessary for consumer acceptance, such as colour and smoothness. Ice cream with reduced total fat has similar physical properties to full-fat ice cream and has a lower melting rate and higher expansion rate.

6. Future Applications: Oleogels for Delivery of Lipid-Soluble Nutrients

Emerging research suggests that oleogels can play a role other than replacing fat as a delivery system for fat-soluble nutrients. Fat-soluble nutrients as well as various antioxidants and bioactive compounds, play a vital role in human health. Their bioavailability may be compromised when delivered in conventional lipid matrices due to factors such as poor solubility or stability [17]. The unique structure and properties of oleogels can solubilise large amounts of hydrophobic bioactive molecules, improving the bioaccessibility of lipid-soluble molecules and providing additional protective capacity. Oleogel matrices can influence the efficiency of delivery of important nutrients, as well as their binding, protection and release in the human digestive system. The development of functional and fortified foods may find new directions as a result of these connected studies.

The special structure of the oleogels mimics the properties of traditional fats and improves the bioavailability. The incorporation of fat-soluble molecules into oleogels can be absorbed more efficiently by the body than conventional delivery methods. This is because nutrients dispersed in the oil phase tend to migrate out of the oleogel network during digestion. A study by Wang et al. found that monoglyceride oleogels could act as carriers for astaxanthin, providing a good physical barrier and enhancing its stability (Fig.3) [17]. Cui et al. looked into the β-carotene's chemical stability in monoglyceride oleogels [18]. A higher solubility of β-carotene in the oleogels was measured. The authors concluded that as the concentration of monoglycerides increased, the gel network became more compact, thereby enhancing the retention and stability of β-carotene. However, the link between the bioavailability and digestibility of this fat-soluble nutrient and the oleogels still needs to be confirmed by further studies. In addition, further studies are still needed to establish optimal formulation strategies and to investigate long-term stability and consumer acceptance.

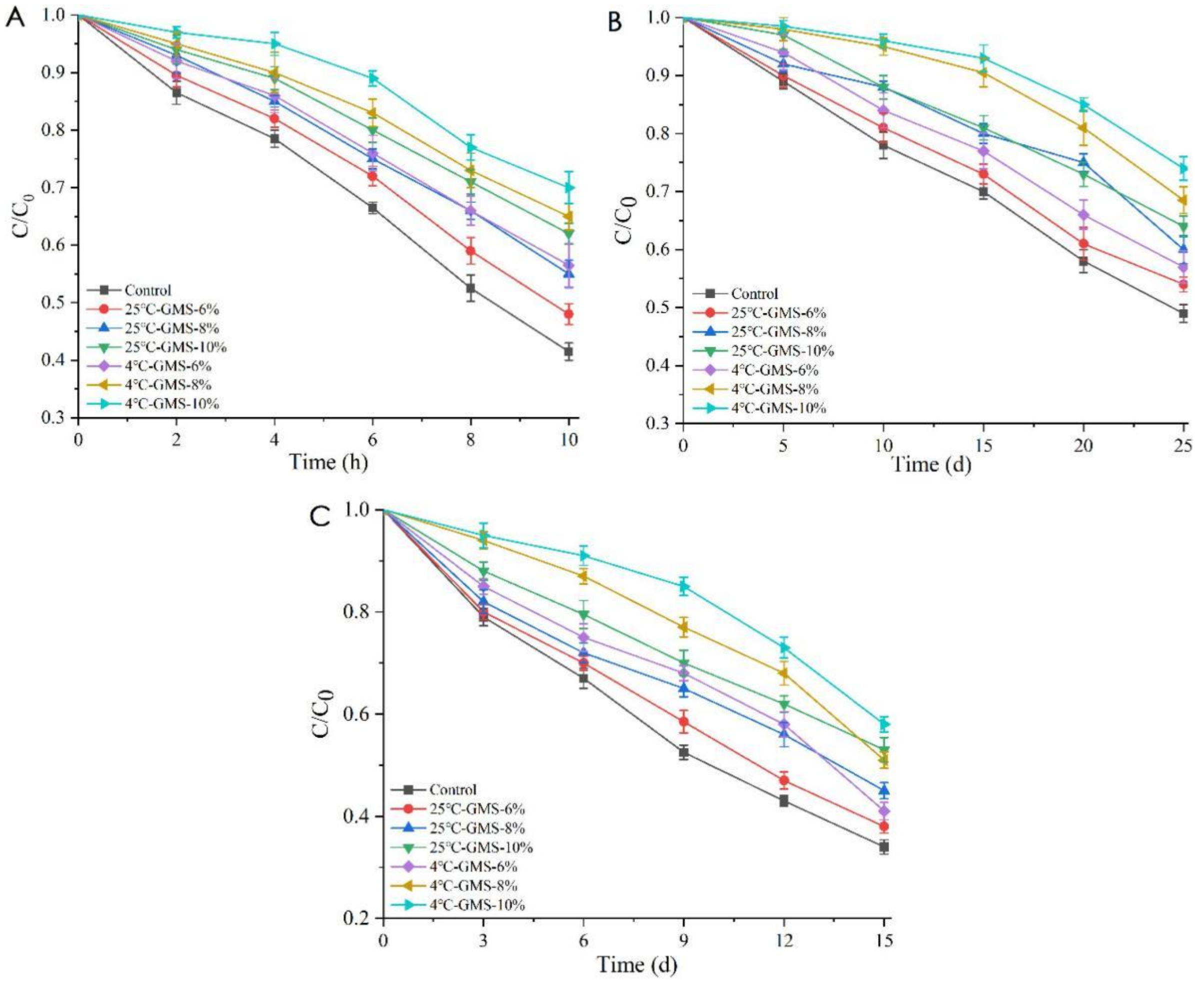

Fig 3. Degradation of astaxanthin with 6, 8, 10% GMS contents and different cooling temperatures[17].

The combination of oleogels with hydrogels to form Bigels is also one of the emerging areas of development for oleogels. The higher the oleogel content in these Bigels, the higher the stability of the dissolved beta-carotene. In addition, the probiotic bacteria carried in Bigels are more viable than those in yoghurt. Encapsulation of probiotics in Bigels can provide protection during yoghurt processing and storage, while effectively avoiding the effects of harsh gastrointestinal conditions [3].

7. Challenges and Opportunities

Current applications of oleogels in the food industry are focused on specific properties of a small number of common foods and there is a lack of large-scale commercial applications. For example, research on meat products has only focused on minced meat, or the enhancement of chocolate properties by oleogels has mostly focused on heat resistance, ductility etc [7]. The challenge to full commercialisation is consumer acceptance. The shift from traditional fat-based products to oleo-gel-based alternatives involves changes in texture, mouthfeel and possibly flavour.

However, more research has shown that the use of oleogels as potential substitutes, or dietary supplements for transporting nutrients, is highly feasible. Relying on the plasticity of oleogels, they can be made suitable for a wider range of applications (e.g., drug therapy, low-fat foods, functional foods, etc.) through various physical parameters during processing. The various lipid raw materials and vegetable oils can be flexibly adapted to the production costs and regions. Further research directions need to be determined depending on the desired effect, the target blocking site.

8. Conclusion

A growing body of research into the use of oleogels is providing promising insights into the development of healthier alternatives to traditional fats. The unique properties of oleogels have led to applications across a variety of fields such as bread making, meat products, dairy products and the delivery of fat-soluble nutrients. In bread making, oleogels have demonstrated the potential to extend shelf life and reduce SFA content without inhibiting the formation of gluten networks, a key determinant of the texture and volume of the final product. However, the use of oleogels in this context also presents new challenges related to the production process that need to be further explored. Oleogels have been used in meat processing mainly in terms of reducing total fat content and improving fatty acid profiles. The overall effect of oleogels on the texture, flavour and other organoleptic qualities of meat products needs further research. The challenge is to replace saturated fat without affecting the desired textural characteristics of the dairy product. Nevertheless, preliminary studies suggest that it is feasible to use oleogels to reduce the SFA content of dairy products. The use of oleogels as delivery systems for fat-soluble nutrients is a promising new area of research. They offer potential benefits in terms of increased bioavailability and protection of these nutrients, potentially opening up new avenues for the development of functional and fortified foods.

However, their large-scale commercial application is still challenged by factors such as production complexity, altered food properties and consumer acceptance. The potential of oleogels should be further explored through continued research into their use in a wider range of foods and as delivery systems for fat-soluble nutrients. Future research should also focus on addressing the technical challenges associated with their application in food production, while also considering consumer acceptance of these new ingredients. As the field of food science continues to evolve, oleogels represent a promising avenue for the development of healthier and more sustainable foods.

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