

Recent Advantage Of Oleogel Application In Food And Their Significant Impact On Textural & Sensory Properties: Review

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Abstract:

The scientific community is confronting a novel issue stemming from increasing concerns regarding the intake of detrimental trans fats and saturated fats in our diet. They must identify viable substitutes to replace these harmful fats without sacrificing the flavor and sensory qualities of the food product. Oleogels are a novel structural fat system employed in commercial applications to eliminate or substitute trans fats and saturated fats in food products. They provide nutritional and environmental advantages, rendering them a favored option among alternative strategies. Fats and oils in food augment its flavor and texture while promoting satiety. While it is recommended to predominantly consume unsaturated lipid sources, their liquid form at room temperature makes them inappropriate for several industrial applications. Oleogel is a novel technology capable of wholly or partially substituting conventional fats, which are significantly associated with cardiovascular diseases (CVD) and inflammatory processes. A primary problem in formulating oleogels for the food sector is identifying structural agents that are Generally Recognized as Safe (GRAS), cost-effective, and do not alter the flavor of the oleogel. Consequently, multiple research have investigated the diverse possible applications of oleogels in food products. Previous studies suggest that oleogels may be utilized in the manufacturing of bread items, breakfast spreads, margarines, chocolates, chocolate-based products, and some meat products. A new study indicates that replacing shortening with oleogels may diminish the saturated fat level in gluten-free aerated products without compromising their physical properties. Consequently, the use of oleogels may provide more alternatives for those with celiac disease to vary their dietary options.

Keywords: oleogel, structured lipids, Oleogelator, edible oleogel, trans and saturated fats alternatives.

1. INTRODUCTION

Edible oleo gels can be used to replacing saturated animal fat, thereby enhancing the nutritional profile of food products. Oleo gelation is under consideration as novel technique to replace liquid vegetable oils in the formation of solid structures that mimic the properties of traditional fats (Martins A. Jet et al., 2018). The oleo gelation method has been applied in a wide range of fields such as food, drug and cosmetics, and drug-delivery products (Balasubramanian R et al., 2012). That process involves turning a liquid vegetable oil into a gel-like consistency, while still maintaining its chemical properties. This is achieved by embedding structural agents with high or low molecular weight (Davidovich-Pinhas M. et al., 2019). In this category, oleogelators can include waxes, fatty acids, alcohols, mono-acylglycerol, oryzanol and ceramides, or a mixture of low molecular weight organic gelators such as fatty acids, fatty alcohols, lecithin/tocopherol and waxes/monoacylglycerols (da Silva T L et al., 2018) When mixed with liquid oils, natural waxes can gel them at concentrations as low as 1-4 wt%, forming a three-dimensional network which traps the oil in the pore space and attracts oil molecules to its surface. Aliphatic oleo gels are formed by heating waxes in liquid oil above their melting point followed by cooling to 27 °C under shear or static conditions. The chemical composition of waxes (fatty alcohols, fatty acids, hydrocarbon chains) has a dramatic impact on their gelation properties. Oleogels based on waxes demonstrate many advantages. Among these are their broad availability and lower cost, food-grade properties, ability to create water-in-oil structured emulsions in a way both with or without the introduction of emulsifiers, and the facility of them to exhibit thermo-reversible behaviour. As a result, they are particularly well positioned for use in food that requires temperature changes (Blake A I et al., 2014). Among the several waxes that have been proposed for use in edible oleogels, candelilla wax (CDW), carnauba wax (CBW), rice bran waxes (RBW), beeswax (BW) and sunflower waxes are considered to be highly significant. The key factors influencing oil binding capacity of oleogels are crystal morphology and three-dimensional network structure. Mean

acid compositions of food goods, so rendering them more nutritious. Health researchers have demonstrated significant interest in the applications of oleogel within the food industry, prompted by consumers' heightened awareness of the adverse effects of solid fats on human health and recommendations from governmental agencies, such as those outlined by (Klintman M, & Kronsell A. 2010) in their dietary guidelines.

Recent study has repeatedly shown that replacing dietary saturated fats with unsaturated fats decreases the risk of developing cardiovascular disease (Bemer H L et al., 2016). The adverse effects of saturated and trans-fat consumption on health are associated with their role in elevating LDL (low-density lipoprotein, also referred to as bad cholesterol). Research has demonstrated a link between trans-fatty acids and elevated levels of LDL cholesterol, alongside reduced levels of HDL cholesterol. Conversely, research indicates that shorter-chain saturated fatty acids can elevate LDL levels without impacting HDL levels (Co E.D. et al., 2012).

1.3 Components of the Oleogel System

Oleogels consist of two essential components: an encapsulated organic solvent and an oleogelator that immobilizes the solvent. In the food sector, only edible oil is employed for the formulation of oleogels among other organic solvents. The principal oleogelators utilized in the food industry include waxes, ethylcellulose, alcohols or esters from fatty acids, phospholipids, and phytosterols, among others (Lim J et al., 2017). The selection of oleogelator and the technique used for oleogelation (direct or indirect) significantly affect the properties of the resultant oleogels. The oleogel's appropriateness for application in the food industry is assessed based on several critical criteria: (i) the presence of lipophilic and interactive components, (ii) surface activity, (iii) thermoreversible characteristics, (iv) natural origin, and (v) GRAS status (Pérez-Monterroza E J et al., 2014). The next sections will analyze the components of oleogels, focusing on how their composition influences the properties of the oleogels.

1.4 Oil

The type of oil significantly affects the rheological, textural, and thermal properties of oleogels, in conjunction with the type and concentration of the oleogelator. Oleogels can be formulated using various vegetable oils, such as sunflower oil, corn oil, olive oil, canola oil, and hazelnut oil (Jang et al., 2015; de oliveira et al., 2012; Jimenez-Comenero F et al., 2015; ÖgütçüM,&Yılmaz E. 2015; Patel A.R et al., 2015). Patel et al., (2015) examined the influence of oil type on the rheological, textural, and thermal characteristics of oleogels. Evaluation of different oil types on the rheological and microstructural properties of oleogels. The pore width of the oleogel was measured to determine the effect of several oils including canola, soybean and flaxseed oil (Zetzl et al., 2012). Canola oil displayed a larger pore diameter, which diminished with an increase in the quantity of unsaturated fatty acids in the oil.

1.5 Oleogelator

BW (Beeswax), an oleogelator, is a naturally occurring material produced by honeybees for the construction of honeycombs. It functions as a repository and safeguarding mechanism for honey, pollen, and larvae. The wax glands of worker bees produce beeswax (Bogdanov S. et al., 2004). Honey has several carbs, such as glucose and sucrose. Prior research has demonstrated that waxes serve as highly efficient oleogelators. They can crystallize at concentrations under 10% and establish a network, attributable to their robust capacity to retain oil (Hwang HS 2012; Patel AR et al., 2014)^{22, 23}. The crystallization characteristics of waxes stem from their low polarity, extended chain length, and elevated melting point (Mukkamala R et al., 1996). Therefore, it is essential to integrate the correct wax kind and concentration into the food composition to attain the desired product quality. Waxes are typically identified as long-chain fatty acids, although they also include a range of other compounds such as hydrocarbons, fatty alcohols, ketones, mono-, di-, triacylglycerols, and sterol esters (Toro-Vazquez JF et al., 2010). Oleogelation necessitates the crystallization of oleogelators, an essential process for the formation of a gel network. This process entails the interaction of crystals and crystalline aggregates, leading to the immobilization of liquid oil within a three-dimensional network.

2. Oleogel Production Techniques

Oleogels consist of three distinct systems: (i) crystalline particles and self-assembled structures of low molecular weight, (ii) self-assembled structures of polymers or polymeric strands, and (iii) various structures (Friggeri A et al., 2002; Edmund Daniel Co et al., 2012; Patel AR et al., 2015). Gelation occurs primarily by the trapping of the liquid oil phase within triacylglycerol (TAG) particles Marangoni AG et

al., 2011; Zetzl AK et al., 2011; Marangoni AG, 2004). Diacylglycerols (DAG), monoacylglycerols (MAG), and fatty acids can generate structures analogous to triacylglycerol (TAG) (Calligaris D et al., 2012; Calligaris et al., 2010; Da Pieve S et al., 2010; Ferro AC et al., 2019; Naderi M et al., 2016; Ojijo NK et al., 2004; Perneti M et al., 2007). Self-assembled fibrous networks (SAFIN) are created using low molecular weight gelling agents, including phytosterols (oryzanol, 12-hydroxystearic acid) and ricinoleic acid (Wright AJ et al., 2006). This system produces helical and twisted crystalline ribbons (Jana S et al., 2017; Pehlivanoglu et al., 2018). The second strategy involves gelation by the production of self-assembled structures using polymeric materials, such as ethyl cellulose (Edmund Daniel Co et al., 2012; Patel AR et al., 2015). Ethylcellulose, a hydrophobic derivative of cellulose, is chemically synthesized from cellulose. Hydrophobic compounds such as polysaccharides and proteins can function as gelling agents (Zhang L., 2022). Certain researchers utilized inorganic particles to establish a gel network (Pehlivanoglu et al., 2018). (Patel AR, 2015) employed fumed silica as a gelling agent for sunflower oil. The standard production methods for oleogel entail the following stages, melting the oleogelators, heating the oils to the oleogelators' melting point, amalgamating the oleogelator with the oil, and ultimately cooling the mixture to form the gels. The formation of oleogels requires two components. One ingredient is oil, while the other is an oleogelator utilized specifically for gelation. This portion of the review will detail the oils and oleogelators employed in oleogel production and their importance in influencing oleogel characteristics.

3. Limitations of oleogels in food formulations

To properly harness the advantages of oleogels in food formulations, it is essential to overcome numerous challenges and limitations, notwithstanding their potential to improve the texture and sensory attributes of food products. A primary challenge is guaranteeing the compatibility of oleogels with various food matrices. Substituting saturated fats with oleogels can yield a more advantageous fatty acid profile. Nevertheless, entirely replacing saturated fats with oleogels often leads to diminished sensory acceptance due to adverse effects on texture and aroma. For example, large amounts of the wax oleogels applied can provide a waxy feeling on the tongue. However, their usefulness might not be relevant in the case of meat and baked products, as there are some undesirable odours. Temperature fluctuations, mechanical stress in the production process, or long-term storage can affect the stability of oleogel structure and lead to oil syneresis, phase separation or changes in texture. The stability of oleogels must be enhanced to commercialize them and to overcome those challenges. In addition to this, the use of that oleogels in food items is subjected to regulatory perspectives, especially in terms of safety and acceptability of oleogelators.

4. Health Advantages of Oleogel

Human dietary practices have experienced considerable alterations in recent years, leading to a parallel increase in the incidence of food-related illnesses. The changing food consumption landscape led to a notable increase in grain consumption, subsequently followed by a rise in meat-based item consumption. The dietary adjustments led to decreased consumption of plant-based goods, resulting in diminished amounts of important fatty acids and plant-derived antioxidants. The utilization of oleogels (or organogels) has steadily increased in both industrial and scientific sectors due to their advantageous properties (Dassanayak et al., 2011; Marangoni et al., 2018; Terech AJ et al., 1997). The primary aim of employing oleogels in the food industry is to reduce the intake of saturated fatty acids, as their excessive consumption is associated with numerous health complications, including obesity, cardiovascular disease, metabolic syndrome, and diabetes (Grevelle AJ et al., 2014). One consequence of these dietary modifications, linked to the prevalent consumption of trans and saturated fats, is their substantial effect on human health, particularly regarding the adverse effects on lipoprotein profiles. Ingesting high-fat foods may result in several health issues, including coronary heart disease, inflammation, oxidative stress, endothelial dysfunction, elevated body weight, and metabolic syndrome (Mozaffarian D. et al., 2009). Excessive intake of saturated fats, typically derived from animal sources including meat and dairy products, alongside trans-fatty acids, can lead to detrimental health consequences. These fats are significantly linked to health problems including obesity, cardiovascular disease, metabolic syndrome, and diabetes. The World Health Organization (WHO) recommends that the proportions of total, saturated, and trans fats in the diet should not surpass 30%, 10%, and 1% of total energy intake, respectively. Recently, heightened public awareness of the detrimental impacts of specific food additives on human

health has led scholars to explore alternative applications that are health-neutral. The solid fats or shortenings employed in the food industry raise concerns regarding human health due to their elevated concentrations of saturated and trans fatty acids. Recent nutritional guidelines from various government entities recommend decreasing dietary saturated fat and substituting trans fatty acids with unsaturated alternatives (Mert et al., 2016). The application of oleogels in processed foods has increased as a substitute for solid fats derived from hydrogenation, esterification, and fractionation techniques. This transition is motivated by apprehensions regarding the detrimental effects of ingesting saturated and trans fatty acids. The consumability of the things depends on additional quality characteristics and the health advantages they offer. Furthermore, oleogels with Generally Recognized as Safe (GRAS) designation can function as dietary supplements, offering an alternative for applications reliant on the release of hydrophobic bioactives in biological tissues (Davidovich-Pinhas M et al., 2015). Furthermore, oleogels possess the capacity to improve the bioavailability of specific active components, including lycopene, phytosterols, and vitamin E. This enhances their prospects for future application in the food business (Martins AJ et al., 2020). To date, there is limited data on oleogel digestion. Tan and their co-researchers have worked in this area. Postprandial blood triglyceride (TAG) levels are inversely associated with cardiovascular disease (CVD) risk. Effect of lipid structure of oleogel of rice bran wax (RBW) network type on lipid absorption in rats compared to margarine and bovine tallow. Four weeks of a high-fat regime plus oleogel lowered serum and liver triacylglycerol (TAG) by 30% in rats (Limpimwong W et al., 2017). In addition, adipose tissue development was suppressed, and hepatic total cholesterol levels were decreased. Additionally, stools from other TAGs contained significantly more of the total excreted amounts of TAG (30%), total cholesterol, and bile acid (compared to tallow/margarine). The data revealed that the gel matrix played a major role in decreasing lipid digestibility. Another study reported by (Dong et al., 2020) investigated the role of self-assembled crystalline structures on the digestibility of phytosteroleogels. The results showed that the degradation of lipids, including both emulsion and further fat liberation, was robustly affected by properties which indicated gel strength and crystalline structure.

5. Food Applications of Oleogel

The application of oleogels (or organogels) has steadily increased in commercial and scientific fields owing to its advantageous properties (Dassanayake LS et al., 2011; Marangoni AG et al., 2018; Terech P et al., 1997). The main aim of employing oleogels in the food sector is to reduce saturated fatty acid content, as high intake has been associated with numerous health problems, including obesity, cardiovascular disease, metabolic syndrome, and diabetes (Marangoni AG et al., 2018; Gravelle et al., 2014). Recently, heightened public awareness of the detrimental impacts of specific food additives on human health has led scholars to explore alternative applications that are health-neutral. The solid fats or shortenings employed in the food industry raise concerns regarding human health due to their elevated concentrations of saturated and trans fatty acids. Recent nutritional guidelines from many government entities recommend decreasing dietary saturated fat and substituting trans fatty acids with unsaturated alternatives (Mert B. et al., 2016). The application of oleogels in processed foods has increased as a substitute for solid fats derived via hydrogenation, esterification, and fractionation methods. This change is attributable to the detrimental effects of ingesting saturated and trans fatty acids. Nevertheless, the consumability of the commodities is also dependent on additional necessary quality measures and health benefits. Table 1 shows various applications of oleogels in food industry.

Bakery products often have a high proportion of saturated fats, varying from 31% to 7.5%, which greatly affects the characteristics of the final product (Schickenberg B. et al., 2009). Oleogels utilized in baked goods provide a healthful alternative to saturated and hydrogenated fats, while preserving the essential characteristics of the finished product. Cookies, biscuits, cakes, muffins, and crackers are essential elements of bakery items, produced from cereals with a high gluten content. Gluten is the primary etiological factor in celiac disease. It was discovered that persons with celiac disease consume a greater quantity of gluten-free crackers and biscuits than gluten-free bread. Gluten-free cookies, biscuits, cakes, muffins, and crackers are mostly composed of gluten-free flours such as rice, maize, sorghum, buckwheat, quinoa, lupin, chickpea, and various other types (Di Cairano M et al., 2018).

Table 1: Application of oleogel in Food Products.

Food Matrix	Types of oleogel	Food Application	Reference
Spreads	Shellac wax/Rapeeed oil	The Applications of shellac oleogels as a shortening alternative for spread preparationShellac wax/Rapeeed oil	²³
Cake	Beewax, Sardine Fish Oil	Decrease hardness with beewax oleogel	⁵⁴
Cookies	Beeswax of oil (w/w) Sunflower wax, Hazelnut oil Ethylcellulose / MCT (Medium Chain Triglycerides) Oil	Enhance Physicochemical, sensory and texture properties Provide the softer texture of cookies	⁵⁵
Burgers	Beewax, Sesame oil	Replacement of fats beef flank	⁵⁶
Ice cream	Rice bran wax/Sunflower oil	To replace solid fat and to enhance unsaturated fat content	⁵⁷

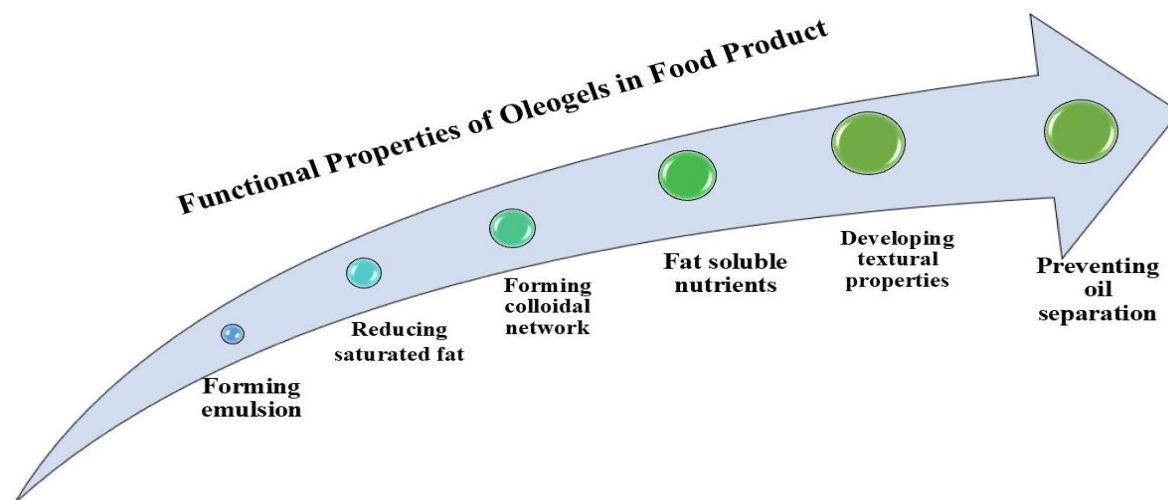


Figure 3: Functional properties of Oleogels in food product.

5.1. Texture and Sensory Properties

The advancement of healthy food alternatives is fundamentally reliant on the exploration of oleogel applications and their subsequent impact on food texture. Oleogels, displaying varied physical properties based on their composition and processing circumstances, present a distinctive opportunity to replicate the textural characteristics of conventional solid fats. The interactions among many components make it difficult to summarize the effects of oleogels on food texture. Cimbois et al. find that the composition of food (its many components and processing methods) can lead to different interactions during both the manufacturing and storage stages. This inquiry is essential for achieving the primary objective of reducing harmful saturated and trans fats in diets, while also maintaining consumer satisfaction through constant texture and mouthfeel. It is crucial to acknowledge that the food matrix is a complex system, and outcomes can vary significantly depending on the unique attributes of different food systems (Badem S. et al 2023; Espert S, 2023).

5.2. Bakery Product

5.2.1. Shortening

Oleogels are utilized in baking applications mainly to substitute shortenings, regarded as the principal source of trans fats. The cookies displayed the anticipated characteristics when shortening was largely replaced with wax-based oleogels, except for those incorporating carnauba wax and candelilla wax. These cookies exhibited a denser texture and an increased spread ratio. The research concluded that replacing shortening with healthier oleogels can significantly decrease saturated fatty acids and trans fats (Mert B. et al., 2016).

5.2.2. Spread

The choice of emulsifier and hardstock is essential for creating low-fat spreads with a fat level of 35-42% by weight. Shellac wax oleogels shown efficacy as fat substitutes, enabling the formulation of diverse emulsions with varying fat concentrations, without requiring extra emulsifiers or supplementary hard stock. The trapping of oil in shellac oleogels is due to wax esters and hydrocarbons, which form a three-dimensional crystalline network at a minimal mass fraction (Patel AR et al., 2014). The stabilizing impact of shellac wax oleogels on these emulsions is due to the substantial presence of fatty alcohols, which facilitate the early dispersion of water droplets with amphiphilic characteristics.

5.2.3. Oleogels in Bread Formulations

Loaf A recent study investigated the characteristics of fats treated with ethyl cellulose polymers. The objective was to improve the efficacy of these fats when employed as components in bread products. Different combinations of palm stearin and soybean oil were proposed, yielding compositions with differing concentrations of saturated fats. The structures consisted of cellulose and exhibited different viscosity characteristics, namely ethyl cellulose (EC7, EC20, EC50, and EC100), together with 1% emulsifier (triglycerylmonostearate). The properties of the formulated oleogels were assessed to determine which one yields a resilient and soft bread. Replacing 100% of the bakery shortening in bread with 4% EC100 oleogel, possessing a 30% degree of saturation, produced new products with a volume comparable to the control. This replacement resulted in a notable inclusion of air bubbles in the dough. The use of an oleogel structure yielded bread with a firm consistency and a unique texture (Demirkesen I et al., 2020). Monoglycerides (MAG) or rice bran wax (RBW) were used into bread and cracker formulations as substitutes for shortening. The additives were present at a concentration of 10 weight percent in high oleic soybean oil. The fast viscoanalysis results indicated that the oleogel derived from monoglycerides (MAG) had an extended peak time and elevated pasting temperature. This indicates that the oleogel can inhibit the gelatinization process of bread and cracker doughs. The farinography and rheology assessments demonstrated that replacing shortening with monoglycerides (MAG) and rice bran wax (RBW) oleogels did not significantly affect the dough's properties. Concerning the baked bread, all fats, including oleogels, demonstrated adequate symmetry and form, featuring small crumb cells, and the crust coloration was uniformly distributed across all bread variants. The research examined the development of oleogels utilizing ethylcellulose polymers as a structural element (Ye X et al., 2019). The effectiveness of ethylcelluloseoleogels was assessed against commercial shortenings in bread formulations.

5.2.4. Oleogels in Cake Formulations

The procedure of shortening is a vital element in cake production. Batters are oil-in-water (O/W) emulsions that incorporate dry components, which are either suspended or dissolved in the continuous aqueous phase (Rios RV et al., 2014). The main purposes of shortening in cake recipes are to aid in air integration during mixing and to enhance air bubble production during baking. A trial was performed to evaluate the efficacy of oleogel samples composed of a blend of water-soluble food polymers, namely xanthan and methylcellulose gum, in cake formulations (Patel et al., 2014). The assessment concentrated on elements including air incorporation, rheology, and texture examination. The rheological studies indicated that the oleogel samples displayed inferior viscoelastic properties relative to shortening and margarine. Moreover, both oleogel and oil batters had a notable frequency dependence.

In a distinct study, the researchers utilized HPMC to create solid-like oleogels with sunflower oil. The researchers subsequently assessed the influence of these oleogels on the physical properties of muffins (Lee S. et al., 2018). Replacing shortening with HPMC oleogels produced muffin mixes with diminished viscosity and reduced shear-thinning properties. The viscoelastic findings demonstrated that HPMC oleogels significantly influenced the viscosity of muffin batters.

5.2.5. Formulations of Cookies

In the preparation of cookie samples, it is crucial for the shortening to provide lubrication and tenderness rather than aeration. The shortening must not impair the flour's capacity to absorb water. The significance of shortening in the formation of a three-dimensional gluten network structure in baked goods is well acknowledged. For specific bakery items such as breads, a substantial development of the gluten network is essential. For items made with short dough, such as cookies, a robust gluten network is undesirable (Mert B & Demirkesen 2016). Thus, short dough products are created with a minimal amount of water and a significant amount of shortening. The incorporation of shortening in cookie dough is essential since it forms a protective coating of fat crystals around the gluten strands, inhibiting excessive crosslinking within the gluten network during mixing. Previous studies have shown that candelilla wax can form oleogels when mixed with safflower and soybean oil. A study by (Jang et al., 2015) assessed the feasibility of using oleogels composed of candelilla wax and canola oil as a replacement for shortening in cookies (Jang A et al., 2015).

Dough samples generally had similar melting behaviour to oleogels. Results showed that kneading of oleogel did not affect the melting characteristics of wax crystallites. Other than waxes, other structural agents have recently been studied for use in cookie oleogels. In 6% oleogels, (Li et al., 2021) assessed the performance of BEW, RBW, HPMC, MAG, and sodium stearyl lactate (SSL) (Li S. et al., 2021). Remarkable properties were found in the MAG and RBW oleogel cookies, mimicking the shortening cookie in texture, microstructure, colour, rheological properties, and sensory acceptability. WAX-STRUCTURED OLEOGELS Wax-structured oleogels have been extensively explored as a potential shortening replacement in cookies. The feasibility of employing oleogels sourced from diverse oils (olive oil, soybean oil, and flaxseed oil) and waxes (sunflower wax, rice bran wax, beeswax, and candelilla wax) as alternatives to shortening in cookies (Hwang et al., 2013). The results indicated that both wax and oil types significantly influenced the properties of the oleogel, particularly its hardness and melting behaviour. Field studies indicate that sunflower wax and rice bran wax give the most significant hardness to cookie dough. Research has shown that oleogel firmness measurements do not correlate with dough hardness. It suggests that the impact of wax on dough hardness is likely to be modulated by the other constituents in the dough or because of the physical transformations of oleogel phases during kneading. The melting behaviour of oleogels and cookie dough was evaluated with differential scanning calorimetry (DSC).

5.3. Meat Products

Diverse techniques have been utilized to formulate meat suspensions in the guise of sauces, batters, and pastes (Lupi FR et al., 2014), alongside processed meat products including sausages, patties, and frankfurters, employing oleogels, structured emulsions, and oil bulking systems (Zetl et al., 2012). Hydroxypropyl methylcellulose (HPMC) was applied to harden canola oil, which subsequently served as a replacement for beef tallow in meat patties. This change led to a 15% reduction in saturated fat relative to the beef tallow sample. The research shown a notable reduction in cooking loss (Oh I et al., 2019). Minimizing pork back fat presents a considerable challenge in the formulation of frankfurter sausages. Fifty percent of the porcine back fat was replaced with sunflower oil, which was formulated with monoglycerides and phytosterols in a 3:1 ratio. The synergistic impact of monoglyceride and phytosterol produces a crystalline network, enhancing gel strength and elevating the storage modulus. The manufactured frankfurters exhibited comparable attributes regarding cohesion, flexibility, and oxidation levels. Furthermore, sensory panelists deemed them more acceptable, as indicated by (Kouzounis et al., 2017). The researchers employed an oleogel derived from ethylcellulose as a replacement for beef fat in the manufacture of frankfurters (Barbut S. et al., 2016). The ethylcelluloseoleogel's ability to accurately mimic the distribution of fat globule sizes within the designated range resulted in the produced frankfurters demonstrating comparable firmness and chewiness to the control group.

5.3.1. Meat Burger

In a previous experiment, scientists sought to investigate the viability of producing an oleogel with ethylcellulose and adipic acid (AA) for application in beef patties. The 2018 paper by Moghtadaei et al. indicated through FTIR analysis the establishment of new intramolecular and intermolecular hydrogen bonds upon the introduction of AA to oleogels (Moghtadaei M et al., 2018). Furthermore, the application of differential scanning calorimetry (DSC), X-ray diffraction, and microscopic analyses demonstrated that the inclusion of AA improved the thermal characteristics and crystalline structure of EC-based oleogels.

Thus, the oleogel sample including 2% ethylcellulose and 4% AA demonstrated the greatest oil-binding capability of 97%. Consequently, it was selected as the "optimal" sample for incorporation into beef burger compositions. The burgers made with an oleogel comprising 2% ethylcellulose and 4% AA4 demonstrated outstanding texture, color, and flavor.

The feasibility of employing ethylcellulose and beeswax oleogels, comprising a lipid mixture of olive, fish, and linseed oils, as a substitute for fat in the creation of novel fresh meat products (Gomez-Estaca J et al., 2019). The oleogels were considered suitable for their intended use based on their physicochemical properties, including color, thermal characteristics, texture, and fatty acid composition. The goods were stable for at least one month when stored at a temperature of 3 ± 1 °C. When oleogels entirely replaced hog backfat in low-fat pork patties, the burgers exhibited reduced firmness, yet their appearance remained mostly unchanged compared to the control group. Despite substantial lipid oxidation, especially with the EC oleogel, the modified burger exhibited a markedly enhanced fatty acid profile relative to the control. The PUFA/SFA ratio rose by 3.6-fold, but the n-6/n-3 ratio diminished by 23-fold. Moreover, burgers prepared with BEW oleogel surpassed those cooked with EC in a taste evaluation, with EC receiving a score below the neutral threshold. Nonetheless, the findings suggest that the BEW oleogel may be utilized in the formulation of more nutritious, low-fat pig patties with an enhanced fatty acid composition.

5.3.2. Meat Patties

Oleogels as an animal fat replacer in beef patties. Recent studies have focused on the potentials of oleogels as an animal fat replacer in beef patties. HPMC was used to convert canola oil into a solid, oleogels. These oleogels showed an appropriate alternative to beef tallow in meat patties. The substitution of beef tallow with HPMC oleogels caused a significant decrease in the cooking loss of meat patties, ranging from 50% to 100%. In addition, the sensory study showed that the maximum overall acceptance was obtained by replacing 50% of beef tallow. In addition, the researchers used HPMC oleogels instead of beef tallow, leading to a reduction in saturated to unsaturated fat ratio from 0.73 to 0.18, thus application of HPMC oleogels resulted in healthier meat patties (Oh I et al., 2019).

To our knowledge, a study was conducted and observed the replacement of fat in pig patties for oleogel from linseed oil which is rich in polyunsaturated fatty acids (PUFA). In another study, fat in pig patties was altered through substituting 25% and 75% of solid fat with an oleogel consisted of 8% γ -oryzanol and β -Sitosterol (Park C. et al., 2018). Large changes in fatty acid composition and corresponding large reductions in omega-6: omega-3 fatty acid ratio was observed through the inclusion of oleogels. According to the results of the study in 2023, the textural properties of both the oleogel and control patties were similar and included hardness, cohesiveness, and chewiness. This holds true for either fat substitution level. While the sensory panel discriminated against the samples with control, the acceptability and preference tests are able to detect products with 25% oleogel only.

5.4. Dairy Products

5.4.1. Frozen dessert

A new study explored the use of wax-oleogel to reduce the fat level in ice cream (Airoldi E et al., 2022). The 7% BEW oleogel in camellia oil served as the oleogels used to formulate the control ice cream which used only camellia oil. The results showed that the oleogel ice cream had a moderate overrun rate, melting rate and hardness compared with traditional ice creams. The dropping time of oleogel ice cream was not significantly different from the control and was also significantly longer than camellia oil ice cream. The control ice cream was the highest scoring formulation in sensory analysis and was the most positively received by the public. On the other hand, the sensory analysis score of the camellia oleogel cream was deemed less satisfactory (Jing X et al., 2022).

5.4.2. Cream Cheese

The rheological characteristics of cream cheese have been widely studied, and most focus on its basic rheological behaviour in the heating and cooling process, especially in baked products such as cheesecake. The proportions of saturated and unsaturated fatty acids in cream cheese have an impact on its rheological and textural properties. Previous studies have shown that cream cheese from whole milk exhibited superior firmness and reduced stickiness when compared with cream cheeses prepared from low or fat-free milk (Khanal BK et al., 2020; Limbaugh et al., 2015). The study was conducted to investigate oleogel utilization in cream cheese production. Vegetable oils and other non-fat components were incorporated into RBW and EC oleogelators. Two reduced butterfat content (RBW) and two enhanced creaminess

(EC) oleogel cream cheese (OCC) were created and evaluated against commercially available full-fat and fat-free cream cheeses.

There is adverse effect of heat processing on oleogelation and thus on manufacturing of oleogel-based foods (Park C. et al., 2018). The experiment entailed the formulation of an oleogel utilizing high oleic sunflower oil (HOSO) and 10% RBW, and then employed to produce oleogel cream cheese. The oxidative stability and tocopherol content of the laboratory samples (HOSO, oleogel, and oleogel cream cheese) were compared with both the ungelled control and commercially available samples. The oxidation study indicated that the oleogel sample had a greater quantity of volatile chemicals than the high oleic sunflower oil (HOSO) samples. Nevertheless, the disparity in volatile content between the oleogel cream cheese and ungelled cream cheese samples was negligible. Furthermore, the research indicated that the high oleic sunflower oil sample possessed a higher initial total tocopherol concentration. After 14 days of storage, the oleogel cream cheese exhibited a total tocopherol level similar to that of the ungelled control and commercial samples. Different types of cheese Oleogels were formulated using BEW (7%) and either olive oil or sunflower oil as a fat replacement in the production of pickled or unpickled soft cheese (Gab-Allah RH, 2018). The cheese samples were manufactured with shortening, oleogels, and milk fat. Thereafter, the texture and sensory attributes of the cheese samples were evaluated. The use of oleogels resulted in enhanced stiffness, stickiness, and resilience of the texture, while the overall cohesiveness values generally decreased. Cheese made with oleogels demonstrated much higher values for all textural parameters, including hardness and chewiness. Although consumers may hold a moderately favorable view of the created oleogels considering color and flavor, excluding texture, the total acceptance ratings suggest that this perception may be constrained.

5.5. Confectionery

5.5.1. Chocolate

Research on oleogels in various food items, especially chocolate and its derivatives, indicates that their textural and rheological characteristics are akin to those of conventional products. Research has revealed that oleogels can be utilized to manufacture heat-resistant chocolate (Stortz TA et al., 2013). The aforementioned findings are significant as they illustrate the ability to extend the shelf life of these products in diverse climatic conditions, while also addressing quality concerns that may emerge from improper storage and marketing environments. Oleogels rich in unsaturated fatty acids may effectively diminish the requirement for cocoa butter in chocolate manufacturing (Li L et al., 2019).

6. Future Trends in Oleogel Utilization in Food

Moreover, oleogels seem to improve the absorption rate of lipid-soluble substances. The conversion rates of β -carotene into micelles during digestion were assessed for canola oil and a 12-HSA canola oil gel. The results indicated that the greatest quantity of β -carotene was liberated from the oil within the initial 30 minutes of intestinal digestion, while the oleogel exhibited peak release between 30 and 75 minutes (Stortz TA et al., 2012). Oleogel emulsions incorporating β -carotene were developed utilizing Zein as the primary constituent. Glycerol and zein were both excellent carriers for the incorporation and maintenance of the color of the β -carotene molecule. The zein oleogel efficiently maintained the preservation and stability of beneficial β -carotene while inhibiting lipid oxidation (Chen XW et al., 2016).

7. CONCLUSION

Oleogels have effectively substituted solid fats in food while maintaining food quality characteristics and meeting the health requirements of a growing number of health-conscious consumers. The composition of oleogels determines their behavior and suitability in food systems as a replacement for undesired solid fats. The extensive use of oleogels in bakery products, meat products, chocolates, and frying applications demonstrates the effectiveness of this technology as a substitute for solid fats. Consequently, it holds great potential in guaranteeing the production of food items without any negative impact on health. Consumers' health worries compelled them to opt for products with reduced levels of saturated and trans-fatty acids, as these substances have been linked to detrimental health impacts such as cardiovascular disease, diabetes, and obesity. Thus, a primary objective of the food business and researchers is to provide solid fats with high levels of unsaturated fatty acids.

REFERENCE

1. Martins A J, Vicente A A, Cunha R L, & Cerqueira M A. (2018), Edible oleogels: An opportunity for fat replacement in foods. *Food & function*, 9(2), 758-773.
2. Balasubramanian R, Sughir A A, & Damodar G. (2012), Oleogel: A promising base for transdermal formulations. *Asian Journal of Pharmaceutics (AJP)*, 6(1).
3. Davidovich-Pinhas M. (2019), Oil structuring using polysaccharides. *Current Opinion in Food Science*, 27, 29-35.
4. da Silva T L, Arellano D B & Martini S. (2018), Physical properties of candelilla wax, monoacylglycerols, and fully hydrogenated oil oleogels. *Journal of the American Oil Chemists' Society*, 95(7), 797-811.
5. Blake A I, Co E D, & Marangoni A G. (2014), Structure and physical properties of plant wax crystal networks and their relationship to oil binding capacity. *Journal of the American Oil Chemists' Society*, 91(6), 885-903.
6. Lim J, Hwang H S, & Lee S. (2017), Oil-structuring characterization of natural waxes in canola oil oleogels: Rheological, thermal, and oxidative properties. *Applied Biological Chemistry*, 60, 7-22.
7. Marangoni A G, & Garti N. (2018), Edible oleogels: structure and health implications. Elsevier.
8. Baçoğlu F. *Yemekliyağteknolojisi*. (2006), Nobel Yayın Dağıtım.
9. O'Brien R D. (2008), Soybean oil purification. In *Soybeans*. Elsevier, 377-408.
10. Klintman M, & Kronsell A. (2010), Challenges to legitimacy in food safety governance? The case of the European Food Safety Authority (EFSA). *European Integration*, 32(3), 309-327.
11. Bemer H L, Limbaugh M, Cramer E D, Harper W J, & Maleky F. (2016), Vegetable organogels incorporation in cream cheese products. *Food Research International*, 85, 67-75.
12. Co E D, & Marangoni A G. (2012), Organogels: An alternative edible oil-structuring method. *Journal of the American Oil Chemists' Society*, 89, 749-780.
13. Lim J, Jeong S, & Lee S. (2017), Evaluation of soybean oil-carnauba wax oleogels as an alternative to high saturated fat frying media for instant fried noodles. *Lwt*, 84, 788-794.
14. Pérez-Monterroza E J, Márquez-Cardozo C J, & Ciro-Velásquez H J. (2014), Rheological behavior of avocado (Persea americana Mill, cv. Hass) oleogels considering the combined effect of structuring agents. *LWT-Food Science and Technology*, 59(2), 673-679.
15. Jang A, Bae W, Hwang H-S, Lee H G, & Lee S. (2015), Evaluation of canola oil oleogels with candelilla wax as an alternative to shortening in baked goods. *Food chemistry*, 187, 525-529.
16. de Oliveira Otto M C, Mozaffarian D, Kromhout D, Bertoni A G, Sibley C T, Jacobs Jr D R, & Nettleton J A. (2012), Dietary intake of saturated fat by food source and incident cardiovascular disease: the Multi-Ethnic Study of Atherosclerosis. *The American journal of clinical nutrition*, 96(2), 397-404.
17. Jimenez-Colmenero F, Salcedo-Sandoval L, Bou R, Cofrades S, Herrero A M, & Ruiz-Capillas C (2015), Novel applications of oil-structuring methods as a strategy to improve the fat content of meat products. *Trends in Food Science & Technology*, 44(2), 177-188.
18. Ögütçü M, & Yılmaz E. (2015), Characterization of hazelnut oil oleogels prepared with sunflower and carnauba waxes. *International Journal of Food Properties*, 18(8), 1741-1755.
19. Patel A R, Rajarethinam P S, Cludts N, Lewille B, De Vos W H, Lesaffer A, & Dewettinck K. (2015), Biopolymer-based structuring of liquid oil into soft solids and oleogels using water-continuous emulsions as templates. *Langmuir*, 31(7), 2065-2073.
20. Zetl AK, Marangoni AG, Barbut S. (2012), Mechanical properties of ethylcellulose oleogels and their potential for saturated fat reduction in frankfurters. *Food & function*, 3(3), 327-337.
21. Bogdanov S, Ruoff K, Oddo LP. (2004), Physico-chemical methods for the characterisation of unifloral honeys: a review. *Apidologie*, 35(Suppl. 1), S4-17.
22. Hwang HS, Kim S, Singh M, (2012), Winkler-Moser JK, Liu SX. Organogel formation of soybean oil with waxes. *Journal of the American Oil Chemists' Society*, 89(4), 639-647.
23. Patel AR, Cludts N, Sintang MD, Lesaffer A, Dewettinck K. (2014), Edible oleogels based on water soluble food polymers: Preparation, characterization and potential application. *Food & function*, 5(11), 2833-2841.
24. Mukkamala R, Weiss RG. (1996), Physical gelation of organic fluids by Anthraquinone-steroid based molecules. Structural features influencing the properties of gels. *Langmuir*, 12(6), 1474-1482.
25. Toro-Vazquez JF, Morales-Rueda J, Mallia VA, Weiss RG. (2010), Relationship between molecular structure and thermo-mechanical properties of candelilla wax and amides derived from (R)-12-hydroxystearic acid as gelators of safflower oil. *Food Biophysics*, 5, 193-202.
26. Friggeri A, Gronwald O, Van Bommel KJ, Shinkai S, Reinhoudt DN. (2002), Charge-transfer phenomena in novel, dual-component, sugar-based organogels. *Journal of the American Chemical Society*, 124(36), 10754-10758.
27. Edmund Daniel Co, Marangoni AG. (2012), Organogels: An alternative edible oil-structuring method. *Journal of the American Oil Chemists' Society*, 89, 749-780.
28. Patel AR. (2015), Alternative routes to oil structuring. New York, NY, USA: Springer International Publishing, 18.
29. Marangoni AG, Garti N. (2011), An overview of the past, present, and future of organogels. *Edible oleogels*, 1, 1-7.
30. Zetl AK, (2011), Marangoni AG. Novel strategies for nanostructuring liquid oils into functional fats. In *Edible Oleogels*, 1, 19-47.
31. Marangoni AG. (2004), The nature of fractility in fat crystal networks. In *Fat crystal networks*, 430-457.
32. Calligaris D, Verdier-Pinard P, Devred F, Villard C, Braguer D, Lafitte D. (2010), Microtubule targeting agents: from biophysics to proteomics. *Cellular and molecular life sciences*, 67, 1089-1104.
33. Calligaris S, Da Pieve S, Arrighetti G, Barba L. (2010), Effect of the structure of monoglyceride-oil-water gels on aroma partition. *Food Research International*, 43(3), 671-677.

34. Da Pieve S, Calligaris S, Co E, Nicoli MC, Marangoni AG. (2010), Shear nanostructuring of monoglyceride organogels. *Food Biophysics*, 5, 211-217.
35. Ferro AC, Okuro PK, Badan AP, Cunha RL. (2019), Role of the oil on glycerylmonostearate based oleogels. *Food Research International*, 120, 610-619.
36. Naderi M, Farmani J, Rashidi L. (2016), Structuring of chicken fat by monoacylglycerols. *Journal of the American Oil Chemists' Society*, 93, 1221-1231.
37. Ojijo NK, Neeman I, Eger S, Shimoni E. (2004), Effects of monoglyceride content, cooling rate and shear on the rheological properties of olive oil/monoglyceride gel networks. *Journal of the Science of Food and Agriculture*, 84(12), 1585-1593.
38. Perneti M, van Malssen K, Kalnin D, Flöter E. (2007), Structuring edible oil with lecithin and sorbitan tri-stearate. *Food Hydrocolloids*, 21(5-6), 855-61.
39. Wright AJ, Marangoni AG. (2006), Formation, structure, and rheological properties of ricinelaidic acid-vegetable oil organogels. *Journal of the American Oil Chemists' Society*, 83(6), 497-503.
40. Jana S, de Frutos M, Davidson P, Abécassis B. (2017), Ligand-induced twisting of nanoplatelets and their self-assembly into chiral ribbons. *Science advances*, 3(9), e1701483.
41. Pehlivanoglu H, Demirci M, Toker OS, Konar N, Karasu S, Sagdic O. (2018), Oleogels, a promising structured oil for decreasing saturated fatty acid concentrations: Production and food-based applications. *Critical reviews in food science and nutrition*, 58(8), 1330-1341.
42. Zhang L, Zheng J, Wang Y, Ye X, Chen S, Pan H, Chen J. (2022), Fabrication of rhamnolacturonan-I enriched pectin-based emulsion gels for protection and sustained release of curcumin. *Food Hydrocolloids*, 128, 107592.
43. Dassanayake LS, Kodali DR, Ueno S. (2011), Formation of oleogels based on edible lipid materials. *Current opinion in colloid & interface science*, 16(5), 432-439.
44. Marangoni AG, Garti N, editors. (2018), Edible oleogels: structure and health implications. Elsevier.
45. Terech P, Weiss RG. (1997), Low molecular mass gelators of organic liquids and the properties of their gels. *Chemical reviews*, 97(8), 3133-3160.
46. Gravelle AJ, Barbut S, Quinton M, Marangoni AG. (2014), Towards the development of a predictive model of the formulation-dependent mechanical behaviour of edible oil-based ethylcelluloseoleogels. *Journal of Food Engineering*, 143, 114-122.
47. Mozaffarian D, Aro A, Willett WC. (2009), Health effects of trans-fatty acids: experimental and observational evidence. *European journal of clinical nutrition*, 63(2), S5-21.
48. Mert B, Demirkesen I. (2016), Reducing saturated fat with oleogel/shortening blends in a baked product. *Food chemistry*, 199, 809-816.
49. Davidovich-Pinhas M, Barbut S, Marangoni AG. (2015), The role of surfactants on ethylcellulose oleogel structure and mechanical properties. *Carbohydrate Polymers*, 127, 355-362.
50. Martins AJ, Vicente AA, Pastrana LM, Cerqueira MA. (2020), Oleogels for development of health-promoting food products. *Food Science and Human Wellness*, 9(1), 31-39.
51. Limpimwong W, Kumrungsee T, Kato N, Yanaka N, Thongngam M. (2017), Rice bran wax oleogel: A potential margarine replacement and its digestibility effect in rats fed a high-fat diet. *Journal of Functional Foods*, 39, 250-256.
52. Dong L, Lv M, Gao X, Zhang L, Rogers M, Cao Y, Lan Y. (2020), In vitro gastrointestinal digestibility of phytosteroleogels: Influence of self-assembled microstructures on emulsification efficiency and lipase activity. *Food & function*, 11(11), 9503-9513.
53. Mert B & Demirkesen I. (2016), Evaluation of highly unsaturated oleogels as shortening replacer in a short dough product. *LWT-Food Science and Technology*, 68, 477-484.
54. Ramadhan W, Krisnawan WV, Firdaos AN, Riyanto B, Suseno SH, Trilaksana W, Santoso J, Pari RF. (2024), The feasibility of marine oleogel based on fish oil canning industry by-products, structured with beeswax and rice bran wax. *International Journal of Food Science & Technology*, 59(2), 754-764.
55. Yılmaz E, Öğütü M. (2015), The texture, sensory properties and stability of cookies prepared with wax oleogels. *Food & function*, 6(4), 1194-204.
56. Moghtadaei M, Soltanzadeh N, Goli SA. (2018), Production of sesame oil oleogels based on beeswax and application as partial substitutes of animal fat in beef burger. *Food Research International*, 108, 368-377.
57. ZulimBotega DC, Marangoni AG, Smith AK, Goff HD. (2013), The potential application of rice bran wax oleogel to replace solid fat and enhance unsaturated fat content in ice cream. *Journal of food science*, 78(9), C1334-1339.
58. Schickenberg B, van Assema P, Brug J, Verkaik-Kloosterman J, Ocké MC, de Vries NK. (2009), Replacing foods high in saturated fat by low-saturated fat alternatives: a computer simulation of the potential effects on reduction of saturated fat consumption. *British journal of nutrition*, 102(3), 478-483.
59. Di Cairano M, Galgano F, Tolve R, Caruso MC, Condelli N. (2018), Focus on gluten free biscuits: Ingredients and issues. *Trends in Food Science & Technology*, 81, 203-212.
60. BademŞ, Baştürk A. (2023), Oxidative stability and characterization of oleogels obtained from safflower oil-based beeswax and rice bran wax and their effect on the quality of cake samples. *Journal of the American Oil Chemists' Society*, 100(8), 635-49.
61. Espert S. (2023), Experimental and theoretical investigation of strong acid hydrates.
62. Demirkesen I, Mert B. (2020), Recent developments of oleogel utilizations in bakery products. *Critical reviews in food science and nutrition*, 60(14), 2460-2479.
63. Ye X, Li P, Lo YM, Fu H, Cao Y. (2019), Development of novel shortenings structured by ethylcelluloseoleogels. *Journal of food science*, 84(6), 1456-1464.
64. Rios RV, Pessanha MD, Almeida PF, Viana CL, Lannes SC. (2014), Application of fats in some food products. *Food Science and Technology*, 34, 3-15.

65. Lee S. (2018), Utilization of foam structured hydroxypropyl methylcellulose for oleogels and their application as a solid fat replacer in muffins. *Food Hydrocolloids*, 77, 796-802.
66. Li S, Wu G, Li X, Jin Q, Wang X, Zhang H. (2021), Roles of gelator type and gelation technology on texture and sensory properties of cookies prepared with oleogels. *Food Chemistry*, 356, 129667.
67. Hwang HS, Singh M, Bakota EL, Winkler-Moser JK, Kim S, Liu SX.(2013), Margarine from organogels of plant wax and soybean oil. *Journal of the American Oil Chemists' Society*, 90, 1705-1712.
68. Lupi FR, Gabriele D, Seta L, Baldino N, de Cindio B. (2014), Rheological design of stabilized meat sauces for industrial uses. *European Journal of Lipid Science and Technology*, 116(12), 1734-1744.
69. Oh I, Lee J, Lee HG, Lee S. (2019), Feasibility of hydroxypropyl methylcellulose oleogel as an animal fat replacer for meat patties. *Food Research International*, 122, 566-572.
70. Kouzounis D, Lazaridou A, Katsanidis E. (2017), Partial replacement of animal fat by oleogels structured with monoglycerides and phytosterols in frankfurter sausages. *Meat Science*, 130, 38-46.
71. Barbut S, Wood J, Marangoni A. (2016), Quality effects of using organogels in breakfast sausage. *Meat Science*, 122, 84-89.
72. Moghtadaei M, Soltanizadeh N, Goli SA. (2018), Production of sesame oil oleogels based on beeswax and application as partial substitutes of animal fat in beef burger. *Food Research International*, 108, 368-377.
73. Gómez-Estaca J, Pintado T, Jiménez-Colmenero F, Cofrades S. (2019), Assessment of a healthy oil combination structured in ethyl cellulose and beeswax oleogels as animal fat replacers in low-fat, PUFA-enriched pork burgers. *Food and Bioprocess Technology*, 12, 1068-1081.
74. Martins AJ, Lorenzo JM, Franco D, Vicente AA, Cunha RL, Pastrana LM, Quiñones J, Cerqueira MA. (2019), Omega-3 and polyunsaturated fatty acids-enriched hamburgers using sterol-based oleogels. *European journal of lipid science and technology*, 121(11), 1900111.
75. Airoidi R, da Silva TL, Ract JN, Foguel A, Colleran HL, Ibrahim SA, da Silva RC. (2022), Potential use of carnauba wax oleogel to replace saturated fat in ice cream. *Journal of the American Oil Chemists' Society*, 99(11), 1085-1099.
76. Jing X, Chen Z, Tang Z, Tao Y, Huang Q, Wu Y, Zhang H, Li X, Liang J, Liu Z, Cai H. (2022), Preparation of camellia oil oleogel and its application in an ice cream system. *Lwt*, 169, 113985.
77. Khanal BK, Bansal N. (2020), Dairy fat replacement in low-fat cheese (LFC): A review of successful technological interventions. *Dairy fat products and functionality: Fundamental science and technology*, 549-581.
78. Limbaugh MD. (2015), Replacement of saturated fats in a cream cheese product (Master's thesis, The Ohio State University).
79. Park C, Bemer HL, Maleky F. (2018), Oxidative stability of rice bran wax oleogels and an oleogel cream cheese product. *Journal of the American Oil Chemists' Society*, 95(10), 1267-1275.
80. Gab-Allah RH. (2018), Manufacture of pickled and un-pickled high fat soft cheese using olive and sunflower oleogels. *Sciences*. 8(1), 223-230.
81. Stortz TA, Marangoni AG. (2013), Ethylcellulose solvent substitution method of preparing heat resistant chocolate. *Food Research International*, 51(2), 797-803.
82. Li L, Liu G. (2019), Corn oil-based oleogels with different gelation mechanisms as novel cocoa butter alternatives in dark chocolate. *Journal of Food Engineering*, 263, 114-122.
83. Stortz TA, Zetzl AK, Barbut S, Cattaruzza A, Marangoni AG. (2012), Edible oleogels in food products to help maximize health benefits and improve nutritional profiles. *Lipid Technology*, 24(7), 151-154.
84. Chen XW, Fu SY, Hou JJ, Guo J, Wang JM, Yang XQ. (2016), Zein based oil-in-glycerol emulgels enriched with β -carotene as margarine alternatives. *Food chemistry*, 211, 836-844.