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Review paper

OLEOGELS – AN ALTERNATIVE TO REPLACE ANIMAL FATS IN MEAT PRODUCTS

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Abstract

The changes in lifestyle of modern consumers have increased demand for healthier meat products. Animal fat, which is an integral part of meat products, is directly related to the occurrence of chronic diseases and overweight. Polyunsaturated vegetable oils are healthier for human consumption, but their liquid consistency can pose a problem when directly applied in the technological process. Application of oleogels, obtained with innovative technology for gelling vegetable oils using gelators, is a new approach to create healthier meat products with an improved fatty acid profile. This paper aims to review the different approaches for obtaining oleogels and the latest trends for their use in meat products.

Key words: *oleogels, gelators, vegetable oils, meat products*

INTRODUCTION

Fats can be present from 30% to 50% in some types of meat products, thus directly affecting their technological (Badar et al., 2021; Oliveira et al., 2021) and sensory characteristics (Totosaus-Sanchez, 2008; Zampouni et al., 2022). Although meat products contain a high percentage of fat in their composition, they are still highly respected and consumed mainly because of their sensory attributes (Agregán et al., 2018). However, a higher intake of saturated and trans-fatty acids is associated with the prevalence of various diseases, including diabetes, obesity and especially cardiovascular diseases (de Souza et al., 2015; Hooper et al., 2020).

In the past, reducing total fat intake was recommended as a preventive measure for cardiovascular disease (Mozaffarian et al., 2018), but today, the focus is shifting to improving the quality of dietary fat (Schwingshackl et al., 2022). The trends for the creation of new formulations, in which complete or partial replacement of saturated and trans-fatty acids with unsaturated fatty acids, present a challenge for the food industry (Hooper et al., 2020).

By applying oleogels there is an opportunity to create a wide range of semi-solid and solid meat products with an improved lipid profile suitable for consumption (Wang et al., 2023). The market for healthier processed meats is expected to grow. Current generation of consumers are health conscious and choose 'health', regardless of the price of meat products (Badar et al., 2021).

OLEOGELS AS ALTERNATIVES TO ANIMAL FATS

Incorporating unsaturated fats into meat products is difficult due to maintaining the consistency of the product and obtaining a final product with undesirable softness, lower sensory acceptability and greater chances of oxidative degradation (Pintado & Cofrades, 2020). Lima et al., (2022) consider that the incorporation of vegetable oils into meat products is a viable alternative, and oleogelation, as the technological strategy for the restructuring of vegetable oils into oleogels and their incorporation into meat processing, will meet the demands of the industry and consumers.

The ideal fat should have the chemical composition of liquid oil (high fraction of mono and polyunsaturated fats) and all the functional properties of solid fat (Pehlivanoğluet et al., 2016). Oleogels have the characteristics of solid fats (providing unique taste, texture and plasticity) without changing the health and nutritional composition of vegetable oil (Ferro et al., 2021; Li et al., 2021). In fact, oleogels are solids with a three-dimensional network structure obtained by dissolving a gelator in an organic solvent under the influence of various interactions (Perta-Crisan et al., 2023). To obtain oleogels, direct and indirect methods are used (Feichtinger & Scholten, 2020), but the most commonly investigated are: straightforward dispersion and indirect approaches such as foam or emulsion-templated processes (Wang et al., 2023).

Direct dispersion involves: adding the gelator to oil, heating to a point above the melting point of the gelator, and natural or forced cooling. As a result of the cooling process, nucleation, crystallization and self-assembly occur (Aguilar-Záratea et al., 2019). The most commonly investigated gelators used in the direct dispersion method are: glycerol esters of fatty acids such as mono- and di-acylglycerols, natural waxes, hydroxylated fatty acids such as 12-hydroxy stearic acid and its 12-hydroxy derivatives, trans-9-Octadecenoic acid (ricinelaidic acid), sphingolipids and mixed systems such as a combination of phytosterols and sterol esters in particular, β-sitosterol + γ-oryzanol and ethylcellulose (Draper & Adams, 2017).

The emulsion approach involves several steps: adding the gelator to the oil and stirring at low speed to achieve dispersion, adding water (T< 100 °C) and homogenizing at 16 500 rpm. The resulting emulsion is transferred to a mould and dried by forced convection. The dried samples are processed at a high number of revolutions until the formation of an oleogel (Espert et al., 2021). In the foam approach, the gelator is dissolved in water, homogenized at 13 000 rpm to obtain a foam that is dried by lyophilisation to obtain a cryogel, which is ground and oil is added to it, after which it is processed by homogenization at 10 000 rpm in order to obtain an oleogel (Abdollahi et al., 2019). The most commonly used gelators for indirect methods are polysaccharides, proteins, polymers (Kavya et al., 2022).

The technological challenge is to design oleogels that exhibit the desired structural and physicochemical properties (Feichtinger & Scholten, 2020). The different approaches, the type and content of oil, as well as the type of gelator allow obtaining oleogels with different properties and functions (Wang et al., 2023). By using various types of gelators to structure oil, oleogels with distinct textural and thermorheological characteristics can be produced (Lim et al., 2017). Oleogel properties are closely related to solvent structure and processing conditions (Patel et al., 2015). By adding larger amounts of gelator, oleogels with higher viscosity are obtained, but as the temperature of the oleogel increases, its viscosity decreases (Ruiz Martinez et al., 2003). Oleogels that have a higher proportion of polyunsaturated fatty acids in their oil composition exhibit faster gelation rates, more extensive microstructures under varying cooling rates, and stronger Van der Waals forces (Han et al., 2022).

POSITIVE PROPERTIES OF OLEOGELS

Oleogels excel in the ability to encapsulate and aid in the controlled release of lipid-soluble nutrients (Manzoor et al., 2022). The solid-phase gelator can modulate lipid digestion, that is, alter the release of lipids into the bloodstream as a result of the complex network structure, protecting the sites for triacylglycerol digestion by the enzyme lipase (Hwang, 2020). During digestion, an oil-water interface is formed, this interface allows the binding of surfactant components in the small intestine, such as bile salts and colipase/lipase complexes. Unlike classical lipids, the structuring networks of gelators act as a physical barrier preventing digestive enzymes from coming into close proximity to lipids and causing a delay in digestion (Tan et al., 2023). After 4 weeks of feeding rats an oleogel formed from rice bran and rice bran oil, compared to margarine and beef tallow, it was confirmed that the levels of triacylglycerol decreased by about 30% in the serum and liver and increased the levels of excreted triacylglycerol by 30% in feces, compared to rats fed margarine and beef tallow (Limpimwong et al., 2017).

In their study, Ghosh et al. (2017) evaluated the nutritional properties of oleo-gels made from a blend of palm stearin with cetyl laurate and palm stearin with cetyl caprylate as gelators at 15% (w/w) for a blend of linseed oil and rice bran in rats. The analysis of the blood lipid profile revealed that rats fed with oleogels had lower cholesterol levels compared to those fed only the oil mixture. In a separate study, Tan et al. (2017) examined the effects of coconut oil in liquid or oleogel form on triglycerides, glucose, insulin, and hunger when consumed with a high-carbohydrate meal. The results indicated significant changes in glucose, insulin, triglycerides, and hunger. Gelled coconut oil also reduced the peak glucose response and increased the incremental area under the curve for postprandial triglycerides

The absorption rate of plant sterols in the gastrointestinal tract is much lower, about 5% compared to cholesterol absorption which is about 55% - 60% (Scharfe & Flöter, 2020). Phytosterols such as β-sitosterol and γ-oryzanol, which are used as gelators, can affect the inhibition of intestinal absorption of cholesterol, thereby reducing the level of LDL cholesterol in the blood. For example, phytosterols in doses of 2-3 g/day reduce LDL-cholesterol levels by 6%-15% (NCEP 2002). Three different gelators were investigated for the gelation of canola oil: ethyl cellulose, mono- and di-glycerides, and a mixture of β-sitosterol + γ-oryzanol. Simulated intestinal lipolysis revealed a significantly different pattern of lipolysis for the different gelation mechanisms. Ethylcellulose-based oleogels are more susceptible to lipolysis compared to the β-sitosterol + γ-oryzanol mixture, while glycerides showed a high level of lipolysis up to 90% due to the hydrolysis of the gelator itself (Ashkar et al., 2019). However, it is challenging to incorporate these oleogels into water-containing systems, because the presence of water can interfere with the ability of the gelator to assemble into tubules or cause recrystallization of the network (Duffy et al., 2009). Applications are successful where water activity is controlled through the interaction of other ingredients such as proteins and hydrocolloids (Matheson et al., 2018).

Another positive property of oleogels is the delivery of bioactive molecules, as a result of their lipid medium which is well suited to prevent deposition of bioactive substances, slow lipolysis and release of nutrients from crystalline and fibrillar networks (O'Sullivan et al., 2016; Martins et al., 2020). Two types of gelators, beeswax and a mixture of β-sitosterol + γ-oryzanol, were used for gelation of long-chain triglycerides. In both cases, the gelator was added in an amount of 8% (w/w) and enriched with 0.1% (w/w) β-carotene. In vitro digestion indicated a bioavailability of 26% of β-carotene in sterol-based oleogels and approximately 20% in beeswax-based oleogels (Martins et al., 2018). In vitro lipolysis and transfer of β-carotene was also investigated by Chloe et al., (2017) in canola oil gelled with ethylcellulose, results indicated increased stability of β-carotene in the oleogel and antioxidative behavior. Curcumin, a natural polyphenolic compound, possesses a spectrum of health benefits, including anticancer, anti-inflammatory, antioxidant, antiviral, and cytoprotective properties. However, its limited solubility in water, susceptibility to degradation from light, heat, and physiological pH conditions result in an exceptionally low bioavailability (Pérez et al., 2019). To address this challenge, curcumin was incorporated into a corn oil oleogel structured by β-sitosterol and lecithin. The oleogel demonstrated heightened oxidative stability and improved bioavailability compared to the control. Specifically, crosslinking curcumin in the oleogel increased its bioavailability in the fasting state to 67.66% (Li et al., 2019)."

A positive feature of oleogels is that they are obtained by gelation without hydrolysis, while sterols and vitamin E remain stable during gel formation (Xu et al., 2022). However, the effect of processing, cooking, freezing storage as well as the type of fat used can affect the stability and content of vitamin E in meat products (Wan Rosli et al., 2006).

APPLICATION OF OLEOGELS IN MEAT PRODUCTS

Oleogels have been recognized as a very promising alternative to replace trans and saturated fats, but no oleogels have yet been used on a commercial basis in food production (Hwang, 2020). By applying oleogels there is an opportunity to create a wide range of semi-solid and solid meat products with an improved lipid profile suitable for consumption (Wang et al., 2023). The use of low-quality oleogels can cause technological problems, such as improper drying, greasy appearance, delamination, etc. (López-Pedrouso et al., 2021).

By replacing 50% of the animal fat with an oleogel structured from sunflower oil using monoglycerides of phytosterols in a ratio of 15:5 (w/w) in sausages of the "Frankfurt" type, a product with an improved fatty acid profile is obtained without significantly compromising the physical, chemical, textural and sensory characteristics (Kouzounis et al., 2017). 12-fold reduction of the ratio of polyunsaturated fatty acids, n-6/n-3 compared to control samples, in fermented sausages of the "Fuet" type using oleogels based on 80% olive oil and 20% chia seed oil, obtained by direct dispersion using beeswax or emulsion approach using isolated soy protein and gelatin (Pintado & Cofrades, 2020). By completely or partially replacing the animal fat in foie gras with oleogel obtained from olive oil (44.39%), linseed oil (37.87%) and fish oil (17.74%) with gelators ethyl cellulose and beeswax, an optimal fatty acid profile was obtained, a high PUFA/SFA ratio and a low n-6/n-3 ratio. Lipid oxidation was increased while, the substitution insignificantly affected the emulsion stability, color and texture, compared to the control. Sensory characteristics were insignificantly affected using beeswax, while a negative effect on sensory properties was confirmed when using ethyl cellulose, depending on the level of substitution (Gómez-Estaca et al., 2019). A different degree of lipid oxidation depending on the oleogel used for fat replacement has been reported (Wolfer et al., 2018). Increased lipid oxidation compared to the control sausage was reported in samples using the rice bran wax oleogel (10%) during 0, 42, 70 and 84 days of storage, but the thiobarbituric acid TBA value never exceeded 0.201 mg/kg for any day of analysis. Curcumin was added to oleogels gelled with beeswax and ethylcellulose. The resulting oleogels are incorporated into pork burgers. Curcumin effectively reduced the oxidation process, burgers with beeswax oleogel showed adequate technological properties, but with the addition of curcumin, a yellow color was obtained, which reduced the sensory acceptance (Gómez-Estaca et al., 2020). Incorporated into paté, oleogels obtained in optimal conditions 9.12% beeswax and 0.54% curcumin. The oleogels showed a mechanical strength similar to porcine hard adipose tissue and a high oil binding capacity of over 90%. The addition of added curcumin attenuated lipid oxidation during cold storage (Ramírez-Carrasco et al., 2020). Jeong et al. (2021) found that applying an oleogel with added β-carotene as an antioxidant resulted in lower peroxide number values in muffins. However, further research is needed to investigate the application of β-carotene or other antioxidants in oleogels and their use in meat products.

Replacing 50% of animal fat with an oleogel of glyceryl-monostearate with sunflower oil did not impact the firmness of sausages, while sensory evaluations showed that they were more acceptable than the control (Ferro et al., 2021). For good retention of the oil phase in foie gras, Barbut et al. (2020) recommend replacing 60% of the animal fat with an oleogel based on canola oil gelled with 12% ethyl cellulose and 3% glycerol monostearate. Also, Barbut et al. (2021) recommend replacing 60% of lard with an oleogel based on canola fat, ethyl cellulose and glycerol monostearate in foie gras to retain oil and maintain textural properties without affecting sensory properties and colour. Contrary to this, Martins et al. (2020), report a decrease in hardness and increased stickiness in foie gras by replacing animal fat by 60% with oleogel from linseed oil and beeswax, but also an increase in the percentage of polyunsaturated fats and a decreased ratio of n6/n3 by 90%. Tarté et al. (2020), obtained a softer product and an improved fatty acid profile by replacing 41.9% of the animal fat with soybean oil oleogel with rice bran wax in sausages, linseed oil-based oleogel, structured with a mixture of γ-oryzanol and β-sitosterol and beeswax, and incorporated into fermented sausages in an amount of 20% and 40% resulted in products with reduced sensory quality, which decreased with an increase in the percentage representation of oleogel (Franco et al., 2020). Incorporation of oleogel obtained by gelling cannabis oil using gelators such as rice bran wax (5%; 7%) or candelilla wax (3%; 7%) in meat patties improved their fatty acid and oxidative stability but sensory acceptability was low (Hamidioglu et al., 2022).

CONCLUSION

The attractiveness and actuality of oleogels obtained by gelling vegetable oils with the help of gelators is growing daily. The use of different vegetable oils and their combinations, as well as the use of different gelators offer a wide range and design of oleogels with different characteristics. However, as a common positive characteristic of meat products in which animal fats have been replaced with oleogels, it is an improvement in the fatty acid profile of meat products, which makes the products more nutritionally acceptable for consumers. With the suitable choice of: technique, oil, gelator and selection of the optimal amount of replacement, a product will be obtained that will satisfy the sensory and technological qualities of the conventional product. The acceptability of a product by consumers is important assessment in creating a quality product with a successful replacement of the fats.

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ОЛЕОГЕЛОВИ – АЛТЕРНАТИВА ЗА ЗАМЕНА НА ЖИВОТИНСКИТЕ МАСТИ ВО ПРОИЗВОДИТЕ ОД МЕСО

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Резиме

Промената на животниот стил на современите потрошувачи ја зголеми побарувачката на поздрави производи од месо. Животинската маст која е составен дел од месни производи е директно поврзана со појавата на хронични заболувања и прекумерна телесна тежина. Полинезаситените растителни масла се поздрави за човечка исхрана, но нивната течна конзистенција може да претставува проблем при директно аплицирање во технолошкиот процес. Олеогеловите добиени со иновативна

технологија за желирање на растителните масла со помош на желатори и нивната апликација во производите од месо е нов пристап за креирање на поздрави месни производи со подобрен масно-киселински профил. Овој преглед има за цел да ги разгледа различните пристапи за добивање на олеогелови и најновите трендови за нивна употреба во производите од месо.

Клучни зборови: *олеогелови, желатори, растително масло, производи од месо.*