



## A review of the use of oleogels to improve the quality of sheep and goat meat products

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### ABSTRACT

Global demand for healthy, sustainable meat is rising due to consumer preferences for nutritious options. Sheep and goat meat, valued for flavor and leanness, require innovative quality assurance, especially outside Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) labels. Oleogels, solid at room temperature but melting at body temperature, enhance meat quality by replacing saturated fats with healthier unsaturated fats, aligning with health-conscious consumer trends. They also reduce environmental impact and cardiovascular risks. Oleogels maintain meat's mouthfeel and texture, aiding in the development of healthier, sustainable products. While gelled emulsions show promise as fat replacers, their use in sheep and goat meat is largely untapped. This review highlights oleogels' potential in transforming these meats, focusing on formulation, functionality, and benefits, to meet consumer demands for healthier, sustainable options.

### 1. Introduction

The global demand for high-quality, healthy, and sustainable meat products is steadily increasing, driven by growing consumer awareness and preference for nutritious food options. In many regions, sheep and goat meat are highly valued for their unique flavor, palatability, nutritional benefits, and cultural significance. Notably, goat meat is leaner than other red meats, which has led to its growing popularity among consumers seeking lower-fat options. Furthermore, sheep and goat meat consumption is often associated with specific ethnic groups and is closely linked to religious festivities (Teixeira et al., 2019). However, ensuring its quality and increasing its appeal to consumers requires innovative approaches, especially for meat from less commercially valued animals, such as meat and carcasses outside the brands with PDO and PGI quality labels.

Oleogels represent a promising technological advancement in the meat industry, offering a range of benefits that enhance the quality and nutritional profile of meat products. These materials, solid at room temperature but melts at body temperature, are derived from edible oils and fats, which are stabilized by solid particles or molecules that immobilize liquid oils or organic phases within a gel network. These systems have garnered significant attention in the food industry due to their ability to modify fats' physical and functional properties without compromising their health benefits (Fig. 1).

The Figure outlines the process and benefits of using oleogels in meat products. Oleogels are created by blending edible oils with gelling agents to form a stable matrix. This matrix can be injected or mixed into meat formulations to replace saturated fats, offering a healthier lipid profile. The benefits include improved flavor release, extended shelf life, and better marketability due to healthier options and labeling advantages (Zetzel et al., 2012; Co et al., 2012; Barbut et al., 2016). Quality meat products retain juiciness and flavor while providing a healthier option for consumers. This innovative approach enhances both the nutritional value and consumer appeal of meat products.

In recent years, oleogels have emerged as promising techniques to mainly enhance meat quality and sensory attributes (Ferdaus et al., 2024; Jovanovics et al., 2023), making their use in meat products particularly noteworthy for several reasons. Oleogels can be formulated to contain healthier fats, such as unsaturated fatty acids, which can replace less healthy saturated fats commonly found in meat products. This substitution not only improves the nutritional profile of the meat but also contributes to better health outcomes for consumers (Ferdaus et al., 2024; Gengatharan et al., 2023). Also, Oleogels can serve as a viable alternative to animal fats in meat products, which is beneficial for both ethical and health reasons. This substitution helps in reducing the environmental impact associated with animal farming and processing (Ferdaus et al., 2024). By reducing the amount of saturated and trans fats, oleogels help in lowering the risk of cardiovascular diseases,

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making meat products healthier options for consumers. This aligns with current health guidelines and consumer preferences for healthier food choices (Gengatharan et al., 2023). To ensure consumer satisfaction, the use of oleogels is important for preserving the desired mouthfeel and structural integrity of the meat (Liu et al., 2024). In summary, the use of oleogels in meat products not only improves their nutritional value and health benefits but also enhances their texture and stability, making them a valuable tool for developing healthier and more sustainable meat products.

Recent studies have shown the potential of using gelled emulsions as fat replacers in meat products (Botella-Martinez et al., 2021; Barros et al., 2021; Botella-Martínez et al., 2021; Guterres, 2023). However, the use of oleogels in processed sheep and goat meat products is not so popular. In the case of meats, particularly those from animals that fall outside the quality mark and have a lower commercial value, with a low fat content such as goat meat, the use of oleogels could be a way of valorising these meats and conquering new consumer markets. By integrating these gels into sheep and goat meat products, it is possible to enhance texture, reduce fat content, change the lipid profile, improve stability, and extend shelf life while maintaining or even boosting the nutritional profile of the meat. Considering the challenges of incorporating different fat sources, as fat plays a crucial role in texture, juiciness, and flavor—factors influencing consumer acceptance—it is essential to assess their potential impact on sheep and goat meat products.

The use of oleogels in food products, particularly in meat formulations, can be studied from a food composition and analysis perspective to understand their impact on nutritional, sensory, and structural properties. The study of oleogels from a food composition and analysis perspective involves a multidisciplinary approach, combining techniques from chemistry, physics, microbiology, and sensory science. By analyzing the compositional, structural, nutritional, and sensory properties of oleogels, researchers can optimize their use in meat products to create healthier, more appealing options for consumers. This innovative approach not only enhances the nutritional value of meat products but also aligns with the growing demand for functional and sustainable foods.

The application of oleogels in sheep and goat meat represents a promising yet underexplored area of research. While oleogels have been widely studied in beef, pork, and poultry, their use in mutton and goat meat products remains limited, creating a significant research gap. This innovative approach can address challenges such as high saturated fat content, texture variability, and consumer perception of these meats.

This revision explores the potential of oleogels in transforming sheep and goat meat products, focusing on their formulation, functionality, and benefits regarding food quality enhancement. By delving into current research and technological advancements, this discussion aims to provide insights into how these innovative gels can be leveraged to meet consumer demands for healthier and more sustainable sheep and goat meat product options.

## 2. Understanding of oleogels (definition and characteristics, properties and applications in food technology)

The oleogels represent innovative structures that can substitute saturated fats in food products while preserving desirable physical properties (Stortz et al., 2012). In accordance to Arketerian and Arkerian, (2022) authors, to differentiate the conventional “organogels” used in chemical engineering from the edible oil gels, they are called oleogels. These gel-like materials are created by structuring liquid oils with different gelling agents, immobilizing a solvent in a cross-linked elastic or viscoelastic network called gelators (Esposito et al., 2018). The majority of network-forming structurants are classified as either polymeric organic gelators or low- and high-molecular weight organogelators (Davidovich-Pinhas, 2019; Marangoni, 2012). The fatty acids, fatty alcohols, waxes, wax esters, sorbitan esters, phytosterols, and mono- and diglycerides (Hwang et al., 2012; Palla et al., 2017; Perneti, et al., 2007) and ethyl cellulose, protein and polysaccharides (Meissner et al., 2019; de Vries et al., 2017; Fu et al., 2020; Abdollahi et al., 2019; Davidovich-Pinhas, 2019) are some examples of low- and high gelators approved and used in food matrixes.

Among the most widely used, 12-Hydroxystearic acid and ethyl cellulose are a notable food-grade polymer organogelator (Stortz et al., 2012; Davidovich-Pinhas et al., 2016). In his work, the latter author explains ethyl cellulose-based oleogels and refers to several comprehensive review articles that have been published on the various oleogel systems. Depending on the solvent’s nature, gel formulations can be classified as hydrogels or organogels (or oleogels). Oleogels analogous to hydrogels, are bicontinuous systems (the gelling agent and the organic solvent) in which the molecules of the gelling agent self-assemble to create the network structure, trapping the liquid (Barragán-Martínez et al., 2022). They can be prepared through direct methods, which involve the temperature-induced reorganization of gelators, or through indirect methods like emulsification and solvent exchange (Martins et al., 2018). In this sense, oleogels allow properties that are not

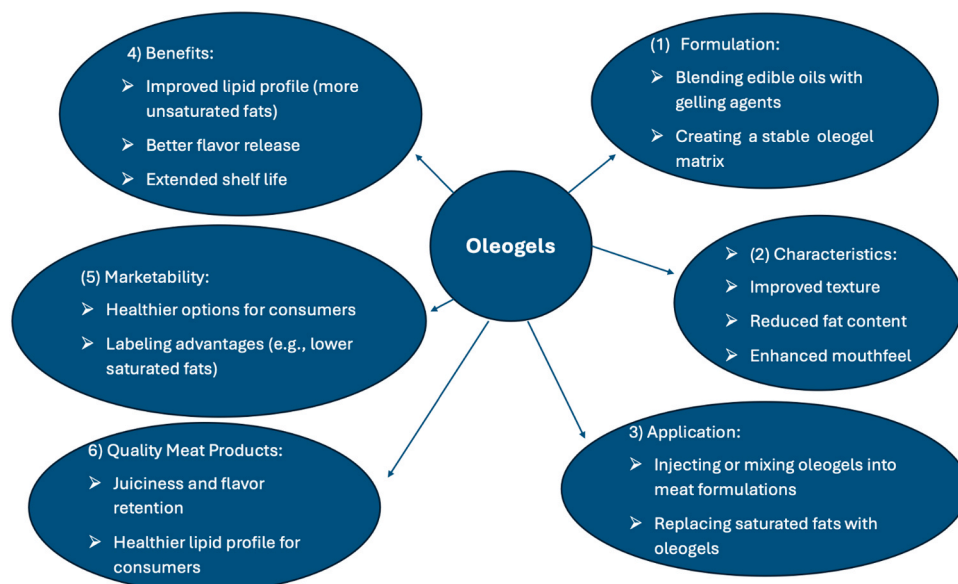


Fig. 1. Enhancing lipidic quality of meat products using oleogels.

compatible with hydrogels, such as the hydrophobicity of the compounds (Davidovich-Pinhas et al., 2016).

The reviews of Pinto et al. (2021) authors showed the main differences between hydrogels, oleogels, bigels, and emulgels and then focused on different methodologies for the preparation of oleogels and oleogel-based emulsions for food applications.

One of the most used procedures is the oleogelation, which converting liquid vegetable oil into a solid-like gel with the use of organogelators give a liquid oil the characteristics of solid fat without using a lot of saturated and trans fat. (Marangoni, 2012). Several gelation methodologies have been studied, that can be divided into direct dispersion, biphasic template, and solvent exchange methods. (Puscas et al., 2020). There are several applications in food technology, firstly by offering innovative ways of structuring lipids and modifying textures, allowing more sustainable alternatives to traditional fats (Esposito et al., 2018), and secondly by increasing the stability of food products and improving the nutritional profile of foods (Martins et al., 2018; Pinto et al., 2021).

However the food industry continually seeks to maximize the potential for application by creating acceptable reformulated products, allowing their versatility to replace hydrogenated oils and improve food properties (Xu et al., 2022; Puşcaş et al., 2020; Cerqueira et al., 2022). The big challenge is to vary the proportions of the different components in a blend of oleogels, thus increasing the possibility of using different oleogel inclusion systems in food products.

They have attention due to their low saturated fatty acid. They work exceptionally well to replace hydrogenated oils, which are heavy in trans fats, their safety application, and easy production with legal requirements. Specific applications of oleogels include their ability to supply an extensive range of oils and fats to meet the body's needs (Xu et al., 2022). Additionally, functional molecules can be delivered at the macro, micro, and nanoscales, producing distinct release behaviors for various applications (Cerqueira et al., 2022). Examples include its application in chocolate to modify fat content and melting behavior, ice cream to enhance creaminess and stability, or even baked goods to improve texture and moisture retention. Some studies assessed the replacement of animal fat added to meat products by different sources of vegetable oils (Domínguez et al., 2017; Heck et al., 2017; Pires et al., 2019). The challenges are to find an oil capable of promoting the improvement of the fatty acid profile and a better technique to insert oleogels without affecting the characteristics of the final product.

As far as meat is concerned, this application can reduce the fat content of processed meats while maintaining juiciness, one of the most desirable characteristics. However, there is low compatibility with water-based food matrices. As mentioned before, the solution is to use oleogels in emulsion models by applying conventional emulsification techniques, such as high shear homogenization (Mao et al., 2020).

These applications broaden the applications of oleogels in the food industry, making them essential for creating healthier food products that are more acceptable to consumers, without sacrificing product quality.

Despite that, the oleogels can encapsulate and protect sensitive ingredients such as flavors, vitamins, antioxidants, or probiotics, allowing for their more controlled release in the consumer's digestive tract. Replacing traditional fats with them can help create low-fat versions of popular food items without compromising taste or texture while maintaining desirable sensory attributes.

Generally, they offer innovative solutions in food technology for fat replacement, texture modification, and the encapsulation of active ingredients. They are valuable instruments in creating novel and enhanced food products because they offer healthier substitutes for conventional fats while retaining their desired sensory qualities (Manzoor et al., 2022). Their application in producing controlled-release foods creates opportunities to improve different foods' nutritional value and overall health benefits. According to some authors (Puscas et al., 2020), further refinement of oleogelization methods and industrial processes is still needed to enhance the technological and rheological properties in

applications of reformulated food products.

The figure below (Fig. 2) shows a schematic of how to make oleogel for use in the food sector.

The oleogel can be prepared according to the guidelines established by Barros et al., (2020): 56 % water, 37.3 % olive oil or sunflower oil and 6.7 % Prosella® (Laboratorios Amerex S.A.U., Madrid, Spain), a mixture made up of calcium sulphate, sodium alginate, wheat glucose, disodium diphosphate and sodium ascorbate.

### 3. Quality enhancement in sheep and goat meat product

The consumption of processed sheep and goat meat products is less prevalent than that of other meats, including pork, beef, and poultry. Although this type of meat is not the most widely consumed worldwide, it should be noted that there are countries with a strong tradition of consuming these meats and their processed products. This tradition is linked to religious issues that prohibit the use of pork in processed products. It is therefore of the utmost importance to devise strategies that will render the processing of this type of meat both appealing and diversified for the market, and consequently for the end consumer. Some of the animals from this breed are covered by Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) quality labels, which indicate a high level of quality. Conversely, other animals do not meet the criteria for these quality labels for various reasons. One of the most significant factors is exceeding the maximum weight and age requirements. Consequently, these animals as a starting point, it is essential to investigate and develop a new generation of goat and sheep meat products that can respond to the constant innovation required in the food industry. Nowadays there are numerous strategies for making a product more appealing, healthier and with a higher nutritional and sensory quality. To this end, there have been many studies aimed at improving meat products. However, not all species are covered. Bearing in mind that pork, beef and poultry are the most consumed meats worldwide, it is these species that the studies focus on. Concerning the introduction of oleogels, this topic is practically non-existent for goat and sheep meat, as can be seen in Table 1.

Like other types of meat processes sheep meat provides energy for growth, participates in all metabolic processes, and is an important source of protein and essential nutrients in the human diet (Hygreeva et al., 2014). Sheep and goat meat is unique in flavor and taste, and goat's meat is leaner than other red meats and is now the preferred choice for low-fat meats (Teixeira et al., 2019). Although there are tremendous benefits to eating meat and processed products, there is a scientific link in which high fat intake can lead to the onset of cardiovascular disease. The World Health Organization has established recommendations for replacing the fats in meat products to reduce the consumption of saturated fats. Therefore, it is crucial to remember that overconsumption of animal fat can harm health, so studying the partial replacement of this fat (Forouhi et al., 2018). The formulation of hydrogels is simple and economical, with the added advantage of the ability to incorporate functional hydrophobic compounds, so these gels have great potential for the food industry (Cittadini et al., 2022). However, there are some disadvantages to replacing animal fat with analogs (such as oleogels) as far as the product is concerned. These inconveniences are significant from a nutritional and sensory point of view (Domínguez et al., 2021). Because of these drawbacks, the scientific community linked to the food industry has investigated different gel structures (such as oleogels and emulsions) capable of imitating the firmness of the fat used in most processed meat products and protecting them from oxidizing agents (Herrero et al., 2014; Pintado and Cofrades, 2020).

Table 1 gives some examples of the use of oleogels as partial or total substitutes for animal fat. As you can see, there are few studies on the substitution of goat and sheep fat with oleogels, as these species are not widely consumed.

Sheep and goat meat have distinct flavors and textures, with goat



Fig. 2. Preparation of oleogels.

Table 1  
Use of oleogels in meat products.

Product	Findings	Ref.
Beef	The fat replacement had a significant effect on texture profile analysis: hardness decreased and Springiness, cohesiveness, gumminess and chewiness increased.	Moghtadaei et al., 2021
	The fat content decreased significantly as the percentage of oleogel increased.	Moghtadaei et al., 2021
	Replacing 25 % of animal fat causes color changes. Although this change was perceived, the tasters preferred the color of burgers made with oleogel.	
	Substantial decrease in hardness, gumminess and chewiness of raw burgers. Increasing the concentration of oleogel in the burger is related to a 1.5 per cent reduction in fat absorption.	Moghtadaei et al., 2018
Pork	The addition of oleogels significantly reduced water retention capacity	Barbut et al., 2016
	Linseed oleogel introduced into sausages significantly improved the fatty acid profile; The amount of cholesterol decreased significantly with the substitution of this oleogel.	Franco et al., 2019
	Pork burgers formulated with beeswax oleogel showed good overall sensory acceptability.	Gómez-Estaca et al., 2019
	The introduction of oleogels into pork burgers showed that improving the fatty acid profile is possible.	Martins et al., 2019
	Improvement in the fatty acid profile and texture attributes in the samples incorporating oleogels. However, the addition of oleogels affected overall acceptability.	Wolfer et al., 2018
Chicken	The use of an oleogel in mortadella resulted in a product with a more favourable fatty acid profile.	Tarté et al., 2020

meat being notably leaner than other red meats (Teixeira et al., 2019). Several studies have been carried out on the physicochemical characteristics of processed sheep and goat meat products. Most products have a high protein content, a balanced fat and fatty acid profile, low cholesterol levels and resistance to lipid oxidation. The colour parameters in different meat processing techniques showed some oxidation of pigments due to the preservation methods (Leite et al., 2015; Linares et al., 2012; Monego et al., 2018; Das et al., 2014).

Although the use of oleogels has not yet been studied, there has already been some work on replacing the fat of this type of species with emulsions. Some studies replace goat burgers and nuggets supplemented with a linseed oil emulsion (Romero et al., 2023). Other studies have

shown the benefits of replacing lamb fat and starch with oils and defatted flours from seeds and nuts (Rabadán, et al., 2021).

Using oleogels in goat and sheep meat has not been particularly attractive to the industry. One possible reason for the lack of studies in this area is the dominance of other meat types—such as beef, pork, and chicken—in the global market. Goat and sheep meat are associated with seasonal consumption and are therefore less widely consumed worldwide, significantly reducing interest in innovation for processed products.

A major challenge in incorporating oleogels into meat products is maintaining their sensory characteristics without noticeable changes for the end consumer. Given that goat and sheep meat have a distinct lipid profile and flavor, developing new formulations for these products is particularly demanding. Another contributing factor to the limited research in this area is that goat and sheep meat is primarily consumed in its traditional form, making it more difficult for consumers to accept. Thus, this review could serve as a starting point for the application of oleogels in goat and sheep meat, following the example of other species. Collaboration between industry and research is essential to meet the needs of both global and niche consumers.

As shown in Table 1, introducing oleogels is advantageous, although disadvantages may be associated with this substitution. One of the related drawbacks is the oleogels preparation process, which requires melting points to be achieved, which may result in susceptibility to lipid oxidation (Ferreira et al., 2022). Although there are studies in which this susceptibility was not observed, it is one of the most harmful points associated with substituting oleogels in meat and processed products. Much less information is available on goat and sheep meat and derived products. The results show that fat substitution in goat and sheep meat is not harmful from the point of view of lipid oxidation. Studies on goat meat burgers (Romero et al., 2023) and sausages (Adili et al., 2020) showed that oxidative stability was not affected, and in some cases, the introduction of oleogels made the final product more stable. Another negative aspect of replacing these emulsions is that they can affect sensory aspects perceived by consumers. In the various studies, sensory acceptability and oxidative stability were some of the most common negative aspects. Although some points still need to be studied and improved, using emulsion gels is an effective method for replacing fats in meat products. Reducing total fat and improving the lipid profile is a common aspect of all the studies, but they still need to be improved when it comes to certain species, such as goat and sheep meat.

In the following table (Table 2) we have listed a series of physicochemical parameters that have been observed by other authors. We can

**Table 2**  
Changes in physicochemical characteristics with fat substitution in meat and sheep products.

Product	Replacement	pH	WHC	SF	FAT	PROTEIN	TBARS	Color parameters			Reference
								L*	a*	b*	
Sheep sausages	Linseed oil	Non-significant	Increased significantly	Increased significantly	Decreased significantly	Increased significantly	Increased significantly	Decreased significantly	Increased significantly	Decreased significantly	Lima et al., 2021
Goat hamburgers	Olive oil	no change	*	*	Decreased significantly	Non-significant	Non-significant	no change	no change	no change	Ferreira et al., 2022
Lamb sausages	Chia	no change	*	*	Decreased significantly	Decreased	*	Increased significantly	Decreased	no change	Carvalho et al., 2019;
Lamb sausages	Linseed	Non-significant	*	*	Decreased significantly	Decreased	*	Increased	Decreased	Increased	Carvalho Barros et al., 2020
Lamb sausages	Olive oil	Non-significant	*	*	Non-significant	no change	*	Increased significantly	Decreased	Increased	
		decreased			increased			significantly	significantly	significantly	

\*parameter not analysed in the study.

see that some physicochemical parameters were altered by replacing animal fat with oleogels.

#### 4. Consumer acceptance

Consumer acceptance is not just a factor but the cornerstone of success for any product. The success of producing something is only guaranteed if it pleases consumers, as its purpose is based on their acceptance. Changing ingredients or ways of making a well-established product in the market is no exception. That's why researchers consider sensory analysis when using oleogels to enhance the food quality of sheep and goat meat products. While oleogels can improve the nutritional profile, their impact on sensory properties (texture, flavor, and overall acceptability) is crucial. Research from [Manzoor et al. \(2022\)](#) indicates that when oleogels are used appropriately, they can maintain or even enhance sensory attributes compared to traditional fat-containing products.

[Teixeira et al. \(2021\)](#) found that the fat source significantly affects the sensory quality of goat meat burgers. Replacing pork fat with olive oil oleogel reduced hardness and chewiness, enhancing tenderness. Burgers with olive oil (GOO) had better flavor and juiciness than pork fat (GPF). Higher fat content in commercial beef burgers (CH) increased their juiciness and flavor. GOO burgers were darker, while CH burgers showed higher redness, yellowness, and brightness. Overall, goat burgers were less preferred than beef burgers, but olive oil oleogel improved their sensory attributes, making them more appealing.

The potential of oleogels to enhance the sensory attributes of meat products is intriguing and needs further research.

Another study ([Yılmaz and Toksöz, 2022](#)) found that the texture and sensory attributes of oleogel-containing sucuk samples (Sucuk-SWO and Sucuk-BWO) differed notably from the control sample (Sucuk-CNT). The control sample had significantly higher hardness (185.50 N) compared to Sucuk-SWO (97.60 N) and Sucuk-BWO (45.83 N). Oleogel samples were less cohesive, with lower adhesiveness, cohesiveness, springiness, and gumminess. The control sample scored best in appearance and had higher aroma and flavor scores. While oleogel samples were softer and more chewable, they were perceived as less tasty. Sucuk-BWO had the highest fattiness and juiciness scores. Overall, oleogel use provided nutritional benefits but resulted in inferior texture and sensory qualities compared to the control.

[Romero et al. \(2022\)](#) found no significant sensory differences between goat meat nuggets with the linseed oil emulsion containing lyophilized *Eugenia uniflora* fruit extract (NLEUE) and those without it (NC). The emulsion did not affect taste or overall acceptability but improved tenderness, a positive sensory attribute. This indicates that the emulsion can enhance the nutritional profile while maintaining or even improving sensory qualities, such as flavor and texture. The study suggests that substituting pork fat with the linseed oil emulsion not only boosts nutritional value but also preserves or enhances the sensory appeal of the nuggets, making it a viable option for healthier meat snacks. [Table 3](#) summarizes the above.

[Table 3](#) shows a summary of studies on the consumers' acceptability of meat products with oleogels.

While the potential of oleogels to enhance the sensory attributes of meat products is intriguing and needs further research, the consideration of cross-cultural sensory data is essential for understanding and optimizing consumer acceptance in various regional markets. Cultural, traditional, and socio-economic factors dictate the consumption patterns and preferences for sheep and goat meat. In the Middle East and Northern Asia, sheep meat is highly consumed despite its strong flavor, whereas in Europe and North America, the flavor limits its popularity. Goat meat is less consumed in Northern Europe except by emigrant populations, while in the Mediterranean, the seasonal consumption of unweaned kids is traditional ([Karakus, 2006](#); [Mandolesi et al. 2020](#)). These cultural differences highlight the need for cross-cultural sensory research to understand how oleogels might impact consumer acceptance

**Table 3**  
Summary of acceptability of consumers of replacing animal fat with oleogels in different meat products.

Product	Oleogel	Acceptability of consumers	Ref.
Dry-cured sausage	Linseed oil	Less acceptability than control	Manzoor et al., 2022
Chicken-based bologna sausage	High oleic Sunflower oil	Overall acceptability good	
Frankfurter sausage	Sunflower oil	No difference in sensory acceptability	
Beef burger	Soybean oil	Decreased sensory acceptance	
Meat pattie	Canola oil	Softer texture with good acceptance	
Pork patty	Linseed oil	No significant differences in acceptability	
Goat meat burger	Olive oil	Educed hardness and chewiness and increased juiciness, making it more appealing	Teixeira et al., 2021
Sucuk	Flaxseed oil-wax	Less aroma and flavour but softer and chewier, worse visual acceptance	Yilmaz and Toksöz., 2022
Goat meat nuggets	Linseed oil	Not significant differences	Romero et al., 2022

in diverse settings. Studies comparing sensory attributes and consumer preferences across regions could provide valuable insights, exploring factors such as taste, texture, and aroma preferences in different cultural contexts.

## 5. Nutritional enrichment and clean label formulation

Oleogels can enrich sheep and goat meat products, as referred to by various authors, as mentioned below. The nutritional differences between meat products with and without oleogels primarily revolve around the fatty acid composition and overall fat content (Manzoor et al., 2022). Oleogels can significantly reduce the total fat content in meat products. For instance, studies have shown that substituting animal fat with oleogels can lead to a reduction of up to 80 % (Lopes et al., 2022) in fat content while maintaining desirable sensory properties.

Oleogels are typically made from plant-based oils rich in monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) (Heck et al., 2021). This contrasts with animal fats, often high in saturated fatty acids (SFA) and trans fats. Using oleogels can improve the overall fatty acid profile of the meat product, making it more heart-healthy and helping to follow the “clean label” trend. Oleogels can also enhance the nutritional quality of meat products by incorporating beneficial compounds. For example, oleogels made from linseed oil can increase meat products’ omega-3 fatty acid content, which benefits cardiovascular health (Franco et al., 2020b).

Using olive oil oleogel (GOO) in goat meat burgers (Teixeira et al., 2021) resulted in significant nutritional differences compared to those made with pork fat (GPF). Even though GOO burgers had higher fat content (4.0 %) than pork fat burgers (2.78 %) but much lower than commercial beef burgers (CH) at 13.45 %, GOO burgers had a healthier fatty acid profile, with more monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), leading to better atherogenicity (IA) and thrombogenicity (IT) index values. The polyunsaturated/saturated fatty acid ratio was improved, promoting cardiovascular health.

Additionally, GOO burgers had higher moisture content, enhancing juiciness and overall eating experience. Thus, oleogel in goat meat burgers offers a healthier option with improved nutritional quality and texture.

The authors (Teixeira et al., 2021) discuss the “clean label” trend, highlighting the growing consumer preference for healthier, more natural meat products with fewer additives and transparent ingredient lists.

Alternative fat sources like olive oil and oleogel fit this trend by offering a healthier fat option without artificial additives. This approach enhances the nutritional profile of meat products and meets consumer demand for more straightforward, natural ingredients.

Yilmaz and Toksöz. (2022) found significant differences in the nutritional content of sucuk samples. Sucuk-BWO had the lowest moisture content (41.84 %), while Sucuk-CNT and Sucuk-SWO had higher levels (46.37 % and 47.09 %). Sucuk-BWO also had the highest fat content (34.44 %), compared to Sucuk-CNT (30.11 %) and Sucuk-SWO (30.37 %). Crude protein content was similar across samples (17.35–17.98 %). Sucuk-CNT had the highest saturated fatty acid (SFA) content (79.42 %), while Sucuk-SWO and Sucuk-BWO had lower SFA (45.30 % and 43.02 %). Oleogels (SWO and BWO) increased oleic and unsaturated fatty acids, improving the lipid profile and making Sucuk a healthier option for consumers. Incorporating oleogels can thus enhance the nutritional quality of Sucuk, appealing to health-conscious consumers.

The fat reduction in goat meat burgers, achieved by replacing pork fat with olive or sunflower oil hydrogel emulsions, positively impacts their overall nutritional profile. The study (Ferreira et al., 2022) indicates that this substitution significantly improves the lipidic healthiness of the burgers. Specifically, using these vegetable oils enhances the fatty acid composition, making it more favorable for health. The replacement of pork fat with these hydrogel emulsions results in a lower overall fat content while maintaining the quality of the burgers. The lipid profile changes significantly, aligning with the health benefits of olive and sunflower oils, which are known for their higher levels of unsaturated fatty acids compared to saturated fats in animal fats. This shift contributes to a healthier product that may appeal to health-conscious consumers. Additionally, the study suggests that the antioxidant properties of vegetable oils help prevent lipid oxidation, which is crucial for maintaining the sensory characteristics of the burgers over time. Overall, the reformulation approach reduces fat content and enhances the nutritional quality of goat meat burgers, making them a healthier option for consumers.

The study by Romero et al. (2023) found that incorporating linseed oil emulsion with lyophilized *Eugenia uniflora* fruit extract (NLEUE) significantly improved the nutritional profile of goat meat nuggets compared to nuggets without the emulsion (NC). NLEUE nuggets had higher levels of polyunsaturated fatty acids (PUFAs), including  $\alpha$ -linolenic acid (42.25 % vs. 39.18 % in NC), increasing omega-3 fatty acids. The emulsion also enhanced oxidative stability, with NLEUE nuggets showing lower oxidative values during storage. Lipid bioavailability remained consistent (51–58 %) across all formulations. Overall, the linseed oil emulsion increased beneficial PUFAs and improved oxidative stability, making the nuggets a healthier option. Further research is recommended to explore long-term effects and health benefits.

## 6. Challenges and future trends

The challenges and future trends of using oleogels in sheep and goat meat products should be focused on several key areas, from formulation and processing to consumer acceptance and regulatory issues. As the demand for healthier and more sustainable food products grows, oleogels—structured oils that mimic the properties of solid fats—offer an innovative solution to replace traditional animal fats. However, the implementation of this technology in sheep and goat meat products is still in its early stages, and there is a lack of research and application and limited data on how oleogels interact with specific properties of sheep and goat meat. This gap in knowledge makes it difficult to predict how well oleogels will perform in terms of texture, flavor, and overall product quality. Fat plays a crucial role in meat sensory attributes, particularly in the case of sheep and goat meat, which have distinct flavor profiles compared to other meats. This could make it challenging for oleogels to seamlessly replace traditional fats without affecting the taste. So, oleogels must be carefully formulated to replicate the

mouthfeel and richness provided by natural animal fats. In this sense, the unique flavor of sheep and goat meat is valued by specific groups of consumers, and any change in its sensory characteristics can have an impact on market acceptance. Consumers can be wary of new ingredients such as oleogels, especially if they are too processed or unfamiliar. Educating consumers about the health benefits of oleogels, such as their ability to reduce saturated fat content, will be vital to overcoming this obstacle. Sheep and goat meat products, such as patties, sausages, kebabs, or minced meat, require specific processing techniques. Integrating oleogels into these processes without negatively affecting product stability or performance is a technical challenge. The ability of oleogels to withstand high temperatures during cooking and retain their structure under various processing conditions is crucial for ensuring the quality of the final product.

Exploring the cost-effectiveness of oleogel industrial production is crucial for understanding its economic feasibility and practicality, especially when considering its application in meat products like mutton and goat meat. The cost of producing oleogels depends heavily on the choice of edible oils and gelling agents, which vary widely in price and availability. Some common oils as sunflower, canola, and soybean oils are relatively inexpensive and widely available, making them cost-effective choices for oleogel production. Olive oil or flaxseed oil, while healthier, are more expensive and may increase production costs. Using byproducts from oil refining (e.g., rice bran oil) can reduce costs and enhance sustainability. As gelling agents, the low cost options are waxes (e.g., beeswax, candelilla wax) and monoglycerides are affordable and effective gelling agents. Some specialized agents, such as ethylcellulose and proteins (e.g., whey protein), are more expensive but may offer superior functionality in certain applications. So, the cost-effectiveness of oleogel industrial production depends on factors such as raw material prices, process complexity, and market demand. While oleogels may have higher initial costs compared to traditional fats, their health benefits, extended shelf life, and versatility can justify the investment. For mutton and goat meat products, oleogels offer a unique opportunity to create healthier, more appealing options that cater to modern consumer preferences. By optimizing formulations and production processes, manufacturers can enhance the economic feasibility of oleogels and unlock their full potential in the food industry.

As with other novel food ingredients, the regulatory approval and labeling of oleogels in sheep and goat meat products could pose a challenge. Different regions have varying regulations on how new ingredients must be listed, their health claims, and the level of transparency required on packaging. Manufacturers must navigate these regulatory landscapes to ensure their products comply with food safety and labeling standards.

With consumers increasingly seeking healthier meat options, incorporating oleogels in sheep and goat products could cater to this growing demand. Oleogels offer a way to reduce saturated fat content while maintaining the sensory characteristics of the meat, allowing for healthier versions of traditional products. This trend aligns with the broader movement toward better-for-you food products that still deliver on taste and satisfaction (Franco et al., 2020). By experimenting with different oil sources and structuring agents, researchers can optimize the functionality of oleogels in sheep and goat meats, ensuring that they enhance rather than detract from the final product's quality.

Plant-based oils, such as olive or sunflower, could be used to create oleogels that appeal to environmentally conscious consumers. Additionally, the clean-label trend—demanding simple, recognizable ingredients—will push for more natural structuring agents in oleogels, such as plant waxes or proteins, ensuring they meet consumer preferences for transparency and sustainability. Sheep and goat meat are often consumed in specific regions and by niche markets, such as Mediterranean, Middle Eastern, and South Asian cultures, where the meats hold cultural and culinary significance (Teixeira & Rodrigues, 2019). Introducing healthier, oleogel-based sheep and goat products could appeal to these markets, particularly as consumers in these regions become more

health-conscious.

Additionally, as the global market for these meats grows, there is potential for oleogel-based products to expand into new territories. The trend toward plant-based and hybrid meat products, combining animal and plant ingredients, may also create opportunities for oleogels in the sheep and goat meat sector. By incorporating plant-based oleogels with traditional animal protein, manufacturers can reduce these products' overall fat content and environmental impact, making them more appealing to health-conscious and environmentally aware consumers.

## 7. Conclusions

In conclusion, oleogels in the sheep and goat meat industry hold great promise, particularly as consumers continue seeking healthier, more sustainable alternatives. However, several challenges must be addressed, including the unique sensory properties of these meats, consumer acceptance, and technical integration.

While oleogels exhibit slower oxidation rates, storage conditions—such as temperature, the concentration and type of active ingredients (e.g., antioxidants), and the oil used—significantly influence oxidation dynamics. The mechanism by which oleogels enhance lipid oxidation stability is rooted in physical encapsulation, antioxidant activity, and reduced pro-oxidant exposure, as demonstrated by experimental results showing reduced peroxide values and TBARS values. The incorporation of antioxidants further strengthens this effect, solidifying oleogels as a promising solution for developing healthier, longer-lasting meat products. With ongoing research, technological advancements, and growing demand for innovative food products, the future of oleogels in the sheep and goat meat industry looks promising. By addressing these challenges and capitalizing on emerging trends, oleogels could play a key role in shaping the next generation of sheep and goat meat products.

## Author statement

As the corresponding author, I declare that experimental protocol was carried out according to the guidelines of the Ethical Review Committee of the Instituto Politécnico de Bragança. I also declare that the authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## CRedit authorship contribution statement

**Leite Ana:** Writing – review & editing, Writing – original draft.  
**Vasconcelos Lia:** Writing – review & editing, Writing – original draft.  
**Rodrigues Sandra:** Writing – review & editing, Writing – original draft.  
**Teixeira Alfredo:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization.

## Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Alfredo Teixeira reports financial support was provided by Polytechnic Institute of Bragança Mountain Research Center. Alfredo Teixeira reports a relationship with Polytechnic Institute of Bragança Mountain Research Center that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

No data was used for the research described in the article.

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