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Professional paper

THE INFLUENCE OF OLEOGELS ON THE NUTRITIONAL VALUE, OXIDATIVE STABILITY, RHEOLOGICAL-SENSORY CHARACTERISTICS OF DIFFERENT TYPES OF SAUSAGES

Tanja STOJANOVSKA[1*], Tatjana KALEVSKA[1], Daniela NIKOLOVSKA NEDELKOSKA[1], Viktorija STAMATOVSKA[1], Eleonora DELINIKOLOVA[1], Katerina TEMELKOVSKA[1]

[1]*Faculty of Technology and Technical Sciences -Veles, University St. Kliment Ohridski - Bitola*
Dimitar Vlahov bb. 1400 Veles, R.N.Macedonia
[*]*Corresponding author e-mail: tanja.b.stojanovska@uklo.edu.mk*

Abstract

Sausages, recognized as one of the oldest forms of meat preservation, have evolved over time, incorporating various ingredients beyond salt. Depending on the type, sausages can contain up to 30% fat, which significantly impacts their sensory and technological attributes. In recent decades, the development of oleogels has garnered increased attention, leading to extensive research on their characteristics and potential applications in the food industry.
In this review, we will explore the possibilities of utilizing oleogels in different types of sausages and examine their effects on nutritional profiles, oxidative stability, and rheological-sensory properties.

Keywords: sausages, oleogels, nutritional value, oxidative stability, rheological-sensory characteristic.

Introduction

Sausages are the oldest form of meat product for which there is written evidence (Mohan, 2014). In the beginning, Initially, sausages were simple mixtures of minced meat and salt, but today, they incorporate a range of non-meat ingredients, blended with minced meat and fatty tissue, and encased within a casing (Akpan, 2017). The Food and Agriculture Organization (FAO) (1985) classifies sausages into two broad categories: raw sausages and heat-treated sausages. Moreover, according to the 'Rulebook on the requirements regarding the quality of minced meat, meat preparations, and meat products' (Official Gazette No. 63/2013), sausages are further classified as fresh, fermented, and heat-treated sausages

The quality of the products reflects the status of the raw materials and the design of the process (Abdolghafour & Saghir, 2014). Fats have a huge impact on meat products, especially sausages (Baer, 2012). Animal fat in sausages affects the improvement of sensory characteristics of sausages, especially taste and juiciness, as well as technological characteristics (texture, emulsion, heat transfer, etc.) (Totosaus-Sanchez, 2008; Pehlivanoğlu et al, 2018; Badar et al, 2021; Zampouni et al, 2022).

Different types of sausages include 15%-45% fat in their composition (Official Gazette No. 63/2013). In addition to the high fat content, sausages are desired and consumed primarily due to their sensory attributes (Agregán et al, 2018). However, fats are considered to cause harmful effects on mental health, obesity, cardiovascular diseases, metabolic syndrome, oxidative stress, diabetes, etc. (de Souza et al, 2015; Marangoni & Garti, 2018; Hooper et al, 2020). This data initiates the need to change the approach to food (Schwingshackl et al, 2022). In the 1980s, a limited intake of saturated fatty acids was recommended (Mozaffarian et al, 2018), but today this approach is changed, emphasizing the quality of fat consumed (Schwingshackl et al, 2022).

As an innovative strategy to reduce trans and saturated fats in food, oleogels have emerged as threedimensional structural systems comprising of vegetable oils and gelators. This approach is gaining recognition primarily because of its environmental and nutritional advantages (Manzoor et al., 2022). At the same time, oleogels have the characteristics of solid fats (they provide a unique taste, texture, and plasticity) without changing the health and nutritional composition of vegetable oil (Ferro et al., 2021; Li et al., 2021).

The influence of oleogels on the characteristics of different types of sausages

Replacing solid fats with structured oils poses a technological challenge (Feichtinger & Scholten, 2020), and resorting to lower quality alternatives can lead to technical difficulties (López-Pedrouso *et al,* 2021). Nevertheless, by partially or fully substituting animal fats with oleogels, there exists an opportunity to develop a diverse range of meat products that offer an enhanced and nutritionally balanced lipid profile suitable for consumption (Wang *et al,* 2023).

The Influence of Oleogels in Fermented Sausages

Fermented sausages possess unique physicochemical and sensory attributes, along with microbiological stability and a prolonged shelf life. Nonetheless, their nutritional suitability is compromised due to the elevated levels of saturated fat (SFA) they contain (Alejandre *et al,* 2016). However, the incorporation of oleogels into fermented sausages has been shown to enhance their fatty acid profile, particularly the ratio of polyunsaturated to saturated fatty acids (PUFA/SFA) (Franco *et al,* 2020), as well as the ratio of PUFA n-6/n-3 (Pintado & Cofrades, 2020), and cholesterol content (Zampouni *et al,* 2022).

Adding oleogels to fermented sausages significantly increases moisture (Pintado & Cofrades, 2020), because oleogels can function as a barrier in the drying process (Zampouni *et al,* 2022). The water content of the samples decreased with an increasing amount of added oleogels (Franco *et al,* 2020). Oleogel-infused sausages are characterized by a higher αw value (Pintado & Cofrades, 2020; Zampouni *et al,* 2022) and a lower pH value of 4.76 compared to the control 4.48 (Zampouni *et al,* 2022). Franco *et al,* (2020) indicate that the pH value is variable and depends on the type and amount of added oleogel. The maximum decrease in moisture and αw value of sausages occurs during the first week of ripening due to the denaturation of meat proteins because of the decrease in pH value and consequently the reduced water binding capacity (Noorolahi *et al,* 2022). According to Pintado and Cofrades, (2020) and Zampouni *et al,* (2022), obtaining microbiologically stable fermented sausage with oleogel requires a modification of the technological process of dehydration, that is, adjustments to the relative humidity and air circulation during the process.

Fermented sausages with incorporated oleogels are characterized by a lighter colour, less consistency, a softer core and reduced case hardening (Zampouni *et al,* 2022). Pintado and Cofrades, (2020) point out that chia seed oil maintains a stable red colour even after 30 days of storage compared to the control sample. While according to Franco *et al,* (2020), the colour change is also influenced by the gelator used. Namely, with 40% replacement of animal fats in fermented sausages, the yellow colour increased by 25.75% for oleogel from linseed oil and $\boldsymbol{\gamma}$-oryzanol and $\boldsymbol{\beta}$-sitosterol and by 62.45% with oleogel from linseed oil with beeswax (Franco *et al,* 2020).

Lipid oxidation is the main non-microbial cause of quality deterioration in fermented meat products (Domínguez *et al,* 2019). Given the higher oxidation of unsaturated fatty acids, higher values for the oxidation rate are expected in products with incorporated oleogels. Franco *et al,* (2020), confirmed that higher values for thiobarbituronic acid-reactive substances (TBARs) were obtained in samples with oleogels, but, the level of oxidation remains well below the rancidity threshold, which typically occurs when the concentration of malonaldehyde (MDA) is above 1 mg/kg sample. The oxidative quality of sausages containing linseed oil oleogel decreases over time storage. The addition pistachio extract to the oleogel as a natural antioxidant reduces these changes, the $TBAR_S$ values were lower compared to the samples without antioxidant and the levels of ω3 and PUFA were higher (Noorolahi *et al,* 2022).

The influence of oleogels in fresh sausages

During the literature review, limited data were found regarding the partial or complete substitution of animal fats with oleogels in fresh sausages. In the studies conducted by Barbut *et al,* (2016), oleogels formulated with canola oil structured with ethyl cellulose (at concentrations of 8%, 10%, 12%, and 14%) and sorbitan monostearate (at concentrations of 1.5% and 3.0%) were utilized as replacements for lard. The incorporation of these oleogels resulted in a decrease in hardness values and elasticity of the fresh sausages compared to the control samples. However, cohesiveness was not significantly affected. In another investigation by Pintado *et al,* (2018), the effects of an emulsion-based oleogel using oat and chia flour were studied. The addition of these oleogels led to an improvement in the content of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), as well as a reduction in cooking loss. The sensory properties of the sausages were influenced by the application of the oleogels; however, the samples were still deemed acceptable in overall evaluation.

The influence of oleogels in heat-treated sausages

Oleogels have emerged as innovative alternatives to replace animal fats in food products by utilizing cross-linked vegetable oils. The primary objective is to enhance the fatty acid profile and address the negative perception often associated with meat products (López-Pedrouso *et al,* 2021). Notably, all authors who have utilized oleogels in heat-treated sausages have reported a significant improvement in the fatty acid profile, as demonstrated in Table 1.

Table 1. Improvement of fatty acid profile in heat-treated sausages with the addition of oleogels

Product	Oleogel	Finding	Reference
Frankfurter sausage	Sunflower oil with monoglycerides and phytosterols (15:5)	Reduction of SFA	Kouzounis et al., (2017)
Bologna sausages	90% conventional or 97.5% high-oleic soybean oil, with rice bran wax	Reduced fat, cholesterol ~10% and energy value	Tarté et al., (2020)
Bologna sausages	Conventional or high-oleic sunflower oil with monoglyceride	Up to 67% SFA reduction. MUFA increase of 49 and 98%	Ferro et al., (2021)
Bologna sausages	Soybean oil with isolated soy protein, carrageenan and inulin	60% increased PUFA content decreased n-6/n-3 ratio	Paglarini et al., (2022)
Smoked sausages	Sunflower oil monoglyceride: beeswax (2:1)	Reduction of SFA content by 35% and 38%, respectively.	Igenbayev et al., (2023)

The source and composition of the fat, i.e., the properties of the oleogels as well as its interaction with the protein matrix affect the textural properties in different ways (Ferro *et al,* 2021). Reducing animal fat or replacing it affects the texture of bologna sausages (Paglarini *et al,* 2022). Less elastic and cohesive samples were obtained with 100% animal fat substitution (Ferro *et al,* 2021). Frankfurters with incorporated oleogels did not differ from controls in any textural parameter, while emulsion treatments had lower chewiness and firmness values (Panagiotopoulou *et al,* 2016). By replacing 50% of the fats with oleogel based on monoglycerides and phytosterols, sausages with lower values for of hardness, brittleness, gumminess and chewiness were obtained in frankfurters, while there was no difference in cohesiveness and elasticity compared to the control (Kouzounis *et al,* 2017). By partially replacing the beef fat with an oleogel structured from canola oil with different concentrations of ethyl cellulose and sorbitan monostearate in the frankfurters there were no significant differences in hardness and shear strength, while increasing the level of oleogel the losses decreased while the juiciness and fat feeling were increased (Barbut *et al,* 2016). An improvement in the technological quality is reported by da Silva *et al,* (2019), in the reformulated bologna sausages with the addition of oleogel from pig skin, water and sunflower oil. This is because the collagen from the skin significantly increased the hardness and chewing strength compared to the control series, but it did not affect the elasticity and cohesiveness of the sausages. Concerning bologna sausages, slight increase in hardness during storage from 0 to 30 days compared to storage after 30 days was noted by Paglarini *et al,* (2022) with the incorporation of soybean oil gel-emulsion with isolated soybean protein, carrageenan and inulin.

In terms of aroma, taste, texture and moisture, no serious differences were reported comparatively among all samples of bologna sausages, except for sausages with hard fatty tissue, where the colour was more intense (Tarté *et al,* 2020). Regarding texture, aroma, and overall taste, based on a 9-point hedonic scale used to rate bologna sausages with oleogel, consumers rated them as 6–7, indicating that they liked them slightly to moderately (Paglarini *et al*, 2022). Sensory analysis of Frankfurt sausages with oleogel showed similar overall acceptability to the control, while sausages with emulsified oils had lower acceptability (Panagiotopoulou *et al,* 2016).

Animal fat replacement had no significant effect on the pH value; the values ranged between 6.42 and 6.51 for different samples (Kouzounis *et al,* 2017). By increasing the percentage representation of oleogels in the frankfurter, the pH value increases while the *aw* value decreases (Pérez-Alvarez *et al,* 2021). In the research of Ferro *et al,* (2021) the pH value varied from 5.96 to 6.19 in different samples, while the *aw* value was not affected by the oleogels and ranged between 0.97 and 0.98. Slightly higher values for *aw* than 0.99 are reported by da Silva *et al,* (2019), while the pH value on the first day ranged from 6.17 to 6.38, and it increased by 0.11 and 0.19 units after 35 days of storage, dey of storage, that could be related with the ammonia produced due to increased proteolysis during storage.

Emulsified meat products are stable to lipid oxidation due to the high content of saturated fatty acids 35% and added sodium nitrite, polyphosphate, and sodium ascorbate (Glorieux *et al,* 2018). All samples prepared with soybean oil gel-emulsion showed higher TBARs values compared to the control (Bologna sausages whit pork fat) during storage up to 60 days, however values below 0.7 mg MDA/kg sample were lower than the rancidity limit (Paglarini *et al*, 2022). TBARs values remained at a constant low level during a storage time of 98 days in bologna sausages with oleogels (Tarté *et al,* 2020). Kouzounis *et al,* (2017) reported no differences in the level of oxidation in frankfurters with animal fat and oleogel during a storage time of 40 days in vacuum packaging. In terms of oxidative stability, Panagiotopoulou *et al,* (2016) performed an analysis of Frankfurter type sausages on a control sample with animal fat, a sample with oleogels and oil emulsions. For all samples, TBA values were within acceptable limits, after 30 days of storage at 4ºC. However, the samples in which emulsions were incorporated, compared to oleogels, had a higher level of lipid oxidation. In contrast, Wolfera *et al,* (2018) reported a difference in oxidative stability between frankfurters with animal fat and frankfurters with 10% incorporated oleogel in which rice bran wax was used as a gelator. It is assumed that the lipid oxidation in the oleogel is due to the process of preparation of the gel, heating, and longer retention at high temperature. However, in all samples the values never exceeded TBA 0.201 mg/kg, while the sensory panellists did not detect bad flavours. According to Pérez-Alvarez *et al,* (2021) samples containing a higher percentage of oleogel are subject to higher lipid oxidation because they contain more unsaturated fats.

Conclusions

Although new approaches and formulations for obtaining oleogels have been intensively researched in recent years, there is still a lack of research on the influence of oleogels on the characteristics of different types of sausages. From the available literature it can be concluded that oleogels can be successfully used in the formulation of sausages with an improved fatty acid composition. In terms of oxidative stability, although oleogels have a higher oxidation rate than animal fats, their values are still within acceptable limits. However, changes to key parameters in some technological processes and additional research on the impact of oleogels on sensory attributes, rheological characteristics and consumer acceptability are needed to create an optimal oleogel formulation.

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