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Review paper

Perspectives in fat replacement in sausages

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A B S T R A C T

Fat replacement in meat products has gained in importance during recent decades, ever since animal fat was recognized as one of the significant causes of chronic non-infectious diseases in modern human populations. Meat products with the highest fat contents include different types of sausages. As fatty tissue plays important roles in sausage quality, fat replacement is not an easy task. There are different approaches which depend on the sausage type. In fermented sausages, the fat substitute should successfully imitate the fatty tissue particles, and in emulsion-type sausages, the fat substitute should be thoroughly mixed and incorporated into the meat batter. The fat substitutes can be of protein or carbohydrate nature, and often are combined with oils rich in polyunsaturated fatty acids, aiming not only to reduce the amount of animal fat in sausages, but also to improve the fatty acid composition of the products. However, fat replacement without affecting sausage quality and shelf life was previously possible only partially and involved a relatively small percentage of replaced fat. Nowadays, some recent studies have reported 100% fatty tissue replacement without adverse effects on the products' properties, opening a new chapter in designing low fat meat products.

1. Introduction

Contemporary scientific findings, but also the growing consumer awareness of the importance of proper nutrition, led to the development of foods that, in addition to the basic nutrients, also contain ingredients capable of providing a positive impact on human health, the so-called functional foods. However, the functional food concept also strives to reduce the content of potentially harmful ingredients in food, such as animal fat (*Vasilev et al.*, 2017). Animal fat is rich in saturated fatty acids and cholesterol and has a high n-6/n-3 ratio, which are all predisposing factors for the development of cardiovascular and other non-infectious chronic diseases (*Astrup et al.*, 2020). Meat products, especially some types of sausages containing more then 40% fat, are considered as some of the main sources of animal fat intake in human nutrition. However, the reduction of fat in sausages is not at all a simple task, because of the important role of fatty tissue in the appropriate sensory properties of the products, such as texture, juiciness and aroma (*Vasilev et al.*, 2013).

There are different approaches in fat reduction in sausages. The oldest and simplest, but at the same time the most unfavourable for the sensory properties of the product, is production of sausages with less fat in the recipe. More promising is the use of some fat replacers that imitate fatty tissue in the stuffing, which is especially favourable in terms of the use of substances with some functional properties, where not only low-fat, but also functionally enriched products can be obtained. That way, sau-

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sage could be simultaneously with reduced fat as well as enriched in prebiotics, fibre, n-3 fatty acids, bioactive compounds etc. (*Vasilev et al.,* 2017b; *Glišić et al.*, 2019; *Stajić and Vasilev,* 2022).

Each of the fat substitutes has its advantages and disadvantages in terms of the quantity of the fatty tissue that can be replaced without adverse effects on the product, but also considering the type of sausage in which they would be used. In fermented sausages, the fat substitute should successfully imitate the fatty tissue particles, both visually and in terms of technological features, where particles of fat substitute should be stably embedded in the stuffing among the muscle tissue particles, forming the white-red mosaic characteristic for the cross section of this type of sausage (*Suvajdžić et al*., 2018). On the contrary, in cooked emulsion-type sausages, the fat substitute should be thoroughly mixed and incorporated into the meat batter, whereby the stability of the filling is based on good emulsification and water binding. Even more, in these products, the fat substitute has to be heat resistant, as the sausages are heat treated (*Rašeta et al.*, 2018). Based on the abovementioned facts, the aim of this study was to review the achievements so far and perceive the future perspectives in fat replacement in sausages.

2. Fat replacement in fermented sausages

Fermented sausages are produced from ground meat and fatty tissue, with the addition of salt, sugar, spices and additives to prepare a mixture which is stuffed into casings and preserved by microbial fermentation, smoking and drying. The amount of added fatty tissue differs a lot, ranging from as low as 5% in some traditional products, such as Sremski kulen (*Suvajdžić et al*., 2018), up to 32% in sausages produced according to a usual recipe (*Yim et al*., 2016). As a consequence of water loss while drying, the fat content in the final product is from 10% in Sremski kulen (*Suvajdžić et al*., 2018) up to 40–50% in usual products (*Yim et al*., 2016). Because of the usually high fat content, there is a reasonable need for fat reduction in such products. Still, this is not at all an easy task bearing in mind that fatty tissue particles play a very important role in providing a balanced drying process as well as in amortising the shrinking and shrivelling of the sausages during the water loss from the meat particles. Because of that, simple fat reduction in fermented sausages usually results in wrinkled sausages, which are of hard texture and less juicy, and which especially applies to sausages stuffed into artificial collagen casings (Wirth, 1988; *Yim et al.*, 2016). However, low-fat fermented sausages of traditionally produced types, such as domestic Kulen, are specific in terms of the nature of the casings, e.g. pork appendix, being wide in diameter and with fat ends (*Wirth*, 1988). The drying and ripening process of such products is slow and requires several months (*Suvajdžić et al*., 2018), whereby the meat particles release water gradually, without adverse effects on sausage appearance.

Since the early observations of the negative impact of simple fat reduction on physico-chemical processes and sensory properties of fermented sausages (*Wirth*, 1988), numerous studies have been devoted to finding suitable substitutes capable of replacing the roles of the fat in fermented sausages. The early attempts aimed to replace a part of the animal fat with oils rich in n-3 fatty acids, aiming to reduce animal fat and to enrich the sausages with n-3 fatty acids (*Jimenez Colmenero*, 2000). However, the simple addition in fermented sausages of such oils is not possible because of their liquid state and proneness to oxidation, which led to the idea to use hydrogenated plant oils that are in solid state and are more stable (*Hilk*, 2005). The main problem with this approach was that hydrogenated fats are rich in *trans*-fatty acids that are proven to be harmful for the consumer's health (*Vasilev et al*., 2010). On the other hand, tropical plant oils, such as palm oil, seemed to be a good solution, as these oils are solid at room temperature. However, the main disadvantages were that palm oil becomes too gritty and fragile at low temperatures, and on the contrary, becomes semi liquid at relatively higher temperatures (*Dreher et al*., 2022). Moreover, as palm oil is rich in saturated fatty acids (palmitic acid, above all), fermented sausages in which the animal fat was partially replaced with palm oil contained more saturated fat than the conventional products produced with pork back fat, which is inconsistent with the basic purpose of reducing fatty tissue in sausages (*Vasilev et al*., 2010).

The idea of using plant oils was further developed through the approach of oil emulsification with plant proteins. Such prepared emulsion is choppable and could imitate the fat particles, but significantly increases the yellowness of sausages, influences aroma and affects the sausages' oxidative stability. Because of these drawbacks, such emulsions could replace a limited amount of fatty tissue in fermented sausages, since defects in sensory properties are already apparent when around 30% of the fatty tissue is replaced (*Muguerza et al.,* 2002). In order to achieve a greater percentage of substituted fatty tissue, it is necessary to provide a better stabilization of emulsion-type systems, so different approaches for encapsulation were proposed: organogelation, which includes the use of a bi-continuous system consisting of gelators (amino acids, carbohydrates, steroid-based molecules etc.) and non-polar solvents; oil-bulking, which is a process of oil incorporation into a gel-like matrix (polysaccharides – inulin, alginate, konjac gum etc.); structured emulsions, where the oil phase is dispersed into hydrogels or organogels and; double emulsions, including oil-in-water emulsion and water-in-oil emulsion, forming a multi-layered system (*Stajić and Vasilev*, 2022).

Another promising solution to substitute a higher percentage of fatty tissue is a quite different approach, in which polysaccharides are applied. Indigestible polysaccharides are of a great significance, because they also are functional ingredients with prebiotic properties. Inulin has been widely investigated, whereby long chain inulin showed the best properties for use in fermented sausages, because after being dissolved in water it forms stable gels, which are white and tasteless. Such gels in a frozen state can be nicely chopped into small particles imitating the particles of fatty tissue (*Vasilev et al*., 2017a). Based on that, *Glišić et al.* (2019) succeeded in replacing 64 % of fatty tissue in sausages with an inulin gel suspension (inulin+water) or with an inulin gel emulsion (inulin+water+lineseed oil), without adverse effects on the sausages' sensory properties.

On the other hand, another very successful approach is the concept wherein turkey lean meat served as an emulsifier, giving a stable olive oil emulsion (*Magra et al*., 2021). Namely, turkey breast meat is a source of myofibrillar proteins that have very good emulsifying properties, but also has a pale colour, so the emulsion obtained had a colour similar to fatty tissue. This emulsion proved to be suitable for the total (100%) substitution of fatty tissue in fermented sausages, without adverse effects on the product's sensory properties (*Magra et al*., 2021).

3. Fat reduction in cooked sausages

The basis of the filling for cooked sausages consists of meat batter or meat emulsion, which are heat treated (mostly by pasteurization) after stuffing into casing. Although the fat content in these products varies widely, ranging from 8% to as much as 33% (*Honikel*, 2004), cooked sausages mostly contain over 25% fat. Fatty tissue plays a very important role in these products, influencing their aroma, colour and texture, so its reduction is also not an easy task (*Vasilev et al*., 2011).

The first attempts to produce fat-reduced cooked sausages by simply decreasing the fat content and increasing the meat content in the recipe resulted in texture failures, and even more, this approach was considered as not cost-effective, so it became clear that adequate fatty tissue substitutes should be found. Further attempts included direct incorporation of plant oils into the filling of cooked sausages followed by proper emulsification. Such an approach resulted in polyunsaturated fatty acid-enriched products, which was desirable from the nutritional point of view, but problems with lipid oxidation proneness as well as textural and aroma defects emerged (*Yilmaz et al*., 2002). In order to provide better oxidative stability of such products and to reduce the adverse effects of added oils on the sensory properties of the sausages, a variety of encapsulation systems were investigated. For emulsion-type cooked sausages, promising results were obtained with oleogels, where oils are immobilized by a gelling agent (waxes, cellulose, ceramides, phytosterols, carbohydrates etc.), as well as with oil-bulking, emulsion structuring, and double emulsion systems as described for fermented sausages (*Stajić and Vasilev*, 2022). Such oil encapsulation systems gave the best results mostly with only partial (about 50%) fatty tissue replacement in cooked sausages. Although *Wolfer et al.* (2018) reported the possibility of total (100%) fatty tissue replacement with an oleogel (soybean oil was stabilized by rice bran wax) in frankfurter-type sausages, the products were prone to fat oxidation and showed some texture problems.

The use of fibre and undigestable polysaccharides as fat substitutes was also investigated in cooked sausages, providing low fat, low energy and prebiotic-enriched products. These materials, because of their ability to retain water and maintain juiciness and their neutral flavour, are suitable for adding to emulsion-type meat products (*Kurćubić et al*., 2020). Fiber and polysaccharides could be used in small quantities of just a few percent in the sausage stuffing, but thanks to their ability to strongly bind water and give stable gels, it is possible to produce emulsion-type cooked sausage containing less fat and more water (*Vasilev et al*., 2011). For example, microcrystalline cellulose and carboxymethyl cellulose can bind water in the ratio of 1:9, forming a stable gel that could replace 50% of the fatty tissue in cooked emulsified sausages without affecting their sensory properties (*Kurćubić et al*., 2020). Although the polysaccharide inulin can bind water in the ratio of only 1:3 to produce a stable gel, such inulin gel suspension can replace up to 32% of adipose tissue, as inulin can be added to the stuffing in higher amounts than can fibre (*Vasilev et al.*, 2013). However, the amount of inulin in the stuffing should not exceed 4%, because otherwise it can cause bloating and diarrhoea in consumers (*Janvary*, 2006). In order to maximize the amount of replaced fatty tissue, *Bajčić et al*. (2023) used a combination of inulin (4%) and collagen powder (1.65%), which provided a strong water binding matrix and was used for total (100%) replacement of the fatty tissue in cooked emulsified sausages without any adverse effect on the product's sensory properties.

4. Conclusion

Meat products with the highest fat contents are mostly fermented sausages and cooked sausages. As fatty tissue plays important roles in sausage quality, fat replacement is not an easy task. In fermented sausages, the fat substitute should imitate the fatty tissue particles, and in emulsion-type sausages, the fat substitute should be thoroughly mixed and incorporated into the meat batter. Fatty tissue substitutes based on oils rich in unsaturated fatty acids could be used in both type of sausages, but such oils should be stabilized by some of the various encapsulation techniques in order to hinder lipid oxidation and mitigate the oil aroma. Fibre and indigestible polysaccharides are capable of forming stable gels with water, but can be added only in limited quantities to both type of sausages. Oil-based as well as fibre/polysaccharide-based fatty tissue substitutes can usually replace about 50% of the fatty tissue in fermented and cooked sausages without adverse effects on the product's sensory properties. However, some recent studies have reported successful 100% fatty tissue replacement with substitutes, such as oil-meat emulsion in fermented sausages and inulin-collagen suspension in cooked emulsified sausages. It is noticeable that, in both cases, animal protein (myofibrillar and collagen protein, respectively, in fermented and cooked emulsified sausages) was used as stabilizers of the fat substitute. Such results have opened a new chapter in designing low fat meat products, because it is not a question any more of how much fatty tissue could be replaced, but which substitute could be another total fat substitute.

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