

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: D Vasilev *et al* 2017 *IOP Conf. Ser.: Earth Environ. Sci.* **85** 012033

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Perspectives in production of functional meat products

**D Vasilev¹, M Glišić¹, V Janković², M Dimitrijević¹, N Karabasil¹, B Suvajdžić¹
and V Teodorović¹**

¹Department for Food Hygiene and Technology, Faculty of Veterinary Medicine,
University of Belgrade, Bulevar oslobođenja 18, Belgrade, Serbia

²Institute of Meat Hygiene and Technology, Kačanskog 13, Belgrade, Serbia

E-mail: vasilevd@vet.bg.ac.rs

Abstract. The meat industry has met new challenges since the World Health Organization classified processed meat in carcinogenic Group 1. In relation to this, the functional food concept in meat processing has gained importance, especially in reducing carcinogenic N-nitroso compounds and polycyclic aromatic hydrocarbons (PAHs) as an additional imperative, apart from the usual fat and salt reduction and product enrichment with functional ingredients. PAH reduction relies on control of the smoking process, but there is also a possibility they could be degraded by means of probiotic microorganisms or spices. The reduction of N-nitroso compounds could be provided by lowering the amount of added nitrite/nitrate, using substitutes for these chemicals, and/or by preventing conditions for the creation of N-nitroso compounds. Nevertheless, fat and salt reductions still remain topical, and rely mostly on the use of functional ingredients as their substitutes.

1. Introduction

The functional food concept in meat industry recently met new challenges, especially since the International Agency for Research on Cancer of the World Health Organization classified processed meat as a Group 1 carcinogen for humans in 2015 [1]. This was mainly because of the presence of N-nitroso compounds and polycyclic aromatic hydrocarbons (PAHs) in meat products [1]. As the design of functional meat products includes two main strategies, the addition of functional ingredients and the reduction of potentially harmful components [2], the importance of the latter strategy has especially grown. Previously, research mainly concerned fat or salt reduction [3], but nowadays, special attention is also paid to nitrite [4] and PAH reduction [5] in meat products. Nevertheless, addition of functional ingredients remains the basis for designing healthier meat products [2]. Bearing in mind the aforementioned, the aim of the paper is to discuss recent studies on perspectives for producing functional meat products.

2. Polycyclic aromatic hydrocarbon reduction

The most frequently mentioned source of PAHs in meat products is smoking, but the importance of heat treatment should also be taken into account [6]. Although there are about 660 compounds belonging to the PAH group, only 16 are of priority according to European Union regulations, with special attention paid to benzo[a]pyrene (BaP) as a marker. The content of PAHs in meat products depends on the type of product. In Europe, the content of BaP in smoked meat products is mostly



below 0.5 µg/kg, and in Germany, it ranged from 0.01 µg/kg in cooked ham up to 0.4 µg/kg in frankfurter-type sausages [7]. In Serbia, it ranged from 0.54 µg/kg in Čajna sausage (a local, dry fermented sausage) up to 2.94 µg/kg in dried beef [8].

The strategies for PAH reduction in meat products are often based on lowering the PAH content in smoke itself, by controlling the pyrolysis temperature (temperature should be lower than 400°C), smoke density (light smoke contains 3.01-4.31 µg PAH/kg; intensive smoke 4.88-7.42 µg PAH /kg), providing suitable distance or a hurdle between the furnace and the products, smoking duration, as well as cooking method and intensity [6,9]. There is also a significant influence of the casing type on the BaP content in frankfurters (0.08 µg/kg in peeled cellulose casing, compared to 0.81 µg/kg in sheep intestine casing) as well as the fat content in sausages (0.28 µg/kg in low fat sausage compared to 1.37 µg/kg in high fat sausage) [10]. Also, PAH reductions in meat products could be achieved through treatment of fermented sausage surface with some lactic acid bacteria strains (*Lactobacillus sakei* KTU05-6, *Pediococcus acidilactici* KTU05-7 or *Pediococcus pentosaceus* KTU05-9), which resulted in a significant reduction of the concentration of PAHs such as benzo[a]pyrene and chrysene [5]. Also, some spices such as onion (30g/100g) and garlic (15g/100g) provided PAH reductions of 45% and 60% in meat, respectively [6].

3. Reduction of N-nitroso compounds

N-nitroso compounds in meat products develop through reactions between nitrite and amines derived from decarboxylation of amino acids from meat, which occurs during meat ripening and heat treatment. Nitrite and indirectly nitrate, which is a source of nitrite after being reduced by microorganisms, are used as preservatives in meat products and play antimicrobial and antioxidative roles, as well as take part in color and aroma formation in cured meat products [11]. Although the use of nitrite/nitrate is characteristic of industrial production, they can also occur in some traditional sausages that are produced without the addition of these preservatives, but originate from spices like pepper and garlic [12]. N-nitrosamines (NA) are mostly formed during heat treatment of cured meat products, especially baking and frying. For example, frankfurters which are pasteurized contain 0.64 µg/kg total NA, cooked (boiled) sausages contain 1.86 µg/kg, and canned pork 5.09 µg/kg, but in grilled and fried meats, the NA content is up to 18.87 and 32.46 µg/kg, respectively. It is important to mention that fried cured lean pork contains only 5.43 µg/kg, but fried pork fat contains 19.31 µg/kg NA [13], which is the result of high content of the amino acids, proline and hydroxyproline, precursors for N-nitrosopyrrolidine formation, in collagen rich fatty tissue [14]. Some products which are not heat-treated also contain NA, such as fermented sausages (salami 3.92 µg/kg) and dry cured ham (7.33 µg/kg) [13]. Such findings are explained by the long ripening period for these products, during which precursors for NA, such as amines derived from free amino acids, are generated [11].

Strategies for reducing N-nitroso compounds in functional meat products include exclusion or at least reduction of the amount of added nitrite/nitrate, as well as prevention of conditions for NA creation. Prevention strategies are alteration of product composition (fatty tissue reduction), appropriate heat treatment and suitable ripening conditions. Total exclusion of nitrite/nitrate is not easy because of their importance for the safety, as well as sensory properties (especially color) of the products [11], so for this, an adequate substitute for nitrite/nitrate is needed. Nitrite-free products lack the desired color of meat products, and this is especially expressed in heat-treated products as a result of metmyoglobin (grey-brown color) formation. Promising results were obtained in nitrite-free cooked sausages produced with 1% acid whey and autoclaved mustard seed, where the antioxidant activity of these ingredients stabilized the porphyrin ring of heme in myoglobin, providing an acceptable color of the product [15]. Nitroso-compounds from the mustard seed also took part in color formation [15]. Low-nitrite cooked sausages with acceptable sensory properties were produced with 1% red grape pomace in combination with 30 mg/kg nitrite, where the grape pomace played antioxidative role, as well as took part in browning of existing tannins (Maillard reaction) during heat treatment [16]. Fermented sausages are produced more easily without added nitrite/nitrate, having in mind that traditional production uses only table salt, and the stable red color is mainly a result of the reduction

and stabilization of deoxymyoglobin [12]. It is known that the microbiota in fermented sausages plays a role in the process of reduction. *Lactobacillus fermentum* inoculated (10^8 CFU/g) into nitrite-free fermented sausage provided a similar red color to products produced with 60 mg/kg nitrite [17]. Interestingly, some lactic acid bacteria strains (*Lactobacillus sakei* KTU05-6, *Pediococcus acidilactici* KTU05-7 and *Pediococcus pentosaceus* KTU05-9) are capable of reducing amine formation during ripening; since amines are precursors for N-nitrosamine, this produced low N-nitroso products [5]. Essential oils with antioxidative and antimicrobial activity could play a promising role as nitrite substitutes. Nutmeg essential oil, when added at 20 mg/kg, extended the shelf life of cooked sausages [18].

4. Fat reduction and fatty acid profile improvement

Fat reduction in meat products is widely investigated, since animal fat is recognized as a source of undesirable saturated fatty acids responsible for cardiovascular diseases. Fat reduction has two directions, the first being to use non-fat, energy-low substitutes, and the second being to use polyunsaturated fatty acid (PUFA)-rich marine or plant oils to improve the fatty acid profile of the products [19].

The prebiotic, inulin, is the most appropriate non-fat substitute to date, because it has neutral aroma, white color, and when dissolved in water forms a stable gel similar to fat. Inulin gel (inulin-water ratio 1:1) was frozen and ground in a bowl chopper providing particles that imitated the fatty tissue in fermented sausages, and could replace 1/3 of the fatty tissue without negative influence on sensory properties [20,21,23]. In cooked sausages, inulin can be added in powder form up to 5% [22] or as a gel (inulin-water ratio 1:3) up to 8% [21]; inulin gel is more easily incorporated in sausage stuffing than powder because the gel contains more easily dispersed, dissolved inulin. Apart from inulin, carrageenans and gums have potential as fat replacers because of their good gelling properties [24].

. However, carrageenans [25] and some gums [26] had harmful effects on experimental animals, so there is reason for concern about their influence on consumer health.

For fatty acid profile improvement, plant oils are most commonly used. Initially, tropical plant oils, which have hard consistency at room temperature and are easy to use, were adopted, but the negative side was their high content of saturated fatty acids. The use of hydrogenated plant fats is also not appropriate because of the presence of harmful *trans* fatty acids [27]. Instead of hydrogenated oils, a study about the use of interesterified palm oil as a substitute for beef fat, and which improved the fatty acid profile in beef fermented sausages [28] indicates that the use of interesterified oils could be a better choice. Liquid plant oils rich in omega-3 fatty acids (α linoleic acid – ALA) can be added to fermented sausages only through adequate emulsions (pre-emulsified) with proteins [29] or inulin [30], and good results were obtained with linseed, flaxseed, corn, canola, cottonseed, soybean and olive oil, where the oil content ranged mostly between 3-6% along with 25-35% fatty tissue in the sausage stuffing. As for fish oil, which is the main dietary source of eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids, the greatest problem is the fishy odor, which can be overcome by the use of either deodorized or encapsulated fish oil. In cooked sausages, the same oils were used in a liquid as well as in pre-emulsified form, mostly in amounts of 5-10 % along with 10-20% fatty tissue in the sausage stuffing [29]. The main problem in oil-enriched sausages is their proneness to lipid oxidation [24], but there are a variety of natural antioxidants which could help to overcome this. For example, spices and herbs contain antioxidative phenolic acid and terpenoids, fruits and leaves contain flavonoids and soluble vitamins, nuts and seeds contain tocopherols and tocotrienols, essential oils contain polyphenols, terpenoids, bioactive peptides and protein hydrolysates with antioxidative properties like carnosine and Tyr-Phe-Glu or Tyr-Ser-Thr-Ala [31].

5. Salt reduction

Meat products, especially dried meats and dry fermented sausages, are recognized as high salt foods. Meat products have salt (NaCl) concentrations ranging from 1.6-2.4% in cooked sausages, 3.5-5.0% in

fermented sausages to and 4-7% (in some cases even more) in dried meat [32]. The main health issue concerning NaCl is the sodium content, a high intake of which could be responsible for hypertension and other cardiovascular problems in consumers [33]. Meat processing techniques include the regular use of NaCl, on the one hand in order to provide adequate sensory and technological properties (aroma, texture, water holding capacity, protein solubility, stuffing stability), and on the other hand to provide safety of the products by lowering the water activity. Thus, just simply reducing the NaCl content in meat products has limits (up to 5-10% reductions can be possible), while further reduction would lead to unacceptable product properties [34]. Because of that, other salts that do not contain sodium should be used. The main limitation of such salts is that they cannot replace table salt completely but only a certain percentage of it. For example, potassium chloride or potassium lactate can replace no more than 40%, and glycine no more than 30% of the NaCl; these amounts do not cause changes in sensory properties of the products. Furthermore, salt mixtures containing combinations of potassium, calcium or magnesium chloride or lactate could replace about 30-53% of the NaCl [35,36,37]. Concerning the antimicrobial effect of salt replacers, potassium and calcium chloride as well as lactates produced similar effects to NaCl, which confirmed that these substances could not only provide similar sensory properties, but also microbial safety similar to that of conventional meat products [35]. Furthermore, the type of salt substitute influences the oxidative changes in fermented sausages, so products with KCl as a partial NaCl substitute underwent less oxidative change, but on the contrary, sausages containing CaCl₂ showed more intensive oxidative change than control sausages [38]. Fermented sausages containing CaCl₂ and lactates had lower pHs than conventional sausages, which was explained by the contribution of divalent calcium ions to the pH decrease, but the pH of sausages was not influenced by KCl [36].

6. Functional ingredients

Functional foods contain functional ingredients, which are added to provide health benefits to consumers. Those ingredients are widely investigated and include probiotic bacteria, prebiotics, dietary fiber, synbiotics, antioxidative substances, polyunsaturated (omega-3) fatty acids, plant sterols, bioactive peptides, minerals and vitamins. As for meat products, it is important that addition of functional ingredients does not alter the properties of the product, and that the new ingredients are present in such quantities to provide beneficial effect on consumers [19]. Many functional ingredients could substitute for unwanted compounds in meat products; e.g. prebiotics, dietary fiber or plant oil emulsions act as fatty tissue substitutes [20,21,22,23,29,30]. Similarly, partial NaCl replacement with KCl, MgCl₂ or CaCl₂ leads to enrichment of the products enriched with K, Mg or Ca respectively [35,36,37]. The use of probiotic bacteria is possible only in non-heated products such as fermented sausages, which gives this type of meat product great potential to be produced as functional food [17,19,36]. Additionally, some probiotic lactic acid bacteria, as already mentioned, can reduce amine formation in fermented sausages, which indirectly could slow down the creation of harmful N-nitrosamine; these bacteria can also decompose PAHs [5]. The use of functional ingredients carries a legal obligation that these be properly listed on product labels in order not to mislead consumers [39].

7. Conclusions

Functional foods as a concept have gained importance in the meat industry, especially since the World Health Organization classified processed meat in carcinogenic Group 1. This engendered special efforts to reduce amounts of carcinogenic polycyclic aromatic hydrocarbons (PAHs) and N-nitroso compounds in meat products. PAH reduction relies on closer control of the smoking process, but there is also a possibility they could be degraded in meat products by means of probiotic bacteria and/or spices. The reduction of N-nitroso compounds could be provided for by the lowering the amount of added nitrite/nitrate, using adequate substitutes, and preventing conditions for creation of NA. To this end, the product composition (fatty tissue reduction), appropriate heat treatment as well as ripening conditions should be addressed. Nevertheless, fat and salt reductions still remain topical, and rely on the use of functional ingredients as their substitutes.

Acknowledgment

The paper is a result of the work on the research Project No III46009 financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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