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# Use of sensory science for the development of healthier processed meat products: a critical opinion

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In the present day, consumers are increasingly concerned about the relationship between diet and health, which has led to an increase in demand for healthier products. However, developing these types of products, while preserving their sensory quality is very challenging. In this sense, the use of sensory science plays an important role in the development of healthier processed meat products. Thus, this communication highlights recent advances in the use of sensory science as a tool to assist the development of healthier processed meat products. The opinion article was structured in 4 parts: (1) different sensory methodologies for sensory profiling of healthier processed meat products; (2) main strategies to improve the sensory quality healthier processed meat products; (3) sensory attributes negatively affected by the reformulation process and (4) conclusions and future perspectives. According to the literature, obtaining healthier processed meat products implies a drastic reformulation process that causes negative changes in sensory attributes. Based on this, the use of sensory science can be an essential tool for the development of healthier processed meat products with greater chances of success in the market.

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## Introduction

Sensory science is pivotal for the development of food and beverages [1] as it provides information about their descriptive and hedonic characteristics [2••]. Recently, both members of academia and industry have been exploring sensory science with the goal of developing potentially successful products in today’s competitive marketplace. In this framework, Meiselman [3•] reported that healthiness will be the focus of research in sensory science. More recently, Tuorila and Hartmann [4] confirmed this projection, showing that two of the main issues for the development of novel foods are health and well-being.

Meat and processed meat products are widely consumed and highly valuable foods for consumers due to their sensory properties and the presence of essential nutritional components, such as high biological value proteins, minerals (iron, zinc, selenium) and some vitamins (mainly B6 and B12) [5]. However, processed meat products are also recognized for their high amount of fat, saturated fatty acids, cholesterol, salt, and synthetic additives [6]. Therefore, the study of processed meat products has gained attention for their association with the occurrence of different non-communicable diseases, such as obesity, type-2 diabetes, cardiovascular disease, and a variety of cancers [7], highlighting the need for a transition toward healthier processed meat products. However, developing a healthier meat product presents a sensory challenge, since, in general, consumers are not willing to accept reductions in sensory quality for nutritional improvements.

Different strategies for the development of healthier processed meat products have been studied, such as: the inclusion of plant-based protein to replace animal protein; the incorporation of probiotics, prebiotics and symbiotics; the fortification/enrichment with minerals, vitamins and bioactive compounds [7]; in addition to three of the main current trends that will be covered in this opinion article: (a) sodium reduction [8,9•], (b) fat reduction [10,11], and (c) replacement of synthetic antioxidants [12,13]. To address these trends, different technological strategies have been developed depending on the type of meat product. However, as a result of any reformulation, several negative sensory drivers of liking have been reported, as 'strange taste', 'off-flavor', 'dry', and 'gelatinous texture' [14,15,9•].

In this context, the aim of this critical opinion is to present the recent advances in the use of sensory science as a tool to assist the development of healthier processed meat products. To achieve this goal, the article was structured in four parts: (1) the use of different sensory methodologies for sensory profiling of processed meat products are presented; (2) the main strategies to improve the sensory quality of healthier processed meat products are summarized; (3) sensory attributes negatively affected by the reformulation process are reported, and (4) conclusions and future perspectives are finally proposed.

## What do we know about sensory methods for profiling healthier processed meat products?

The established and most reliable sensory method for sensory profiling of food products is the descriptive analysis (DA), performed by a panel of trained assessors. This method describes sensory characteristics and uses them to quantify differences between products [16]. Several healthier processed meat products have been characterized using DA, such as beef burgers with improved nutritional profile [17], mortadella manufactured with healthier fats [18•], salt-reduced reconstructed ham [19], Cantonese sausages incorporated with dried straw mushrooms [20], and frankfurter sausage with partial fat substitution by rye bran fiber [21]. Although DA provides accurate and reliable results limiting the statistical bias (expressed as repeatability, reproducibility, and discrimination) caused by the inter-individual variability of the assessors [22], it has a widely reported disadvantage in the sensory field — the excessive time required for the panel' s training [23]. This disadvantage results in the dissatisfaction of large companies with a wide range of products and the academy, which generally has short execution times [24]. For this reason, alternative sensory methods that reduce/eliminate the training saving time and resources have emerged [25••]. Over the last twenty years, several sensory methods have been developed to provide a sensory map similar to that obtained by trained assessors, with the advantage of being created from consumers' responses [26]. These methodologies can be divided into four groups: the first one is based on direct verbal descriptions (Word association [27], Flash profile [28], and Check-all-that-apply CATA questions [14]) of products that subsequently generate a summary table used to create a sensory map via correspondence analysis [29] or generalized procrustes analysis [30]; the second group is based on the comparison of products (Sorting [31] and Napping [32]), providing distance matrices treated through multi-block multivariate analysis, such as Multiple Factor Analysis or Distatis, to display the Euclidian distance between products [33]; the third group comprises methods that compare a target sample with a reference (Polarized sensory positioning [34], Polarized Projective Mapping [32], Pivot Profile [35], in which the first two methodologies are analyzed by multiple factor analysis and the last one by correspondence analysis. The fourth group is comprises methods that record the dynamics of the sensory profile over consumption time (Temporal Dominance of Sensation – TDS [12], and Temporal CATA – TCATA [9•], generating an expressive amount of data evaluated by curves for dominance/citation rates and ANOVA/MANOVA for dominance/citation duration [36•,37,9•]. It is worth mentioning that no consumer-based sensory method is superior to another; each of them has its own particularities and limitations and it is up to the sensory practitioner to wisely select the best method based on the objective of the study.

## What is new in the technological strategies to improve the sensory quality of healthier processed meat products?

Currently, the main approaches to develop healthier processed meat products are based on reducing fat and salt as well as replacing synthetic additives (such as sodium erythorbate, butylated hydroxyanisole, butylated hydroxytoluene) by natural ones. Table 1 summarizes the main findings of studies on the development of healthier processed meat products in the last two years.

Because of the high fat content in processed meat products, synthetic antioxidants are one of the most commonly additives used in the meat industry. However, due to consumers' concerns about a potential toxicity of synthetic antioxidants [38], along with the consumer demand for natural and healthier products, natural antioxidants have been proposed. In recent years, the study of natural antioxidants has attracted the attention of academia and industry due to their positive results in delaying lipid oxidation [39–41]. However, many of these studies also report some negative effects of these natural additives on the sensory characteristics of processed meat products [42–44]. In this context, some innovative techniques have been used to minimize or mask these sensory changes (especially in relation to color and odor), such as microencapsulation and active packaging. In a study conducted by Xu *et al.* [45], the use of mulberry polyphenol microcapsules showed less effect on the color of pork slices when compared to the direct incorporation of mulberry polyphenols. Ghaderi-Ghahfarokhi *et al.* [46] revealed that some of the negative sensory attributes of adding cinnamon essential oil to patties can be overcome by adding this component in the encapsulated form. According to studies, microencapsulation can reduce the adverse sensory effects of the direct addition of natural antioxidants by masking strong flavors and odors, due to their prolonged release during storage. Regarding the incorporation of natural antioxidants in active films, Saldaña *et al.* [14] used the CATA questionnaire with

**Table 1**

**Some approaches for the development of healthy meat products**[a]

| Approach | Specific strategy | Meat product | Main findings | Reference |
|---|---|---|---|---|
| Natural antioxidants | Young kiwifruit as antioxidant | Beef | No deleterious effects in sensory properties. | [13] |
| | Straw mushroom (*Volvariella volvacea*) as antioxidant | Cantonese sausages | Mushroom at 2.0% improved flavor, odor, texture and acceptability. Addition of more than 4.0% affects sensory quality. | [20] |
| | Pink pepper extract as antioxidant | Chicken burgers | Sensory properties similar to those with synthetic antioxidant. | [12] |
| NaCl reduction | KCl, maltodextrin, L-Lys, L-Ala, citric acid, and Ca-lactate as partial NaCl replacers | Harbin dry sausage | 30% NaCl can be replaced by a mixture of these compounds with no detrimental effects on the sensory attributes and acceptability. | [8] |
| | Micronized NaCl as replacer of regular NaCl | Beef burger | 33% NaCl reduction was possible with the use of micronized NaCl without affecting the sensory quality. | [35] |
| | Minimum acceptable level of NaCl reduction | Cooked ham and bacon | It is feasible to reduce NaCl up to 34% and 19% in bacon and cooked ham, respectively. | [69] |
| Fat reduction | Pre-emulsion of fish, canola and olive oils as partial fat replacers | Mortadella | Consumers preferred the commercial sample. Sensory drivers of rejection were identified. | [18•] |
| | Olive and linseed oils mixture as partial and total fat replacers | Beef patties | No sensory detrimental effect on was reported. | [51] |
| | Oleogel as partial fat replacer | Bologna-type sausages | Replacement of up to 50% fat by oleogel did not affect the sensory profile and acceptance. | [10] |
| | *Pleurotus eryngii* (king oyster mushroom) as total fat replacer | Sausages | Using deep-fried and fried *P. eryngii* resulted in good scores for odor, flavor, texture, and overall liking. | [70] |
| | Microparticles of chia oil as partial fat replacer and rosemary leaves as natural antioxidant | Beef burgers | 50% fat replacement by microparticles of chia oil enriched with rosemary decreased the sensory descriptors related do lipid oxidation and were positively correlated with liking scores. | [53] |
| | Chia oil emulsion as total fat replacer and guarana seed and pitanga leaf extracts as antioxidants | Lamb burgers | Taste, odor and acceptance of were not influenced by the addition of natural antioxidants. | [50] |
| Fat reduction, natural antioxidants | *Fucus vesiculosus* extract as natural antioxidant and oleogel as fat replacer | Pork patties | *F. vesiculosus* is not an effective oxidation inhibitor for long-term storage. There was no significant difference among samples in relation to sensory properties. | [71] |
| Fat and NaCl reduction | Mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) flour as partial fat and salt replacer | Beef patties | No sensory detrimental effects added with 2.5% mushroom flour were found. | [54] |

[a] Literature search was performed in *scopus* using 'meat-products' and 'sensory profile' as keywords.

ideal profile as a sensory method and found that the direct addition of natural antioxidants to chicken burgers may lead to a reduction in the liking of the product compared to burgers coated with chitosan active films added with pink pepper extract. Another study combined both techniques and showed that a natural active chitosan coating loaded with nano-encapsulated plant extract (*Paulownia Tomentosa*) improved sensory attributes (color and odor) and increased the overall liking of pork chops [47]. Thus, active packaging and microencapsulation technologies are viable alternatives for the incorporation of natural antioxidants in the industrial processing of meat products.

For sodium reduction, the use of salt substitutes, such as potassium chloride (KCl), is a classic alternative. However, KCl imparts bitter and metallic tastes to the product, which can be reduced through the use of flavor enhancers that mask these undesirable tastes. Chen *et al.* [8] reduced the salt content in Harbin dry sausages using this approach. An interesting alternative was presented by Rios-Mera *et al.* [35], who used micronized salt in beef burgers. This strategy is based on mixing the micronized salt with the lipid component of the product, that is, the animal fat, avoiding the aqueous solubilization of the salt crystals [9•] and thus increasing the perception of the product's saltiness. Another approach is the salt reduction by stealth, which consists of promoting a stepwise reduction of salt without consumer awareness. Cubero-Castillo *et al.* [48] used this approach (constant stimuli threshold method) and demonstrated that it was possible to reduce 18.5%, 19.6% and 21.9% of the salt content of chorizo, regular sausage and low-fat sausage, respectively, without consumer awareness.

Animal fat reduction in processed meat products seems to have diversified strategies, which range from the use of fibers, such as rye bran fiber and fructooligosaccharides [21,49]; emulsions [50,51,18•]; emulsion gels [52]; oleogels [10] and oil microparticles [53]. It is important to mention that the presence of sources of long-chain polyunsaturated fatty acids, such as fish oil, impairs the sensory quality of the product [18•], but the presence of only plant-based sources does not seem to have such a pronounced effect on the sensory characteristics [51]. Some authors demonstrated that it is possible to totally reduce fat through the use of vegetable oil emulsions, but to guarantee the sensory quality it is necessary to use antioxidants, such as vegetable extracts [50]. Among the raw materials that have stood out in studies on low-fat processed meat products are edible mushrooms. In addition to their antioxidant role previously mentioned (Table 1), they can act as fat and salt substitutes [54,11], demonstrating the multifunctionality of this food source. This multifunctionality was clearly demonstrated by Patinho *et al.* [17], using beef burgers as a meat matrix.

## What negative sensory attributes can appear during the development of healthier processed meat products?

Depending on the strategy adopted to develop healthier processed meat products, some negative sensory attributes may arise. Also, it is important to mention that sensory perception is multidimensional, so any change in one sensory dimension can affect another, mainly flavor [55]. In sodium reduction, for example, as the NaCl decreases in the formulation, the 'salty' attribute decreases and a perception of 'tasteless' emerges [56]. This is because sodium enhances some typical meat tastes, such as meaty and savory notes [57]. In addition, salt reduction can affect the appearance and consequently the acceptance of meat products, as found by Guo *et al.* [19] in 50% salt-reduced ham. Meat aroma can also be negatively affected by sodium reduction. This mineral influences the osmotic pressure that reduces the solubility of volatile compounds in meat, favoring their release [57]. Technologically, NaCl activates protein extraction, which enhances the ability to form heat-stable emulsions [58••] and increases the water holding capacity of processed meat products, drastically modifying its texture [59]. Thus, not only taste attributes but texture should also be addressed. In relation to taste, if the sodium reduction process involves replacing NaCl with other salts, the metallic, bitter, astringent and strange tastes may appear [60]. Considering the impact on texture attributes, it is difficult to generalize the findings since they are product-dependent. In addition, the sensory texture is strongly linked to the oral work performed during the chewing process of the product, which makes its study even more difficult [61•,62], since the sensory attributes can change during tasting time. However, few studies have been conducted to assess the dynamic sensory properties of low-sodium processed meat products. Therefore, we encourage the scientific community to study the sensory dynamics of processed meat products that utilize salt replacers, focusing on negative attributes, such as bitter and metallic tastes. Subsequently, cross-modal strategies can be generated to reduce the persistence of these negative attributes by adding, for example, extracts rich in umami compounds. In addition, dynamic methods also allow the attachment of instrumental measures to the bolus during chewing, helping to improve understanding of this complex phenomenon [63].

The fat reduction and lipid profile improvement (n6/n3 ratio less than 4) of processed meat products brings considerable changes to texture and taste. These changes are mainly due to the physical structure, particular taste and susceptibility to lipid oxidation of the incorporated lipid (commonly of vegetable or marine origin). Considering that animal fat is solid at room temperature, its replacement by liquid oils is considered a technological and sensory challenge. It is commonly recommended to use fat substitutes with a similar structure for this replacement [64••]. In this regard, Saldaña *et al.* [18•] studied the incorporation of liquid oils in a pre-emulsion (fish, canola and olive oil + sodium alginate + milk protein concentrate) to obtain a texture similar to that of an animal fat in mortadella. As a result, the hardness and juiciness were not affected, but a gelatinous texture was identified as a negative driver of liking. Another recent alternative to replace animal fat is the structuring of oils within a structured viscoelastic material by a three-dimensional gel network, leading to soft material with functionalities closer to that of animal fat [64••]. According to studies, the stabilization and structuring of oils seems to minimize the instrumental and sensory texture issues of replacing fat with oils [65–68], but improvements still need to be made, mainly with regard to taste, in order to prevent off-flavors from lipid oxidation and mask peculiar tastes of ingredients used in the structured oil.

The use of natural extracts from different sources to replace synthetic antioxidants has been reported to influence sensory properties of processed meat products. The main effects are positive for sensory quality since they act to prevent lipid oxidation and consequently the development of rancid odor, off-flavors and meat discoloration due to myoglobin oxidation. However, depending on the origin and concentration of the natural antioxidant, it can interfere with the color, odor and taste of the meat product, decreasing the sensory liking. This negative effect in sensory properties has been widely reported, as in the studies of Jonaidi Jafari *et al.* [42], who found a decline in odor, taste and overall liking of chicken filets coated with chitosan containing 1 and 2% propolis; Fernandes *et al.* [43], who verified a more intense color of sausages with addition of oregano extract; and Muíño *et al.* [44], who observed the highest scores of odd odor and flavor in patties due to the presence of olive extract. As previously presented, using natural antioxidants in the form of microcapsules or incorporating them in active packaging seems to be the most viable alternative to avoid significant sensory changes in processed meat products.

It is worth mentioning that depending on the product reformulation stage and if time and resources are available, classic descriptive methods are recommended when products are in an intermediate reformulation stage and, as the product development progresses, it is advisable to use consumer-based methods in real contexts of consumption.

## Conclusion and future perspectives

Based on recent scientific literature, sensory science plays a major role in the development of new healthier processed meat products. However, it is necessary to be extremely careful with the level of reformulation and the sensory technique selected to characterize the products because in both cases they can generate different negative drivers of liking by consumers. Some future scenarios for the development of healthier processed meat products, from a sensory perspective, are described below:

1) Consumer-based sensory methodologies are recommended due to their optimal cost-benefit ratio. In addition, they provide a sensory profile directly from the potential consumers of the product.
2) Considering the main approaches to developing healthier processed meat products, the most promising recent alternatives include: the use of microencapsulation and active packaging to add natural antioxidants to the products; the incorporation of micronized salt and the combined use of salt substitutes + flavor enhancers in low-sodium products and; the structuring of oils in oleogels or emulsion gels in low-fat products.
3) Advances in technological strategies to improve sensory quality of healthier processed meat products have shown good results in minimizing sensory changes. However, negative effects on color, flavor, odor and texture have still been reported, which should be considered in future studies.

## Conflicts of interest statement

Nothing declared.

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Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
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