Approaches towards Healthier Meat Products

Subjects: Anatomy & Morphology

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Meat products are a staple of many diets around the world, but they have been subject to criticism due to their potential negative impact on human health. There has been a growing interest in developing novel approaches to improve the healthy characteristics of meat products, with a particular focus on reducing the levels of harmful salts, lipids, and nitrites.

Keywords: meat products ; lipids ; salts ; nitrites ; new technology ; new processes ; reduction/replacement ; health

1. Lipids in Healthier Meat Products

Meat products play a significant nutritious role in our diet, although some ingredients have been linked to unfavorable health effects. The improvement of lipid content has drawn considerable attention among the new trends in the design of healthy meat products, which primarily concentrate on enhancing their composition in quantitative and qualitative ways. Lipids represent an important energy source and assist in nutrient absorption, such as fat-soluble vitamins; apart from that, its consumption should be balanced [1][2].

A high fat intake represents a risk factor for diseases such as obesity, heart conditions, high blood pressure, diabetes, and others; in contrast, there is evidence that consumption of polyunsaturated (PUFAs) and monounsaturated (MUFAs) fats have a beneficial role in health [3][4]. Dietary recommendations for fat intake establish no more than 10% of saturated (SFAs) fats, 25% of unsaturated (UFAs) fats and less than 1% of trans fatty acids [3]. To meet these recommendations and improve the lipid content of meat products, technological strategies generally replace animal fat with different lipids to achieve healthier characteristics without major changes in the product's properties, not only for fat reduction, but also focusing on the optimization of lipidic quality and inclusion of functional ingredients [4][5][6].

Fortifying processed meat products with compounds that may mitigate or neutralize such adverse health effects is one strategy that has been used to prevent detrimental effects linked to the consumption of processed meat. However, physical and thermal properties should be similar to animal fat in order to completely replace it in food products, since the fat contributes to several technological traits in meat products, with variable effects depending on product specifications [7]. The strategies include the replacement of animal fat by vegetable oils, the use of flours and fibers, hydrocolloids, mushrooms, and some animal proteins such as whey and collagen. Although the replacement of animal fat by liquid oils generates primarily textural issues, affecting mouth-feel, juiciness, and fat binding properties, demanding an additional step and components to mimic the fat structure and minimize the impacts of the replacement [5].

Given the difficulty and significance in maintaining meat products quality while replacing fat, some methods to lower the amount of animal fat in meat products or increase the quality of lower-fat meat products consist in substituting animal fat with UFA-enriched lipid sources; the other focus is adapting low-fat formulations using physical methods to minimize the impact caused by fat reduction [8].

On the other hand, there are physical methods that comprise high pressure processing (HPP). During the non-thermal process, a partial denaturation of protein molecules caused by the water molecules being pressed into the muscle fibers reduces the cross-linking between non-polar groups, promoting the interaction between proteins and water molecules [8][9]. This technology acts mainly to improve textural problems caused by fat reduction, maintaining tenderness, juiciness, and chewiness as similar as possible to the traditional products. Another physical method is ultrasonic technology, which uses cavitation phenomena to alter intermolecular interactions for the formation of a gel, being used for improving color parameters, water-holding capacity, and texture [8].

Overall, a reduction in total fat, and an increase in mono- and polyunsaturated fatty acids, mainly oleic and linoleic acids, was observed. Implications on physicochemical, rheological, and sensory characteristics varied among the studied products. In some cases, the alteration in the type of fat used in the production of the meat product increased, others decreased, and others did not affect the meat product attributes. This means that while trying to improve the product's lipid profile, researchers can aggravate the quality of other attributes. As an example, changes in fat addition caused an increase in lipid oxidation, which means that the products become more perishable [10][11][12]. Hardness increased in goat burgers [13] and beef burgers [14], which can be a less-appreciated characteristic for consumers.

2. Salts on Healthier Meat Products

For millennia, salt has been a key food preservative. Its use can be traced back thousands of years, highlighting its longstanding role in ensuring food safety and extending the shelf life of various food products. The antibacterial properties of salt, in particular their ability to inhibit bacterial growth, have made it an indispensable tool in food preservation techniques across different cultures and civilizations. Even in modern times, salt continues to contribute a significant role in preserving the quality and safety of food. Its effectiveness as a preservative has stood the test of time, making it a staple ingredient in numerous culinary traditions worldwide. In addition to that, sodium plays a crucial role as a vital mineral in maintaining blood volume and pressure. It is recommended that individuals consume up to 5 g of sodium chloride (NaCl) per day [15], as around 90% of the sodium in our diets comes in this form [16]. Unfortunately, the current situation reveals an excessive intake of sodium, primarily through table salt (NaCl), which can elevate the risk of cardiovascular diseases [17].

Sodium has several functions as a food ingredient (curing meat, cooking, thickening, retaining moisture, enhancing flavor, and acting as a preservative). Sodium is present in common food additives such as monosodium glutamate (MSG), sodium bicarbonate (baking soda), sodium nitrite, and sodium benzoate. Although some foods that are not considered salty may be high in sodium, taste alone is not a reliable indicator of sodium levels in foods. In addition, certain foods such as breads (eaten daily) can contribute significantly to total sodium intake, even if an individual serving is not particularly high in sodium. Consumers have the ability to swiftly verify the sodium content of the products they purchase, enabling them to make informed choices by selecting products with reduced sodium levels. Product labeling may feature various claims related to sodium content, such as “no salt/sodium,” “very low sodium,” “low sodium,” “reduced sodium,” “low sodium or slightly salty,” and “no salt added” or “no salt” [18].

One practical approach to reducing sodium is the gradual decrease in its presence over time, giving consumers the possibility to adapt to lower levels of NaCl in their food [19][20]. However, implementing this strategy requires consensus and cooperation between the food industry and health authorities. The food industry has prioritized the reduction in sodium levels in processed foods. According to the WHO, meat products play a significant role in daily sodium intake, accounting for approximately 16–25% of the total. They are considered the second-largest contributor of sodium in the diet, following bakery products. However, lowering sodium content in meat products presents significant challenges due to the vital technological, sensory, and microbiological stability properties provided by sodium chloride (NaCl).

NaCl, for instance, acts as a suppressant in microbial growth, [21][22], helping to maintain product safety. It also plays a role in inhibiting the activity of proteolytic enzymes, which can affect the physicochemical and sensory characteristics of meat products [23]. Moreover, NaCl influences lipid oxidation and lipolysis reactions [21], which impact the flavor and quality of the final product. These properties make it difficult to reduce sodium levels without compromising the desired attributes of meat products [24]. Efforts to reduce sodium in meat products require careful consideration of alternative strategies and ingredients that can provide similar technological functionalities while maintaining sensory acceptance and microbiological stability. Balancing these factors is crucial to ensure that reduced-sodium meat products meet consumer expectations without compromising safety or quality [25].

The production of salted meat products involves several salting steps, which are of extreme importance for obtaining the desired characteristics of the final product. The salting methods employed vary depending on the specific product and its intended purpose, directly influencing its properties. The chosen salting method determines the mechanism of mass transfer and whether there will be an increase or decrease in weight during the process. These factors play a significant role in shaping the final texture, flavor, and preservation of the salted meat. The primary objective of salted meat processing is to lower the water activity to levels that ensure microbiological stability at ambient temperatures. By reducing the activity of water, the growth and proliferation of microorganisms are inhibited, thereby extending the shelf life of the product. Overall, careful implementation of salting techniques is essential in the production of salted meat products, as it directly impacts their quality, preservation, and safety [20].

In many meat products, a significant amount of NaCl is added to improve texture, facilitate emulsion formation, increase production yield, inhibit microbial growth, and provide distinctive sensory characteristics [20][26]. Hence, any modification in meat products concerning reducing salt content must be accompanied by a comprehensive evaluation of their sensory acceptance, physicochemical properties, and stability. Many studies are focused on ways to reduce or substitute sodium that can provide sensorial and technological functions like NaCl: for example, replacing NaCl with other chlorine salts (such as KCl, $CaCl_2$, and $MgCl_2$) [27][28]; replacing for non-chloride salts as lactates and phosphates (such as K-lactate and Ca-lactate) [29]; using flavor enhancers such as taurine, lysine, or monosodium glutamate [30]; incorporating natural products with a salty taste such as yeast extract, hydrolyzed vegetable protein, and seaweeds [20]; or applying novel techniques such as high pressure and ultrasonic methods [31][32][33][34]. The use of ultrasound is based on an understanding of mass transfer processes and how these can modify cell membranes, aiding the various stages in the curing process [35]. Ultrasound is one of the main technologies used in processed meat industry, allowing an increase in shelf-life, thus prolonging the flavor, juiciness, and tenderness of the products for the final consumer. For example, McDonnel et al. [36] studied the possible industrial application of ultrasound-cured ham and used pork meat samples that were treated with different ultrasonic intensities; 40, 56, or 72 W cm^2 for 2, 4, or 6 h, respectively. In all the samples, the desired level of NaCl (2.25%) was reached within 2 h, while the control (employing no ultrasound) required 4 h. Sonication showed no negative effect on cooking loss, moisture, or texture profile. Sensory analysis revealed a positive correlation between the product flavor and a stronger ultrasound power application.

However, despite many studies having shown that partially replacing NaCl with KCl is the most used/common choice for producing low-sodium meat products [37][38], replacing of 50% NaCl with KCl would have negative sensory properties such as a bitter metallic taste and astringency [39][40]. Additionally, the application of basic amino acids including L-lysine (L-Lys), L-histidine (L-His), and L-arginine (L-Arg) has aroused considerable interest. These amino acids can act independently or synergistically because they contain an extra amino group where their positively charged side chains at pH 7 can interact with groups with opposite charges, forming ionic bonds or salt bridges [41]. Thus, they are used as substitutes in ham [42], dry-cured loin [38], cured and cooked loin [43], and sausages [25][44]. In another study [45], salted meat treated with 3% L-Lys + (50% NaCl, 25% KCl, and 25% CaCl2) had a higher overall acceptance compared with the sample treated with only 50% NaCl, 25% KCl, and 25% $CaCl_2$ (i.e., without L-Lys).

Consequently, reducing or substituting NaCl directly with other salts poses a challenging technological task. Furthermore, the demand for clean label foods restricts the use of synthetic ingredients, and the high production costs associated with these ingredients complicate NaCl substitution [46].

3. Nitrites/Nitrates on Healthier Meat Products

The utilization of nitrite and nitrate in meat products has become a topic of heightened scrutiny in both meat science research and the processed meat industry, with a focus on promoting healthier options. However, their inclusion can still offer certain benefits. Nitrite and nitrate are often utilized in cured meat products due to their antimicrobial properties [47], which can help inhibit the growth of harmful bacteria such as *Clostridium botulinum* and *Listeria monocytogenes* [48]. These compounds also exhibit antioxidant activity, which aids in reducing the risk of meat product rancidity [49] and also promotes the development of the reddish-pink color and the flavor characteristics of cured meat products [50]. However, it is crucial to emphasize that the quantities of nitrite and nitrate added must be closely monitored to ensure consumer safety. Excessive consumption of these compounds carries a high risk of certain cancerous diseases [51], as sodium nitrite can serve as a precursor for the formation of carcinogenic compounds such as nitrosamines [52]. The main nitrosamines found in meat products are N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosopiperidine (NPIP), N-nitrosopyrrolidine (NPYR), and N-nitrosomorpholine (NMOR) [51]. The application of nitrite in the meat industry has been a matter of concern for both industry professionals and consumers over the years [53]. As the risk of colorectal cancer associated with the consumption of red meat and processed meat has been acknowledged, it is essential to explore the underlying mechanisms responsible for this link [54]. The cited authors elucidated the evidence on the catalytic effect of heme iron on the endogenous formation of carcinogenic N-nitroso compounds and on the production of cytotoxic and genotoxic aldehydes through lipoperoxidation. Previous investigations on the relationship between processed meat and colorectal cancer have already highlighted that heme iron present in red meat can promote carcinogenesis by enhancing cell proliferation in the mucosa, potentially through lipoperoxidation and/or cytotoxicity of fecal water [55]. According to the cited authors, nitrosation has the potential to increase heme toxicity in cured products. Tackling and comprehending the mechanism of nitrosation is a challenging endeavor that offers the opportunity to lower cancer risks through process modifications rather than resorting to an outright ban on processed meat consumption. Undoubtedly, for today and in the near future, this is one of the most important research topics for production, industry, and consumers that concerns improving meat products' health effects [56][57][58][59].

Considering these concerns, governmental bodies and health institutions have established threshold limits for nitrite consumption. Regulation (EC) No. 1333/2008 [60] of the European Parliament and of the Council of 16 December 2008 on food additives in its Annex II, part E, food category 08.3 “Meat products”, sets maximum levels for potassium nitrite (E 249) and sodium nitrite (E 250) that may be added during manufacture. These maximum levels have been set at 150 mg/kg for meat products in general and 100 mg/kg for sterilized meat products. For a few specific cured meat products traditionally manufactured in certain Member States, the maximum added level is set at 180 mg/kg. Consequently, it becomes imperative to test the nitrite levels in meat products to ensure food safety and safeguard consumers against potential health issues [61]. In a study conducted in fermented sausages processed with different rates of sodium nitrite and sodium nitrate, [56] concluded that the minimum rate of 80/80 ppm nitrite/nitrate was sufficient to provide protection against lipid oxidation in the digestive tract. A food composition database was developed to assess nitrate and nitrite intake from animal-based foods, aiming to investigate the associations between dietary nitrate and nitrite intake and health outcomes [59]. Alternative approaches and ingredients are being explored to reduce the reliance on nitrite and nitrate while still achieving the desired flavor, color, and safety aspects in healthier meat products. Ongoing research aims to identify innovative solutions that balance health considerations with the preservation and sensory attributes of cured meats.

In recent years, there has been a growing discussion about the utilization of natural sources of nitrite [62]. Additionally, strategies were addressed [63] for enhancing the nutritional quality of meat and meat products, highlighting the reduction in nitrite levels as a means for imparting healthier characteristics to these products. Strategies have been explored to achieve this, including the use of natural sources of nitrite, as well as alternative methods and ingredients to preserve the safety, flavor, and overall quality of meat products. Ongoing research and discussions among experts in the field continue to focus on finding innovative approaches to effectively reduce nitrite levels while maintaining the desired characteristics of meat products. Also, the substitution of nitrite with alternative natural ingredients in meat products has gained considerable interest in recent years, regarding the potential health risks associated with nitrite consumption while still ensuring the safety and quality of the final products. Various natural ingredients have been explored as potential replacements for nitrite, such as celery powder, beetroot powder, and sea salt, among others [49][64][65][66][67][68][69]. These ingredients contain naturally occurring nitrates, which can be converted into nitrites during the curing process. By utilizing these natural sources, manufacturers can maintain the desirable antimicrobial and color-preserving properties traditionally associated with nitrite. However, it is essential to note that the use of natural alternatives requires careful formulation and precise control to achieve consistent results. Even if the impact of using nitrate or nitrite as curing ingredients on public health and the sensory properties, particularly the flavor perceived by consumers, has been extensively documented in scientific literature, there is a lack of understanding regarding consumer perceptions of meat products in which nitrite or nitrate has been reduced or replaced by alternative ingredients [70]. The sensory aspects, including flavor and appearance, need to be evaluated to ensure that the final products meet consumer expectations. Researchers, industry professionals, and regulatory bodies are actively involved in studying and developing guidelines for the effective and safe utilization of natural ingredients as nitrite substitutes. Ongoing efforts aim to strike a balance between health considerations and maintaining the sensory characteristics that consumers associate with cured meat products.

By transitioning to nitrate and nitrite substitutes, researchers can preserve the safety of meat products while minimizing the potential harm associated with these compounds. Nitrate and nitrite substitutes offer a promising solution by reducing or eliminating the formation of nitrosamines while maintaining the desired properties of processed meats, providing a healthier alternative that does not compromise the taste, appearance, or shelf life of meat products. Moreover, nitrate and nitrite substitutes can offer additional health benefits. By incorporating these substitutes, researchers can introduce healthier options to consumers, promoting a well-rounded and balanced diet. As the demand for healthier and more natural food options continues to rise, it is essential to keep consumers informed about the use of nitrate and nitrite substitutes in meat products; providing transparent labeling and accurate information empowers consumers to make informed choices and encourages the industry to prioritize their health. The availability of a growing number of “clean” label ingredients provides a new suite of approaches that are available for application by meat processors to help overcome some of the negative connotations associated with processed meat products [69][71][72].

According to a review on “Natural alternatives for processed meat: legislation, markets, consumers, opportunities and challenges” [73], consumers’ interest in food with less and/or free from synthetic additives has increased considerably in recent years. Consumers are willing to pay more for healthier meat products from companies that add this information on the packaging. This trend has induced the meat industry to innovate, promoting new processing methods and technologies to meet new consumer expectations and the trend toward “clean label” foods. The impact of this trend on the market is that companies are seeking ways to incorporate natural alternatives into their products to meet consumer demand. Still, the industry faces some challenges when trying to incorporate natural alternatives into their products, given their importance for sensory characteristics and food safety. A successful reformulation to remove artificial preservatives involves a multifunctional combination between food safety, product development, technology modifications, and ingredient research. It is also important to note that a global reformulation of products will lead to an increase in production costs and, consequently, in the final cost of the food since chemical ingredients and additives are less expensive. However, with a higher production of clean-label foods, new suppliers of ingredients and additives will emerge in the market, and consequently, their prices will be reduced.

Aromatic herbs and essential oils, yeast extracts, and seaweed, among others, are examples of natural ingredients that can be used as substitutes for synthetic additives. The use of aromatic herbs in food products is exempt from mandatory nutrition declarations for labeling purposes, and there are no regulated maximum admissible limits for the use of this type of ingredient according to Regulation (EU) No. 1169/2011 [74].

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