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# Reduced fat-reduced sodium fermented meat products: a review of reformulation strategies

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**Abstract**

The current research in meat products has been aimed to obtain healthier proposals because of the change in the lifestyle and routine of the population. This new point of view has also changed the industry perspective: they are focusing on reformulation to obtain a portfolio of meat products with a healthier appeal. The process of redefining a traditional formulation can negatively affect the acceptance of the meat product (i.e., taste and appearance). However, researchers reported positive effects in this strategy of reformulations (i.e., added value increase, healthiness, and nutritional enrichment of the product). Sodium reduction, saturated fat reduction, chemical additives reduction, dietary fiber addition, addition of vegetable oils, and probiotic addition are examples of already tested and documented reformulation strategies of fermented meat products. The application of one strategy in a traditional product is a challenge. However, the simultaneous use of two or more strategies is more complex. Thus, the aim of this review was to explain the technological and sensorial benefits and challenges of the application of dietary fibers in meat products submitted to two or more reformulation strategies.

**Keywords:** reformulation strategies; healthiness; sodium reduction; fat reduction.

**Practical Application:** Challenges and technological and sensorial benefits of the incorporation of dietary fibers to fat and salt reduction strategies in fermented meat products.

## 1. Introduction

The researchers and professionals of fermented meat products are investing in reformations or addition of functional products in the traditional formulations, in order to fulfill the consumers' needs for healthier food (Alshahrani et al., 2019; Sirini et al., 2022; Teixeira, & Rodrigues, 2021). Some epidemiological studies have associated meat products with the prevalence of a wide range of chronic non-communicable diseases (NCDs) such as high blood pressure, due to the high content of fat, sodium chloride, sodium nitrite, and other additives (Aburto et al., 2013; Bonnet et al., 2020; IARC, 2015; Virtanen et al., 2019).

Traditional ingredients, such as saturated fat and sodium chloride, have the function of improving the sensory acceptance, shelf life, and physicochemical properties of fermented meat products (Barretto et al., 2015; Bis-Souza et al., 2019a; Dos Santos et al., 2021; Zeuthen, 2015). A minimal reduction in the levels of those ingredients in the traditional formulations can imply significant changes in the fermented meat product (Aburto et al., 2013; Zheng et al., 2019).

The study of the viability to reduced fat and salt simultaneously in fermented meat products is still less explored by the academic area (De Sousa et al., 2020). The investigation of the partial reduction of fat (29%) in Spanish *Salchichón* with a 2% incorporation of fructooligosaccharide showed improvements in the texture profile, instrumental color, and sensory attributes such as flavor, color, and appearance (Bis-Souza et al., 2020). The addition of five different types of fibers (i.e., apple, peach, orange, wheat, and oat fiber) at 1.5% and 3% concentrations in fermented meat products with a reduction of 40% of fat obtained a good sensory acceptance (García et al., 2002).

The effect of reduced fat and salt was investigated in beef hamburgers with the addition of dietary fiber and potassium chloride (KCl). Treatments reduced by 50% of fat and sodium obtained good sensory acceptance. For the technological analyses, there was no difference in the control treatment. Thus, fermented meat products can be reformulated by the reduction of fat and sodium chloride (NaCl) simultaneously, can be developed, and can maintain acceptance and technological performance. However, their effects still need to be studied further (De Sousa et al., 2020). According to Dos Santos et al. (2021), in a fermented meat product with 25% reduced fat-reduced salt , the addition of fibers increased the count of lactic acid bacteria (LAB), improved the texture profile, promoted an

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antioxidant characteristic, and did not affect the acceptance of the final product.

In light of this, the aim of this review was to reveal the benefits of dietary fiber in improving technological and sensory properties in reduced fat-reduced sodium fermented meat product reformulation.

## 2. Reformulation strategies of fermented meat products

The term fermented meat product includes a wide variety of products such as Italian salami, German type, Milano type, and Hamburg type. Each type of salami has different sensory characteristics that are the result of its production methods, raw material, and caliber of stuffing (Leroy & De Vuyst, 2016).

Fermentation occurs by adding a *starter culture*, which contains lactic acid-producing microorganisms responsible for the reduction in pH. This process contemplates complex chemical and biochemical reactions, and it also helps to inhibit microbial growth (Aspri & Tsaltas, 2021). The *starter culture* composed of *Staphylococcus xylosus* (*Micrococcus* group) and *Pediococcus pentosaceus* is incorporated into the formulation of salami to improve the flavor and color and to reduce the sodium nitrate to sodium nitrite which increases the shelf life (Zeuthen, 2015).

Microorganisms present in the starter culture, fermentation of sugars and consumption of muscle tissue glycogen reserve, reduction in pH, and reduction of nitrate to sodium nitrite (García et al., 2002) during the fermentation process. After, the LABs reduce the fermentation of sugars and intensify the metabolic reactions that promote proteolysis and lipolysis, producing a characteristic aroma (Zeuthen, 2015).

The alteration in the sodium chloride, fat, or sodium nitrite content or some simple modification on the traditional formulation may affect the sensory and physicochemical characteristics of the final product (Ozaki et al., 2020). However, the need to develop meat products with improved and healthier compositions has stimulated researchers to conduct research about low sodium, low fat, probiotic addition, prebiotic addition, dietary fiber addition, and sodium nitrite reduction (Manassi et al., 2022; Morais et al., 2022).

Replacing saturated fats with prebiotics fiber addition is one of the most promising trends in meat product research (Manassi et al., 2022). So, this reformulated strategy in fermented meat products is well documented (Bis-Souza et al., 2019a; Câmara et al., 2021; Dos Santos et al., 2021; Felisberto et al., 2015; Paglarini et al., 2019; Pintado et al., 2015).

By definition, prebiotics do not necessarily have to be a carbohydrate or act only in the intestinal microbiota, and prebiotic ingredients are food components that are not digestible by the gastrointestinal tract and that beneficially affect the host by selectively stimulating the proliferation or activity of desirable bacterial populations in the colon (Gibson et al. 2017). However, the most known have these characteristics. Other molecules such as polyphenols, polyunsaturated fatty acids (PUFA), and conjugated linoleic acid (CLA) can also act as prebiotics (Gibson et al., 2017). Some common prebiotics are lactulose, galactooligosaccharides (GOS), fructooligosaccharides (FOS), xylooligosaccharides (XOS), and inulin (Granato et al., 2020), and resistant starches, mucilage, pectin, polydextrose, cyclodextrin, β-glucan, wheat fiber, bamboo fiber, chia mucilage (Barros et al., 2020), and microcrystalline cellulose (MCC) (Nsor-Atindana et al., 2017) have been tested as innovation functional ingredient in meat product reformulation.

## 3. Sodium reduction strategy

Sodium chloride (NaCl) is an essential multi-functional ingredient in meat products. Its main effects promoted in meat products are shown in Figure 1. It is responsible for the myofibrillar protein solubilization, enhancing water binding and water retention capacity (thus resulting in the formation of a desirable gel texture), decreasing water activity (thus controlling the growth of pathogen microorganisms), promoting characteristic sensory attributes, and finally controlling biochemical and enzymatic reactions during ripening (Sirini et al., 2022). Consequently, partial or total replacement of sodium chloride is challenging and can cause sensory, technological, and microbiological stability changes.

In another healthier way, excessive sodium consumption can be related to different chronic NCDs. The World Health Organization (WHO) recommends the consumption of less than 5 g of salt per day for adults. Studies report that in high-income countries, it is estimated that 70% of the sodium consumed comes from industrialized products (Kloss et al., 2015; Yin et al., 2021). So, there is a research line for ingredients to substitute sodium chloride in meat products that may confer similar characteristics to the traditional formulation. Some other chlorides have been incorporated into meat products, such as calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and potassium chloride (KCl) with partial substitution of sodium chloride (Barretto et al., 2020; Delgado-Pando et al., 2019; Horita et al., 2011; Kim et al., 2018).

It has been reported that the addition of calcium chloride in reformulated meat product formulations may have less effect on microbial inhibition and reduced water-holding capacity (Lorenzo et al., 2015), which can compromise the final quality

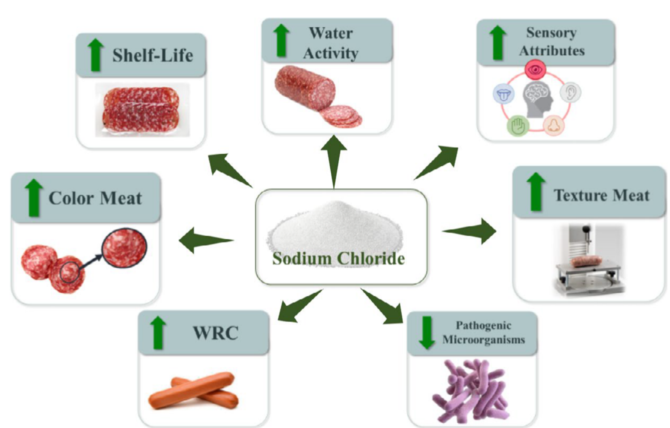


**Figure 1**. Main effects of sodium chloride promoted in meat products.

of meat products. On the contrary, potassium chloride is similar to sodium chloride in terms of ionic strength and presence of monovalent cations and anions (Figure 2), as it provides a better interaction and solubilization of the myofibrillar proteins of meat, aiding its protein-water binding, in addition to the positive aspects of microbiological inhibition and perception of salting but, replacing more than 40% sodium chloride, it can have a bitter taste and a metallic taste in fermented meat products (Desmond, 2006).

Potassium chloride is the most commonly used salt for sodium chloride reduction in low-sodium reformulated meat products (Barretto et al., 2020; Chen et al., 2019; Cittadini et al., 2019; De Sousa et al., 2020; Wilailux et al., 2020; Zhang et al., 2020). In a study that investigated the 50% reduction of sodium chloride by mixtures of potassium chloride and potassium lactate in salami, the proportion of 40% potassium chloride and 10% potassium lactate did not change the overall acceptability of salami (Guàrdia et al., 2008).

In a study that investigated the replacement of pork fat with sunflower oil and the reduction of NaCl (35%) by potassium chloride and potassium lactate, the treatments with greater fat reduction (40%) increased the sensory perception of the bitter taste from the potassium chloride (Mora-Gallego et al., 2014), concluding that the level of fat can contribute to a bitter taste when KCl is used. By reducing sodium chloride by 16% (2.26% NaCl) in fermented meat sausage, the sensory acceptance of the product was reduced in terms of aroma, flavor, juiciness, and overall quality. However, the treatment with the incorporation of 16% of potassium chloride (0.43% KCl) in the partial reduction of sodium chloride (2.26% NaCl) showed no significant difference compared to the control treatment (2.7% NaCl). This conclusion means that the partial reduction of 16% of sodium chloride by the incorporation of potassium chloride in fermented meat sausage is possible (Corral et al., 2013).

A study of dry fermented sausage with 50% reduction in NaCl addition found overall higher acceptability in the low sodium formulation. Therefore, the authors concluded that 2.0% NaCl can be employed as the right level of addition in dry fermented sausage by achieving better quality and flavor with no effects on physicochemical and sensory properties (Hu et al., 2020). Innovative methods based on consumer perception are needed to contribute to a study looking at total or partial sodium reduction in meat product formulations (Vidal et al., 2020).

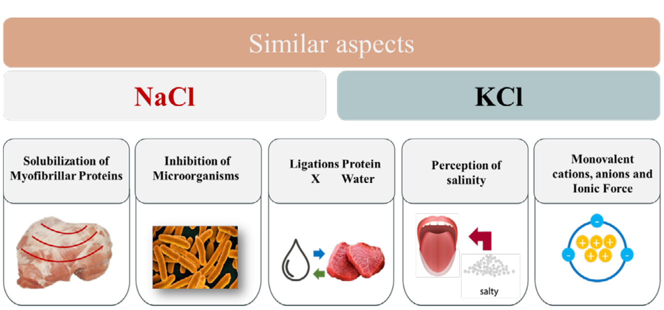


**Figure 2**. Chemical and sensorial characteristics of the sodium chloride and potassium chloride promoted in fermented meat products.

## 4. Fat reduction strategy

Fat is a main component in the production of meat products due to its importance in the sensory and microbial quality. Saturated fat is rich in saturated fatty acids when compared to vegetable oils and its excessive consumption can harm human health (Barbut, 2011). The use of dietary fiber as a fat substitute in the reformulation of fermented meat products has been an alternative to make them healthier (Banerjee et al., 2020; Bis-Souza et al., 2018; Bis-Souza et al., 2019b). Other ingredients have been investigated for fat reduction and health promotion in meat products such as the use of microencapsulated fish oil (Afshari et al., 2017) and vegetable oils (Afshari et al., 2017; Dzudie et al., 2004; Moghtadaei et al., 2018; Mora-Gallego et al., 2014); some types of polysaccharides (Abbasi et al., 2019; Peng & Yao, 2017; Ramírez et al., 2002) are also extensively studied for the incorporation and evaluation of these ingredients in meat products.

## 5. Dietary fibers as an ingredient in reformulated fermented meat products

Dietary fibers have shown good technological and sensory effects as a substitute for saturated fat in meat products. Table 1 presents studies with reduced fat-reduced salt in meat products. Dietary fibers are considered functional ingredients because they can provide some benefits to human health (Jiang et al., 2022; Li & Nie, 2016), such as protection of the intestinal microflora, reducing the risk of developing diabetes mellitus and colon cancers, and reducing gastrointestinal inflammation (Delzenne et al., 2020; Li et al., 2021; Reynolds et al., 2019). In addition, the same dietary fibers can be used as an ingredient reformulated in fat and/or reduce sodium meat products. Some reports show the improvement in the properties of the reformulated meat product added with dietary fibers such as water retention capacity, gel formation, viscosity promotion, fiber-fat binding, texture improvement, and fermentation capacity (Ciudad-Mulero et al., 2019; Kaur & Sharma, 2019; Oliveira et al., 2022).

Dietary fibers are composed of polymers with three or more monomeric units that are not hydrolyzed by endogenous enzymes from the human gastrointestinal tract, i.e., they are resistant to hydrolysis by enzymes from the gastrointestinal tract (Codex Alimentarius, 2008, 2009). They are derived from plants, consisting of polysaccharides, oligosaccharides, lignin, and associated plant substances (AACC, 2001). They are edible carbohydrate polymers that can be present in foods in their natural form or obtained from vegetable and/or synthetic raw materials that are subjected to an extraction process by physical, chemical, and/or enzymatic methods. They can also be of animal origin, such as chitosan, a constituent of the exoskeleton of crustaceans (Ciudad-Mulero et al., 2019).

Among the different constitutions of dietary fiber components are resistant oligosaccharides, resistant starch, lignin associated with polysaccharides, cellulose, hemicellulose, pectins, oat fiber, wheat fiber, and hydrocolloids such as FOS, GOS, and MCC (Dai & Chau, 2017; EFSA, 2011).

Dietary fiber can be classified as water-soluble dietary fiber and water-insoluble dietary fiber (Li et al., 2020). Insoluble fibers

**Table 1**. Different dietary fibers incorporated into meat products.

| Origin | Dietary fibers | Meat products | Technologic effect in meat products | References |
|---|---|---|---|---|
| Amaranth and quinoa seeds flours | 1.5%<br>3% | Goat meat nuggets | Decreased the moisture, increased the fat content and improved the sensorial acceptance. | Verma et al. (2019) |
| Bamboo fiber | 2.5%<br>5% | Bologna mortadella | Improved the emulsion stability, reduced the fat content and demonstrate good sensorial acceptance. | Magalhães et al. (2020) |
| Banana peel powder | 2%<br>4%<br>6% | Chicken sausage | Increased the content of dietary fiber, improved the performance of weight loss for cooking, besides increased in the water capacity retention, delay the lipid oxidation, and decreased the fat. | Zaini et al. (2020) |
| Black quinoa wet-milling coproducts | 3% | Bologna mortadella | The increased of dietary fiber improved the emulsion stability, decreased lipid oxidation and water activity. | Fernández-López et al. (2020) |
| Cellulose fiber | 0.4%<br>0.8%<br>1.2% | Frankfurt sausage | Decreased the fat content and lipid oxidation, increased the emulsion and viscosity of meat mass. | Zhaon et al. (2018) |
| Chia flour | 5%<br>10%<br>15%<br>20% | Chicken nuggets | Elevate the polyunsaturated fatty acids (Omega – 3 α- linolenic fatty acid) content, decreased moisture content and water activity, besides monounsaturated fatty acid. | Barros et al. (2018) |
| Chia seeds | 2%<br>4%<br>8% | Chicken burger | Increased the fat content and decreased lipid oxidation. | Paula et al. (2019) |
| Chia seeds powder | 5%<br>10%<br>15% | Chicken sausage | Reduced hardness and cohesiveness, improved the water capacity retention and the weight loss for cooking, and increased the ash, besides demonstrate a good sensorial acceptance. | Arifin et al. (2021) |
| Chitosan | 1.5%<br>3% | Cooked sausage | Reduced the fat content, improved emulsion stability and parameters of texture profile besides demonstrate antioxidant effect. | Carvalho et al. (2020) |
| Enoki mushroom (*Flammulina velutipes*) stem wastes | 2%<br>4%<br>6% | Goat meat nuggets | Improved the emulsion stability, dietary fiber, ash, phenolic level, water capacity retention and decreased lipid oxidation. | Banerjee et al. (2020) |
| Green pea powder | 3%<br>6%<br>9%<br>12% | Chicken nuggets | Increase the level dietary fiber, reduced the fat content, and improved the texture profile and the nutrition properties | Zaini et al. (2021) |
| Inulin, fructooligosaccharides and α-cyclodextrin | 2% | Italian type Salami | Improved the sensorial evaluate, the texture profile, and the redness. | Bis-Souza et al. (2019b) |
| Kiwi dietary fiber insoluble | 0.5%<br>1%<br>3%<br>5%<br>7% | Pork meatballs | Improved the water capacity retention, emulsion stability, and decreased fat content. | Zhao et al. (2021) |
| Lotus rhizome powder (*Nelumbo nucifera*) | 1%<br>2%<br>3% | Frankfurt sausage | Reduced the fat content and improved the emulsion stability, the apparent viscosity, and the lipid oxidation. | Ham et al. (2021) |
| Microcrystalline cellulose, resistant starch and oat fiber | 2% | Reduced fat – reduced salt in fermented sausage | Decreased water activity, increased the population of lactic acid bacteria, improved the hardness and chewiness besides antioxidant effect. | Dos Santos et al. (2021) |
| Pea fiber | 1% | Beef burger | Reduced the fat content and improved water capacity retention. | Polizer-Rocha et al. (2020) |
| Spinach fiber | 10%<br>30% | Chicken burger | Reduced the fat content and increased the dietary fiber content. | Carvalho et al. (2019) |
| Sunflower seed by-product | 2%<br>4% | Frankfurt sausage | Increased the levels of protein, minerals (potassium, magnesium, copper, and manganese), and decreased the fat content. | Grasso et al. (2020) |

Continue...

**Table 1**. Continuation.

| Origin | Dietary fibers | Meat products | Technologic effect in meat products | References |
|---|---|---|---|---|
| Wheat bran and carrot dry bagasse | 3%<br>6%<br>9% | Chicken sausage | The incorporation the dietary fiber reduced the fat content, cholesterol performance cooking loss, and increased the emulsion stability. | Yadav et al. (2018) |
| Wheat fiber | 1.6%<br>3.1%<br>4.7%<br>6.3% | Beef burger | Decreased fat content, besides caloric values and diameter after the cooking, and increased fiber content also. | Carvalho et al. (2018) |

are MCC fiber, oat fiber (insoluble part), wheat fiber, cellulose, and hemicellulose (Ciudad-Mulero et al., 2019; EFSA, 2011) which have beneficial health characteristics, such as an increase in fecal volume, a reduction in constipation of blood cholesterol, and the development of type 2 diabetes and some types of cancers such as colon cancer (Li et al., 2020; Schulze et al., 2007), in addition to technological functionality such as water retention capacity (Bis-Souza et al., 2018).

Among the soluble dietary fibers are resistant starch, FOS, and inulin known for their hydrocolloid aspects and pectins, gums, β-glucans, soy, and carboxymethylcellulose responsible for increasing viscosity, gel formation, and increased binding affinity with water (Ciudad-Mulero et al., 2019; Delzenne et al., 2020; EFSA, 2011; Momchilova et al., 2021). Furthermore, they can be fermented by bacteria present in the gastrointestinal tract, configuring prebiotic aspects and producing short-chain fatty acids that are considered metabolic by-products (Wilailux et al., 2020). Other beneficial aspects include reducing inflammation, heart disease, and obesity (Kim et al., 2014; Roberfroid, 2005).

International agencies such as the Food and Drug Association (FDA) and the WHO recommend a daily intake of dietary fiber between 20 and 35 g (WHO, 2003). However, consumption by the Brazilian population is deficient (Nsor-Atindana et al., 2019) and meat products with added dietary fiber may be an alternative to increase daily fiber consumption (Ochola & Masibo, 2014).

The addition of up to 5% of three different dietary fibers (i.e., inulin, wheat fiber, and oat fiber) to low-fat mortadella formulations (25%) improved the texture profile, with a significant increase in hardness and cohesiveness and good sensory (Barretto et al., 2015). Another study with partial reduction in fat content (50%) by a maximum addition of 4% resistant starch in frankfurter formulations (Garcia-Santos et al., 2019) showed no difference in the sensory acceptance, texture profile, and protein content of the final product. In bovine hamburger formulations with a maximum replacement of 45% of fat by wheat fiber (¾ fiber), a study showed that treatments with the addition of 3.75 g of fiber per serving had good sensory acceptance and satiety similar to the control (Table 1) (Ramírez et al., 2002).

Several studies have investigated the incorporation of dietary fibers such as inulin, fructooligosaccharide, resistant starch, oat fiber, bamboo fiber, wheat, pineapple, carboxymethyl cellulose (CMC), and MCC in a wide range of meat products, providing improvements in the nutritional characteristics of the product due to the increase in the amount of dietary fiber and reduced caloric content (Barretto et al., 2015; Bis-Souza et al., 2018; Henning et al., 2016; Nsor-Atindana et al., 2017; Pérez-Burillo et al., 2019; Zhao et al., 2011).

The effect of adding three dietary fibers (inulin, fructooligosaccharide, and α-cyclodextrin) to Italian salami with reduced fat on the technological and sensory parameters using the mixture design was investigated. The results showed that an improvement in the parameters of texture, color, and sensory acceptance with the addition of up to 2% inulin and/or fructooligosaccharide was observed (Table 1) (Zaini et al., 2021). The addition of up to 2% citrus fiber, inulin, and acacia fiber to salami demonstrated *in vitro* improvements in the antioxidant capacity and in the amount of short-chain fatty acids. This reformulation also promoted a different microbiota in the human gastrointestinal tract, enhancing not only the benefits of the addition of dietary fiber in nutritional enrichment but also the physiological characteristics beneficial to human health (Pérez-Burillo et al., 2019).

Paglarini et al. (2020) evaluated dynamic sensory techniques to determine the flavor factors in six formulations of bologna sausages with chicken meat and reduced fat and sodium (50% w/w) with added inulin. The descriptive techniques such as temporal dominance of sensations (TDS) consisted of the raters' indication of the sensorially dominant attribute and Temporal Verification of Application (TCATA), where the raters receive a list of terms before the evaluation of the product. In this study, it was possible to observe that saltiness was an attribute significantly affected after chewing; however, it was not the most mentioned in TCATA. The texture attribute was the first to be described by the evaluators and was one of the dominant attributes. In addition, the treatments with reduced salt (50%) and gel emulsion (50% reduction in fat content) were less accepted than the control, which shows that the TDS and TCATA tests are tools that help in the development of reformulated meat products with reduced fat and sodium content.

The incorporation of dietary fiber in meat products aims, besides nutritional enrichment and improvement in sensory properties and physicochemical parameters, to aid in oxidative stability and water retention capacity (Das et al., 2020; Kaur & Sharma, 2019), as well as to promote antimicrobial and anti-inflammatory activities (Saura-Calixto, 1988).

Studies about the reduction of fat and salt in the same meat product have been carried out through the addition of dietary fibers because of the symbiotic effect in the physicochemical, microbiological, and sensory properties (Aburto et al., 2013;

Alshahrani et al., 2019; Dos Santos et al., 2021; Lorenzo et al., 2015). For example, De Souza Paglarini et al. (2021) investigated the addition of inulin-based emulsion gels as a fat substitute in salt-reduced bologna sausage. The results reported an improvement in the profile of unsaturated fatty acids and a lower content of saturated fatty acids in relation to pork back fat. The results also showed improved cooking properties and contributed to the stability of lipid oxidation. In a study using bamboo fiber in a reduced salt and phosphate-free bologna sausage, the results show good sensorial acceptability and improvement in the intensity of redness (a*) and yellow (b*). However, the texture profile was impacted by the reduction of water content in treatments with the addition of bamboo fiber (Magalhães et al., 2020).

There are few studies aimed at reducing the sodium and fat content, so it is necessary to promote the application of these strategies combined with the development of healthier meat products such as fermented meat products.

Oat fiber, resistant starch, and MCC have been investigated in the reformulation of meat products showing positive results on technological and sensory evaluations (Table 1). So, it can represent an important ingredient for the meat industry (Barretto et al., 2015; Dos Santos et al., 2021; Garcia-Santos et al., 2019).

The use of oat fiber (3 and 6%) in mixed low-fat and low-sodium cooked and frozen burgers reported an increased yield, decreased weight loss during microwave heating, and improved color stability during storage. The authors emphasize that oat fiber can be considered a promising ingredient to aid in the formulation of meat products with reduced salt and fat (Trevisan et al., 2016).

## 6. Promising ingredients in the reformulation of reduced fat-reduced sodium fermented sausage

Figure 3 shows a draft for the reformulation of Salami with reduced fat-reduced salt (25%) with the addition of oat fiber, resistant starch, and MCC. The results showed an antioxidant characteristic, improved texture profile such as hardness, chewiness, and thickness, decreased water activity, and increased viscosity and gel structure, and furthermore promoted interaction between fiber and fat using the simplex-centroid design (Table 1) (Dos Santos et al., 2021).

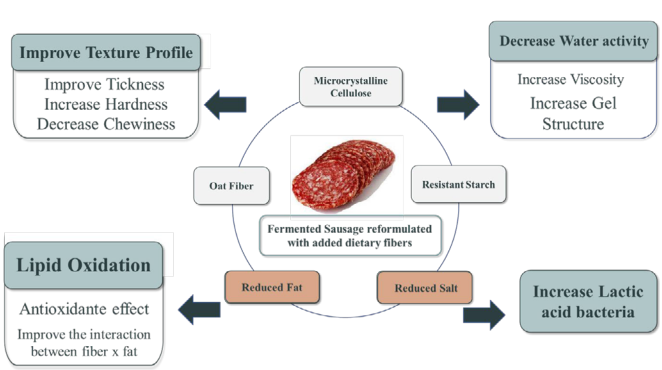


**Figure 3**. Fermented sausage reformulated with added dietary fibers reduced fat-reduced salt.

Resistant starch is an α-D-glucan polysaccharide arranged in linear chains, essentially derived from a retrograde amylose fraction. It has a relatively low molecular weight ($1.2\times10^5$ Da) (Moghtadaei et al., 2018), commonly obtained from rice, potatoes, cassava, corn, and wheat. Among the main components of starch are amylose and amylopectin, and the amounts are different for each variation of starch. They are classified into five different groups, considering their resistance to enzymatic digestion, group 1, encapsulated and physically inaccessible starch; group 2, resistant granules; group 3, retrograde amylose; group 4, chemically modified starch; and group 5, amylose-lipid complexes (Ciudad-Mulero et al., 2019). In this way, resistant starch corresponds to a portion of starch that is not hydrolyzed by endogenous enzymes of the human gastrointestinal tract and, consequently, is not absorbed by the small intestine, being made available in the colon as an energy substrate for bacteria in the microflora to develop and ferment, producing short-chain fatty acids that act as a prebiotic agent (Champ, 2004; Ciudad-Mulero et al., 2019).

The study on the addition of 4% of resistant starch in frankfurters low fat (50% reduction) showed that prebiotic fiber positively influenced the texture profile and sensory acceptance, proving to be a promising ingredient (Garcia-Santos et al., 2019).

A study of a sausage formulation with the addition of the three dietary fibers (i.e., β-glucan, resistant starch, and starch) reported a better performance for the properties of cooking yield and global acceptance, thus making the production of sausages with the addition of prebiotic fibers viable (Sarteshnizi et al., 2015).

MCC is a purified form of cellulose, a natural polysaccharide most abundant in nature, consisting of two consecutive glucose anhydride units called cellobiose, and its chain structure makes it insoluble in water. Its glycosidic β 1-4 structure is responsible for the non-digestive nature of the polymer, β bonds that allow the extension of the molecular chain giving rise to tight linear arrangements between individual polymers (Krawczyk et al., 2009).

The process of obtaining MCC occurs from extraction by acid hydrolysis, where all the amorphous cellulose parts are removed from the fiber. The hydrolyzed product consists of a mass of crystalline cellulose, processed outside the degree of polymerization, during the neutralization, washing, and filtering phases, it is diluted in water, and at the end, the cellulose product is dried using the spray-drying process, producing robust particles (Krawczyk et al., 2009).

MCC is obtained as a crystalline and porous powder, white, odorless, and free of impurities and characterized by its lower degree of polymerization compared to its original raw material. This hydrocolloid has technological characteristics, such as gel formation capacity, volume increase, creamy mouthfeel, and water retention capacity. The MCC is considered a prebiotic (it is not hydrolyzed in the gastrointestinal tract). The total insoluble fiber content is between 93 and 98 g per 100 g serving (Nsor-Atindana et al., 2019).

The addition of CMC and MCC in meat sausages with low-fat content demonstrated a reduction in firmness when

2% CMC was added. However, the MCC addition improved the protein gel formation, contributing to an increase in the functional compounds in the gastrointestinal tract (Schuh et al., 2013). In another study by Dos Santos et al. (2021), the addition of up to 2% MCC in salami with reduced fat and salt content helped to increase the LAB count (Figure 2) and antioxidant activity and did not interfere with the sensory acceptance of the final product.

## 7. Final considerations

Dietary fiber is considered a functional ingredient as it can provide some benefits to human health, such as protection of the intestinal microflora, reducing the risk of developing diabetes mellitus and colon cancers, and reducing gastrointestinal inflammation. In addition, it can positively help reformulated fermented meat products (low fat and low sodium) by improving technological properties such as water retention capacity, gel formation, viscosity promotion, fiber-fat binding, texture improvement, and fermentation capacity. The use of dietary fiber in reduced fat-reduced sodium fermented meat products represents a potential alternative to the possible technological problems faced in a reformulation process. Furthermore, this symbiotic addition can increase the healthier attractiveness of this new fermented meat product formulation.

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