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IMPACT OF CURING SALT (NITRITES) ON THE PROCESSED MEAT PRODUCTS AND ITS ALTERNATIVES: A REVIEW

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Abstract. This study focuses on the significance of nitrite in the methods associated with curing meat, as well as the related health risks. It analyses all aspects of nitrite use, such as how it enhances flavour, prevents bacteria from growing and preserves meat quality. It also discusses the possible health hazards of consuming too much nitrite, such as the creation of nitrosamines that can cause cancer. In addition, other approaches to meat preservation—like natural curing agents and nitrite replacements—are investigated in considering their effectiveness in maintaining food quality and safety without reducing flavour or texture. This research aims to provide valuable insights into the ideal balance between food safety and culinary preferences in meat processing through an in-depth examination of nitrite utilization utilization and its alternatives. This can assist consumers and food industry customers in making informed decisions.

Keywords: *Processed meat, nitrites, natural replacement, health problems.*

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1. Introduction

In meat curing, nitrite is essential for flavour, colour and microbiological safety. However, because it produces nitrosamines that may cause cancer, using it has brought up serious health issues. Therefore, both the meat business and consumers must comprehend how to weigh the advantages and risks of this. The purpose of this review is to fully examine the complex issues around nitrite usage and investigate viable substitutes to reduce related health hazards (Shakil *et al*., 2022). It will begin with an examination of how nitrite enhances meat preservation and how that impacts the end product's quality. Identifying these processes is critical to reducing nitrite usage in a way that maintains food safety and sensory attributes (Iammarino *et al*., 2023). The research carefully

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examines the health effects of nitrite consumption, emphasizing its part in the production of nitrosamine and its consequent carcinogenicity. Examining the most recent scientific data on this topic will highlight the extent of the risk that nitrite in processed meats poses (Wu *et al*., 2022). Lastly, the review evaluates newly developed meat-curing alternatives to nitrite, including natural additives. Future efforts to create safer and more sustainable meat preservation techniques will be guided by assessing the viability and effectiveness of these alternatives (Wang *et al*., 2022).

Nitrite in processed meat

The origins of meat curing date back to 3000 B.C., when salt was used for preservation; with refrigeration and food packaging advancements, curing shifted from preservation to creating convenient products.

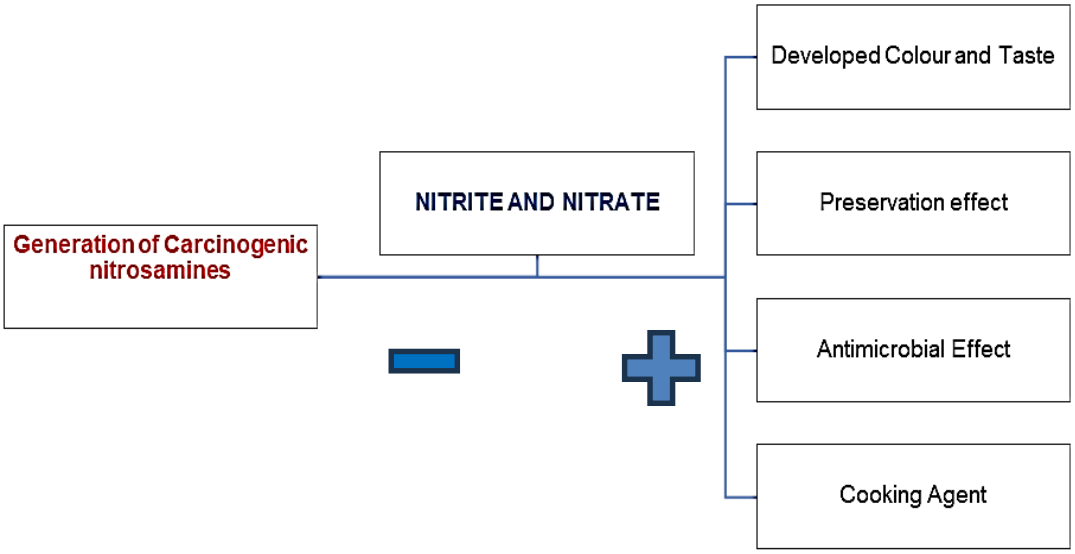

Figure 1. Positive and negative effects of processed meat products on nitrite and nitrate

Nitrite is important in lending cured meats their colour and flavour while also acting as an antioxidant and antimicrobial agent (Lahiri *et al*., 2022). Meat microflora changes natural or added brine-containing nitrate to nitrite or bacteria with nitrate reductase activity (Shakil *et al*., 2022; Iammarino *et al*., 2023).

2. Positive Impact of Using Nitrite and Nitrate in Meat Processing

Colour Enhancement

Many factors affect inherent meat colour, including the introduction of nitrite ions (NO^{2-}). When nitrite reacts with hydrogen ions, it forms nitrous acid (HNO_2), which decomposes into dinitrogen trioxide (N_2O_3) and water (H_2O). Dinitrogen trioxide further breaks down into nitric oxide (NO) and nitrogen dioxide (NO_2) (Iammarino *et al*., 2023; Di Nunzio *et al*., 2022). Nitric oxide reacts with the iron in myoglobin and metmyoglobin, proteins in meat, creating a pink colour in cured products (Wang *et al*., 2022; Dissanayake *et al*., 2023). Heating this process generates the stable pinkish-red colour nitroso-hemochrome (Di Nunzio *et al*., 2022).

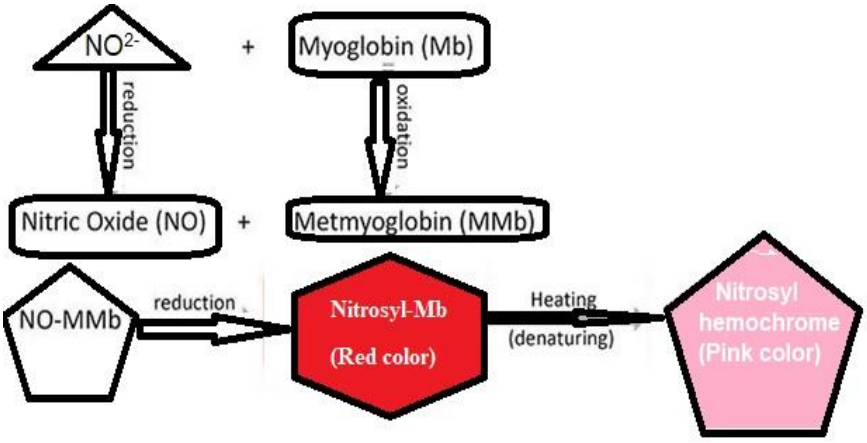

Figure 2. Process of cured meats' colour change (Konteles *et al*., 2023; King *et al*., 2023)

Various additives influence the colour development of cured meats. Antioxidants like erythorbate and ascorbic acid promote nitric oxide (NO) production, enhancing meat colour. Sodium chloride reacts with HNO_2 to generate nitrosyl chloride, increasing NO-myoglobin formation. Higher salt concentrations lead to more redness. pH affects nitric oxide formation; lower pH accelerates it. Residual nitrite levels (10-15 ppm) maintain cured colour (Akwetey *et al*., 2022), but excessive nitrite (less than 600 ppm per kg in meat) and low pH cause discolouration on the effect of nitrite in formation (Patarata *et al*., 2022).

Nitrite Influences the Flavor Development

Nitrite is a valuable meat additive for flavour enhancement of meat products by inhibiting lipid oxidation, suppressing aldehydes like hexanal and simplifying the flavour spectrum. It prevents the formation of specific flavour compounds, masks sulfur-containing chemicals and enhances the production of Strecker aldehydes linked to meat flavour formation (Fu *et al*., 2022). Nitrite's antioxidant effect reduces oxidation products in cured meats, leading to a unique flavour profile. Cured meat flavour results from the interplay between nitrite's role in lipid oxidation suppression and its influence on flavour development, creating a complex and distinctive taste (Ursachi *et al*., 2020).

The Antioxidant Effects of Nitrite on Lipid and Protein Oxidation.

Nitrite possesses significant properties that prevent rancidity and undesirable flavours in heated meat products while inhibiting oxidation during storage. Oxidation affects lipids, proteins and pigments in meat, altering its colour, taste, texture and nutritional value (Tateo *et al*., 2020). Lipid oxidation in cold storage leads to rancid off-flavours and food discolouration (Dissanayake *et al*., 2023), potentially endangering consumers' health. Nitrite acts as an antioxidant by protecting meat lipids from oxidation, inhibiting the formation of harmful chemical components. It chelates metallic ions, stabilises heme Fe and produces nitric oxide, disrupting oxidation chain reactions (Samanta *et al*., 2023; Chu *et al*., 2023). Nitrite inhibits lipid oxidation initiation and reacts with reactive oxygen species, inhibiting protein oxidation. While it exhibits antioxidant properties by reducing carbonyl compounds, it also acts as a pro-oxidant by forming disulfide bonds in proteins. Approximately 65% of lipid oxidation decreases when meat products incorporate sodium nitrite 50 ppm. Nitrite's dual role minimises physicochemical changes, ensuring meat quality and preventing deterioration (Pisoschi *et al*., 2021; Xiao *et al*., 2022).

The Antimicrobial Properties of Nitrite Compounds.

In meat products, nitrite reacts as a strong antimicrobial agent, effectively avoiding Clostridium botulinum growth and toxin formation in sausages. It impedes vegetative cell development from surviving spores and prevents cell division. Nitrite's antimicrobial activity varies based on factors like pH and salt concentration. Hinders bacteria, preventing metabolic enzymes' oxygen intake and minimising iron availability, which is required for bacterial activity. Nitric oxide formation from nitrite disrupts microorganisms by causing protein and lipid oxidation (Zhang *et al*., 2023). Nitrite concentrations above 100 ppm suppress starter cultures and bacteriocin production, inhibiting pathogens, namely Staphylococcus aureus and Listeria monocytogenes in cured meats (García-Díez *et al*., 2021).

3. Health Risks Linked to Nitrite Presence in Meat

The application of sodium nitrite in meat preservation has sparked controversy regarding its interaction with meat components, leading to result nitrosamines of potentially cancer-causing residuals, which nitrosamines are organic compounds with the chemical structure R 2N−N=O (Alexander *et al*., 2011). Factors such as pH, temperature and nitrite levels play a role in influencing the risk. Nitrosamines, considered potential carcinogens, are produced during the cooking and processing of meat.

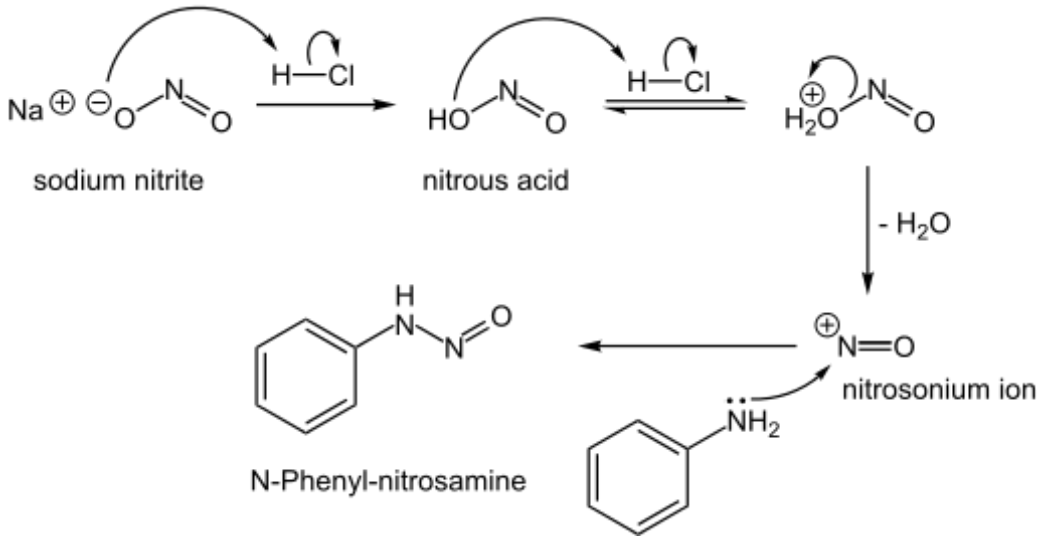

Figure 3. Formation of nitrosamines in cured meat (Shakil *et al*., 2022)

While epidemiological studies hint at a connection between nitrites and cancer risk, the evidence linking processed meat consumption to cancer is inconclusive. High exposure to nitrites can pose health risks, including methemoglobinemia, especially in infants. The association between nitrites and cancer remains a subject of debate, with the International Agency for Research on Cancer recommending a potential carcinogenic effect under specific conditions (Guéraud *et al*., 2023). Concerns about health risks have prompted the exploration of alternative methods in meat processing to reduce nitrite levels without compromising product characteristics, addressing consumer preferences for lower nitrite content. However, the feasibility of enticing consumers with these new products remains uncertain (Munekata *et al*., 2021).

The following outlines the chemical reactions responsible for nitrosamine reactions in commercial processed meat systems:

4. Processed Meat Potential Alternatives for Nitrite and Their Effects for Antimicrobial, Antioxidant, Color and Flavor Properties

Understanding the multifunctional role of nitrite in meat curing is essential for researching alternative options. Leafy green vegetables, such as spinach, celery, arugula, cress, lettuce and others, are rich sources of nitrate, with concentrations exceeding 2500 mg nitrate/kg (Yong *et al*., 2021).

Figure 4. Nitrate and nitrite alternative leafy green vegetables (Yong *et al*., 2021)

Given that various microorganisms can convert nitrate to nitrite, these vegetables present a viable option for substituting or supplementing chemical nitrite in the process of curing meat.

In the realm of meat processing, the elevated nitrate content (ranging from 1000 to 2500 mg/kg) in parsley offers a viable alternative to nitrite (Sindelar *et al*., 2020). Utilising nitrite derived from parsley serves the same purpose as traditional curing in preventing L. monocytogenes in mortadella sausages. This substitution has the potential to positively impact health by reducing residual nitrite levels. Additionally, akin to conventional nitrite, incorporating 4.29g of parsley extract per kilogram of sausage meat effectively preserves its colour. Consumers readily accept higher quantities of parsley extract, suggesting its commercial viability. Notably, parsley extract enjoys greater popularity in food processing due to its lower allergenicity compared to celery extract (Campagnol *et al*., 2023).

In cured meats, celery shows promise as a $NaNO_2$ replacement; industry standards are met when 0.8% of the powdered celery is used in sausage manufacture. Celery powder sausages perform comparably to $NaNO_2$ in factors of pH, TBA, microbiological level, VBN concentration and organoleptic examination, among other variables. Powdered celery, which contains nitrate and natural colours called betalains, improves the colour of meat while lowering the amount of leftover nitrite. Powdered celery, especially in combination with citric acid, enhances the physicochemical properties of sausages and prevents the growth of L. monocytogenes; this is especially true when 10% citric acid is added (Rodríguez-Daza *et al*., 2019).

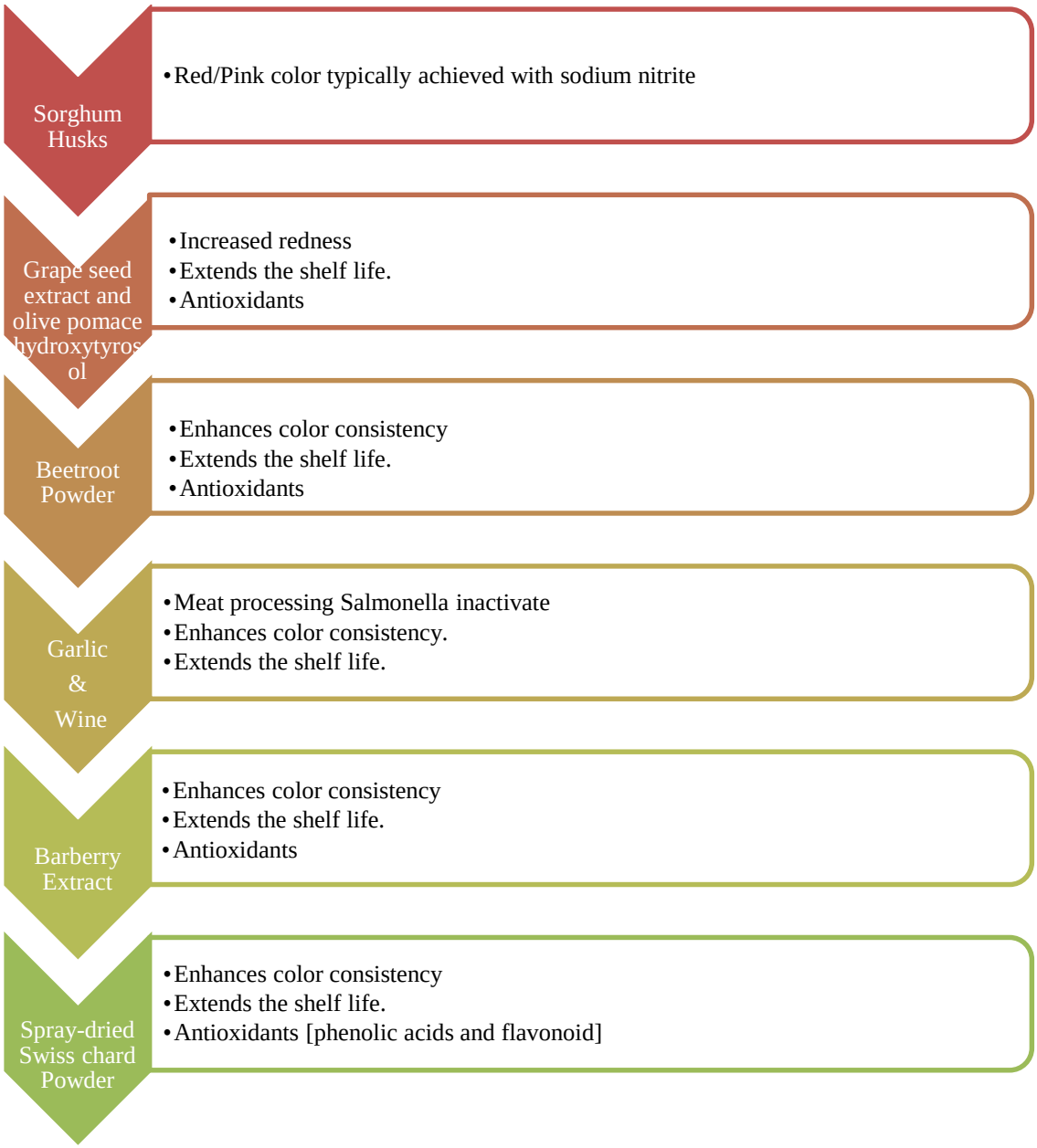

Figure 5. Nitrate and nitrite alternative fruit extraction and natural compound

Utilizing spray-dried Swiss chard powder as a natural nitrate source is a common practice, owing to its nitrate content ranging from 3.0% to 3.5% (Thiruvengadam *et al*.,

2022; Rifky *et al*., 2024). Incorporating the powder into cooked pig patties not only prevents the growth of coliform bacteria but also enhances colour consistency and extends the shelf life. The powder positively influences the formation of nitrosoheme pigments, particularly when pre-converted nitrite is introduced. Additionally, Swiss chard powder contains antioxidants such as phenolic acids and flavonoids (such as syringic acid and kaempferol), which reduce residual nitrite levels and inhibit lipid oxidation. The powder's contribution to the improved flavour and overall acceptability of pork patties is notable and its allergen-free nature is an additional advantage (Babaoğlu *et al*., 2022).

A viable option for replacing nitrite in processed meat with barberry extract is using it as a substitute. The research found that mixing high-concentration extraction of barberry (90 parts per million) with a low nitrite concentration (30 or 60 parts per million) in cooked sausages extended their shelf life during refrigerated storage at 4 degrees Celsius (Serdaroğlu *et al*., 2023). The addition of extracted barberry enhanced the antioxidant properties of the product, suggesting that it could be a healthier alternative to nitrite. Furthermore, barberry extract's antioxidative properties make it a potential replacement for nitrite, reducing the likelihood of carcinogenic nitrosamines forming. In a sensory test, the 90 ppm sample and nitrite contained in extracted barberry 30 or 60 ppm received the highest preference ratings (Ferysiuk *et al*., 2020).

To research novel nitrite alternatives have demonstrated the application of utilizing red wine or a mixture of garlic and red wine as a method for managing biological hazards in the generation of chouriço, a variety of dry-cured sausage. Specifically, the addition of wine, particularly when combined with garlic, has been found to enhance the destruction of Salmonella during meat processing (Patarata *et al*., 2020). Moreover, consumers prefer the chouriço colour produced with garlic and wine or only wine, as it is more natural and less artificial than samples made from traditional $NaNO_2$ (Latoch *et al*., 2023). Indeed, resulted in high red colour (a*) generated red wine 7.5% chourico added sample, which is comparable to the effect compared with sodium nitrite the addition of 150 ppm (Patarata *et al*., 2020). Furthermore, the mixture of 1% garlic and 7.5% red wine was observed in a light brown colour in the end product and developed the yellowness (b*) of the sausage during the interaction with these ingredients. Red wine added sausages or ingredients in cooperation with red wine also had a pronounced cured flavor. Finally, consumers rated samples made with red wine higher than those made exclusively with nitrite salt (Latoch *et al*., 2023; Rifky *et al*., 2024).

The substitution of nitrite with beetroot powder in Turkish fermented sausage resulted in notable alterations in quality characteristics (Aykın-Dinçer *et al*., 2020). The sausage's red hue exhibited variability based on the quantity of beetroot powder, reaching its peak at a concentration of 0.35%. Throughout the storage period, this concentration sustained a heightened level of redness while influencing both yellowness and lightness. Nevertheless, elevated levels of beetroot in the absence or low presence of nitrite are responsible for enhancing oxidation (Sucu *et al*., 2018). Despite the presence of polyphenolic compounds, beetroot did not bring about a reduction in TBARS values. Sensory analysis indicated no noticeable distinctions between sausages containing 0.35%, 0.24% and 0.12% beetroot, as compared to the control group with 150 ppm NaNO2 (Ozaki *et al*., 2021).

Dry-fermented sausage Cinta Senese colour is produced when a combination of olive pomace hydroxytyrosol and grape seed extract along with extracted chestnut and olive pomace hydroxytyrosol. Redness developed the grape seed inclusion sample,

possibly due to the creation of Zn-protoporphyrin. Throughout the initial three weeks of the maturation process, microbial levels for E. coli, L. monocytogenes, Clostridium spp., Salmonella sp. and Staphylococcus spp. were consistently less. Additionally, the extracts demonstrated the ability to inhibit lipid oxidation, courtesy of their polyphenol content (Pini *et al*., 2020).

The results of this investigation indicate that a powder derived from sorghum husks (Sorghum bicolour) yields heat-stable pigments (Sajilata *et al*., 2006). These pigments can be incorporated into a traditional canned meat formulation to achieve the characteristic red/pink hue typically achieved with sodium nitrite (Shukla *et al*., 2022).

5. Conclusion

Nitrite is a mainly utilized utilized preservative ingredient in the meat processing sector. Nitrite is responsible for its inherent reddish-pink hue as well as cured meat salty flavour production. Another benefit is reacts as an antioxidant, which facilitates lipid oxidation in meat and its nitrite bacteriostatic nature preserves the generation of botulinum hazard compounds from Clostridium botulinum. In contrast, sodium nitrite meat additives are subject to some undesirable consequences, such as a carcinogenic influence on human health, according to many research findings. Consumption of high levels of nitrite additives with meat products causes methemoglobinemia and increases the danger of colorectal cancer in the community. There is a current trend in organic meat production and meat producers are conducting research activities to find safe and low-level nitrite residual content alternatives. Many plant extracts are applicable as effective nitrite substitutes in processed meat products. However, there are many alternatives found to fulfil nitrite multifunction activity for processed and cured meat products. Consequently, further research is required to determine a single, cheap replacement for nitrite additions.

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