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Exploration of food risk containing nitrosamine on potential public health implications: A descriptive literature review

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Abstract

Purpose: Nitrosamines, chemical compounds formed from nitrites and amines, are gaining attention due to potential health risks. They are found in processed foods, such as cured meats, smoked fish, and fermented products, prompting a thorough examination of their sources and impact on health. This study aims to explore the nitrosamine content in food and its potential public health implications. **Methods:** This study employs a descriptive literature review methodology to investigate the impact of nitrosamine content in food on human health. It searches peer-reviewed journals, books, and online databases to identify relevant studies on food risk processing that contain nitrosamines and their impact on public health. **Results:** The review includes studies published over the past 20 years, focusing on nitrosamine content, nitrosamine formation processes, and health implications. Data from selected studies is systematically extracted and analyzed, focusing on patterns, risk factors, and health impacts, particularly in terms of cancer risk. **Conclusion:** This review found they pose significant public health risks, especially in meat products. Studies show a strong link between nitrosamine intake and increased risk of gastric and esophageal cancers. The detection and mitigation of nitrosamines are crucial, with more stringent regulations and improved testing techniques being needed in the food and pharmaceutical industries.

Keywords: carcinogenicity; food contamination; health impact; nitrosamines

INTRODUCTION

Nitrosamines, a class of chemical compounds formed primarily through the reaction between nitrites and amines, are gaining increased attention due to their potential health risks [1]. These compounds can be generated during food processing, preservation, or even cooking, particularly in foods such as cured meats, smoked fish, and certain fermented products [2]. In addition to food, environmental pollution is also a source of exposure, primarily through drinking water containing nitrosamines resulting from disinfection processes or the introduction of precursor compounds into water systems [2,3]. In aquatic ecosystems, nitrosamines can be formed from precursor compounds, such as secondary amines, that react with nitrite, thereby expanding the risk of exposure to communities that depend on these water sources [2]. Therefore, controlling nitrosamine exposure from food and the environment is crucial to reducing the societal burden.

Strict monitoring of food processing processes is a crucial step in preventing the formation of nitrosamines, including controlling the use of nitrite as a preservative and maintaining accurate temperature control during cooking [4]. This approach requires not

only the involvement of the food industry but also public health policies that are oriented towards educating consumers about the risks of nitrosamines and promoting the consumption of fresh foods. Thus, public health protection can be enhanced through synergy among food regulations, advancements in processing technology, and promotion of healthy eating patterns [5].

The formation of nitrosamines is particularly concerning due to their recognized carcinogenic properties [6]. Numerous studies have linked nitrosamine exposure to various cancers, including those affecting the gastrointestinal tract, such as stomach and colon cancers [7]. The International Agency for Research on Cancer (IARC) classifies some nitrosamines, like N-nitrosodimethylamine (NDMA), as probable human carcinogens. This raises significant public health concerns, especially given the widespread presence of these compounds in commonly consumed foods [3].

Several factors influence the formation and concentration of nitrosamines in food. These include the type of food, storage conditions, and preparation methods [8]. For instance, high-temperature cooking methods such as frying or grilling can enhance nitrosamine formation in meats [4]. Moreover, the presence of nitrates and nitrites in processed foods, often added as preservatives, can further contribute to nitrosamine levels [9]. Therefore, understanding these variables is crucial in mitigating their presence in the food supply. Additionally, there is a vital role in monitoring food processing to ensure the long-term safety of food. In public health, all food processing poses risks to physical health. Moreover, this issue is not limited to the food industry, but also affects all sectors related to food.

Public health authorities and food safety agencies have implemented measures to limit nitrosamine levels in food products [10]. For example, regulatory limits on nitrite use in food preservation, as well as recommendations for reducing consumption of processed meats, have been introduced to minimize health risks [11]. Nevertheless, ongoing research is needed to identify additional strategies for controlling nitrosamine formation and assessing their long-term health impacts, especially in populations with high consumption of foods prone to nitrosamine contamination [6].

Investigating the nitrosamine content in food is crucial for protecting public health. Given the potential carcinogenicity of these compounds, it is vital to examine their presence in various food products and develop strategies to minimize exposure. This review aims to explore the nitrosamine content in food and its potential health implications. This review aims to contribute to a deeper understanding of the factors influencing nitrosamine formation and their associated health impacts, thereby providing a basis for future research and informed policy development.

METHODS

This study employs a descriptive literature review methodology to investigate the nitrosamine content in food and its potential health implications. The aim is to synthesize and analyze existing research findings rather than conducting new experimental or observational studies.

A comprehensive search of peer-reviewed journals, books, and credible online databases, including PubMed, Google Scholar, and ScienceDirect, will be conducted to identify relevant studies on nitrosamines in food and their associated health effects. Search terms will include combinations of keywords such as "nitrosamines," "food contamination," "health impact," and "carcinogenicity." The search will cover articles published over the past 20 years to ensure the inclusion of both foundational and recent research.

The inclusion criteria focus on the nitrosamine content in food, the processes contributing to nitrosamine formation, and the health implications of nitrosamine exposure. Articles that focus exclusively on non-food-related nitrosamines or studies with limited or insufficient data will be excluded. Additionally, only studies published in English or with available English translations will be considered to ensure comprehension and consistency in the review process.

Relevant data from the selected studies will be systematically extracted and categorized (authors, abstract summary, methodology, and findings). Key information, including the types of foods tested, the methods used to detect nitrosamines, and reported health outcomes, will be collected. The synthesis will focus on identifying patterns in nitrosamine levels across

The literature will be critically evaluated to determine the reliability and validity of the findings. Attention will be given to study designs, sample sizes, and the methodologies used to measure nitrosamine levels and assess health outcomes. This step will also involve identifying any gaps or inconsistencies in the current body of research, such as areas where data are lacking or where studies present contradictory conclusions about different food groups, particularly those associated with higher nitrosamine formation and documented health impacts, including cancer risk.

RESULTS

Table 1 summarizes various studies on the presence and impact of nitrosamines in food and drugs. Nitrosamines, especially N-nitrosamines, are carcinogenic substances and are widely found in processed foods such as meat, cheese, and fish. High nitrosamine content in processed meat can increase health risks, especially cancer, so preventive efforts are needed, such as reducing the use of nitrite and improving the processing process. Additives, nitrite levels, and storage methods influence the formation of nitrosamines.

Several studies have shown an association between nitrosamine consumption and an increased risk of gastric and esophageal cancer, especially from preserved foods. Although the results of case-control studies are quite consistent, cohort studies have given more variable results. Therefore, the detection and control of nitrosamines in food and drugs remains important, with the need for strict regulation and better testing technology. Three related themes, Impact of nitrosamines on public health, focus on the association between nitrosamine intake and cancer risk, especially through consumption of processed foods, nitrosamine control in the food and pharmaceutical industry discusses the importance of regulation, testing, and process improvements to reduce nitrosamine levels, nitrosamine mitigation strategies and detection innovations highlights the technical and scientific measures to inhibit nitrosamine formation and the latest technologies in their detection.

DISCUSSION

Nitrosamines, especially the N-nitrosamines (N-NAs) group, are chemical compounds widely recognized as potent carcinogens. These compounds are formed through the process of nitrosation—the reaction between nitrite and amine—and have the potential to damage DNA through metabolic activation by the cytochrome P450 enzyme. The presence of nitrosamines in everyday life cannot be considered trivial; these compounds are found in various processed food products such as smoked meat, cheese, fish, as well as in chlorinated drinking water and tobacco products.

Factors such as nitrite levels, the presence of carbonyl compounds, and storage conditions greatly influence the formation of nitrosamines. This makes nitrosamines a potential threat in the food system and the environment. Their health impacts are serious—long-term exposure to nitrosamines has been linked to an increased risk of gastric, pancreatic, bladder, and esophageal cancers. Furthermore, nitrosamines are also known to trigger oxidative stress and inflammatory responses by activating the NLRP3 inflammasome, which exacerbates cellular damage.

In the face of this threat, various mitigation strategies have been developed. Modification of food processing processes, such as the use of antioxidants (e.g., ascorbic acid) and natural preservatives, can significantly reduce nitrosamine levels. In the water treatment sector, methods such as ozonation or nitrite control are crucial for minimizing the formation of these compounds. Even oral health aspects contribute—bacteria in the oral cavity can convert nitrates to nitrites, which pose a risk of forming nitrosamines. Therefore, oral hygiene is also an essential component of preventive strategies.

In terms of detection, advances in analytical technology have been of great help. Methods such as gas and liquid chromatography combined with mass spectrometry (GC-MS and LC-MS/MS), as well as DNA-based biosensors, allow monitoring of very low levels of nitrosamines in a variety of products and environments. With a multidisciplinary approach that encompasses detection, prevention, and regulation, the health risks associated with nitrosamines can be effectively mitigated.

CONCLUSION

Nitrosamines are hazardous compounds with high carcinogenic potential that can be formed through various exposure pathways and are influenced by environmental factors and water quality. Scientific evidence shows a close link between nitrosamines and cancer risk, especially due to DNA damage caused by metabolic activation. To reduce its impact on public health, a comprehensive mitigation strategy is needed, such as improving lifestyle, controlling tobacco consumption, and improving water treatment. Early detection of nitrosamines through analytical technology that continues to develop is also an important key in control and prevention efforts. The government and health institutions need to tighten regulations on nitrosamine content in food products, drinking water, and pharmaceuticals. Further research on the mechanism of nitrosamine formation and innovation in detection technology need to be encouraged to support evidence-based policies. Public education must be improved to raise public awareness of the dangers of nitrosamines and the importance of a healthy lifestyle. Cross-sector collaboration between government, academia, and industry needs to be strengthened to develop an effective and sustainable nitrosamine monitoring system.

Table 1. Compilation of all the literature found

No	Title	Abstract summary	Methodology	Finding
1.	Contamination of Food by Nitrosamines and the Associated Public Health Risks [12]	Nitrosamines in food pose a significant health risk and require continued monitoring and mitigation measures.	Brief report	• The presence of N-Nitrosamines (N-NAs) in food poses a serious risk to public health, with the EFSA assessment revealing that the Margin of Exposure (MOE) for the 10 carcinogenic N-NAs in food was highly likely to be less than 10,000 for all age groups, indicating a significant health concern. • The main food category contributing to N-NAs exposure is observed to be meat and meat products. • Contamination of food by nitrosamines poses a significant public health risk, which should be mitigated through strategies such as reducing nitrite use in food and implementing improved quality control solutions with collaborative input from the food industry and regulatory agencies.
2.	Nitrosamines, Their Chemistries and Effects on Health [11]	Nitrosamines formed in meat products during processing can be carcinogenic and threaten public health.	Not mentioned (the paper does not describe any specific methodology or experimental design)	• Nitrosamines are found at high levels in cured meats, cheese, and fish. • The presence of inhibitors, residual or added nitrite concentrations, and storage conditions can affect the amount of nitrosamines in meat products. • Irradiation can reduce the formation of nitrosamines during storage.
3.	N-Nitrosamines in Processed Meats: Exposure, Formation and Mitigation Strategies [13]	Nitrosamines formed in processed meats can have negative health impacts, and mitigation strategies are discussed.	Not mentioned (the abstract does not provide any information about the specific methodology used in this study)	• N-nitrosamines, particularly volatile N-nitrosamines, are highly toxic and carcinogenic compounds that are a major concern in processed meats. • Suppressing the formation and toxicity of N-nitrosamines in processed meats is crucial for human health, while avoiding adverse effects on food flavors. • Potential mitigation strategies include addressing precursors, processing conditions, and using exogenous additives, as well as promoting the degradation of N-nitrosamines.
4.	Nitrosamine Impurities: from Raw Materials to Final Drug Product [6]	This paper discusses the presence of nitrosamine impurities in drug products, but does not address the impact of nitrosamine content in food on health.	Not mentioned (the abstract does not describe the methodology of a specific study)	• Nitrosamines are a class of mutagenic impurities that have been detected in various pharmaceutical products, resulting in recalls and more stringent regulations for their detection and quantification. • Sensitive analytical techniques, such as LC-MS/MS, are necessary to detect and quantify nitrosamine impurities at extremely low levels, to comply with new regulatory requirements. • The discovery of nitrosamine impurities in pharmaceuticals has led to more stringent regulations and testing requirements by regulatory bodies like the FDA and EMA.

No	Title	Abstract summary	Methodology	Finding
5.	The Determination of N-Nitrosamines in Food [14]	The paper reviews analytical methods for detecting nitrosamines in food, which are potent carcinogens formed during food processing.	The history and current state of N-nitrosamine detection methods, particularly for volatile N-nitrosamines, show little advancement since the introduction of the N-nitroso-specific detector, with research into non-volatile N-nitrosamines and total N-nitroso content (ATNC) declining. Still, potential improvements may arise from modern techniques such as mass spectrometry and liquid chromatography-tandem mass spectrometry.	• Analytical methods for detecting volatile N-nitrosamines in food have not undergone significant changes since the introduction of the N-nitroso-specific detector. • Research into non-volatile N-nitrosamines and total N-nitroso content has declined in recent years. • Methods for measuring the total N-nitroso content have not undergone significant improvement in recent years. • Modern techniques, such as mass spectrometry, have been increasingly used for analyzing volatile N-nitrosamines in water, and these methods could be applied to enhance the analysis of these carcinogens in food.
6.	Estimated Cancer Risks Associated with Nitrosamine Contamination in Commonly Used Medications [5]	Consuming high nitrosamine foods, like contaminated medications, can increase cancer risks due to potent carcinogens like NDMA, NDEA, and NMBA, posing a serious public health concern.	The authors use valsartan, a medication for hypertension, as a case study to analyze the impact of nitrosamine contamination. They estimate additional cancer risks using nitrosamine levels from the US FDA and cancer potency data from California's Proposition 65 program and the EPA. The study discusses exposure scenarios and analyzes genotoxic and tumorigenic activity, highlighting shared target tumor sites and potential increased cancer risk.	• Nitrosamine contamination in drugs increases cancer risks. • The Valsartan case study estimates additional cancer risks from contamination.

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