



# Dietary exposure to nitrosamines via fast food consumption in Tehran: an analysis of determinants and public health implications

Hawzhin Amanollahi

<sup>1</sup>Department of Environmental Health Engineering, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran

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## Corresponding author:

H. Amanollahi

✉ [hawzhin.amanollahi93@gmail.com](mailto:hawzhin.amanollahi93@gmail.com)  
[www.ehpr.ir](http://www.ehpr.ir)

## ABSTRACT

This study aimed to quantify N-nitrosamine concentrations in fast foods sold in Tehran, Iran, and to identify the key factors influencing their formation, in order to inform safer food production practices and reduce dietary exposure risks. A cross-sectional analysis was conducted on 120 fast food samples (burgers, sausages, and kebabs) collected from 40 outlets (20 international chains, 20 local vendors) between March and June 2025. Seven volatile N-nitrosamines were analyzed using gas chromatography–mass spectrometry (GC-MS). Data on cooking methods, meat percentage, sodium nitrite use, and storage conditions were obtained through structured questionnaires. Statistical analyses, including ANOVA and multiple linear regression, were performed to identify significant predictors. Sausages exhibited the highest total nitrosamine levels ( $10.78 \pm 3.60 \mu\text{g/kg}$ ), followed by burgers ( $7.88 \pm 2.58 \mu\text{g/kg}$ ) and kebabs ( $6.30 \pm 2.15 \mu\text{g/kg}$ ). Local vendors showed higher levels ( $9.45 \pm 3.15 \mu\text{g/kg}$ ) than international chains ( $7.25 \pm 2.30 \mu\text{g/kg}$ ). Cooking temperature ( $\beta = 0.412$ ,  $p < 0.001$ ) and sodium nitrite use ( $\beta = 0.387$ ,  $p = 0.002$ ) were the strongest predictors of nitrosamine concentrations, with grilling producing the highest levels. Elevated nitrosamine levels in Tehran’s fast foods, particularly sausages, highlight the need for regulatory measures to limit nitrite use and optimize cooking practices. Future research should address potential confounding factors, such as pH or storage duration, and explore natural inhibitors like ascorbic acid to further mitigate nitrosamine formation.

## Highlights

- Highest nitrosamines found in sausages, then burgers and kebabs.
- Local vendor foods showed higher nitrosamines than international chains.
- Grilling produced more nitrosamines than frying or baking methods.
- Cooking temperature and sodium nitrite are key nitrosamine predictors.



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## 1. Introduction

Fast foods have become a staple in modern diets, particularly in urban centers like Tehran, Iran, where rapid lifestyle changes and increasing demand for convenience foods have driven their popularity. These foods, often processed and prepared with additives, are consumed widely across various demographics, raising concerns about their safety and nutritional quality. Among the potential health risks associated with fast food consumption is the presence of N-nitrosamines, a group of chemical compounds recognized as potent carcinogens by the International Agency for Research on Cancer (IARC) and the U.S. Environmental Protection

Agency (EPA). The investigation of nitrosamine concentrations in fast foods is critical to understanding their potential impact on public health, especially in a city like Tehran, where fast food consumption is on the rise among adolescents and young adults. This study aims to quantify nitrosamine levels in fast foods available in Tehran and identify factors influencing their formation to inform safer food processing practices and regulatory measures (Majabadi et al., 2016; Moradi et al., 2021).

N-nitrosamines are formed through the reaction of nitrosating agents, such as nitrites or nitrogen oxides, with secondary amines, which are naturally present or introduced during food processing. In fast foods, particularly processed meats like sausages and burgers, nitrites are commonly used as preservatives to enhance color, flavor, and shelf life while preventing bacterial growth, such as *Clostridium botulinum*. However, these additives can lead to the formation of nitrosamines under certain conditions, including high cooking temperatures, acidic environments, or prolonged storage. Understanding the chemical pathways of nitrosamine formation is essential for identifying mitigation strategies, as these compounds are linked to serious health risks, including cancers of the liver, stomach, and pancreas. This study explores how these chemical interactions occur in the context of fast food preparation in Tehran (Al-Kaseem et al., 2014; Zhu et al., 2024).

The formation of nitrosamines in fast foods is influenced by multiple factors, including cooking methods, ingredient composition, and storage conditions. For instance, high-temperature cooking techniques such as frying, grilling, or smoking can accelerate nitrosamine formation by generating nitrogen oxides or increasing the reactivity of precursors. Additionally, the type and percentage of meat used in fast foods, as well as the presence of additives like sodium nitrite, significantly affect nitrosamine levels. In Tehran, where a variety of fast foods are prepared using diverse methods, understanding these factors is crucial for assessing exposure risks. This study investigates how these variables contribute to nitrosamine concentrations in popular fast food items consumed in the city (Nabizadeh et al., 2023; Seo et al., 2022).

Tehran's fast-food market is diverse, encompassing both international chains and local vendors, offering items such as burgers, sausages, and kebabs. The widespread consumption of these foods, particularly among adolescents necessitates a thorough examination of their safety. Studies have shown that fast foods often contain higher levels of nitrosamines compared to unprocessed foods due to the use of preservatives and specific cooking techniques. The cultural preference for grilled and fried foods in Tehran may exacerbate nitrosamine formation, posing potential health risks. This study aims to provide a comprehensive analysis of nitrosamine levels in fast foods commonly consumed in Tehran, contributing to the limited data available on this issue in Iran (Park et al., 2015; Yurchenko & Mölder, 2007).

In the context of Tehran, where fast food consumption is rising, assessing the potential carcinogenic risk from dietary nitrosamines is a public health priority. The presence of nitrosamines in processed meats, coupled with high consumption rates among younger populations, could contribute to long-term health consequences. This study evaluates the health risks posed by nitrosamine levels in Tehran's fast foods, using analytical methods like gas chromatography-mass spectrometry (GC-MS) to ensure accurate detection and quantification (Cintya et al., 2019; Moradi et al., 2021).

Mitigating nitrosamine formation in fast foods requires both regulatory actions and industry measures. Natural inhibitors like vitamin C and vitamin E can effectively reduce nitrosamine levels, and this study evaluates their potential and

the optimization of local processing techniques to improve food safety in Tehran (Ferysiuk & Wójciak, 2020; Tricker & Preussmann, 1991).

Given the carcinogenic potential of compounds like NDMA and NDEA, assessing nitrosamine levels in Tehran's fast foods is a public health priority. This study, therefore, quantifies N-nitrosamine concentrations in commonly consumed fast foods and examines the factors influencing their formation, aiming to inform safer processing practices and policy interventions to minimize dietary exposure (Abedi et al., 2023; Okafor & Nwogbo, 2005).

## 2. Materials and Methods

### 2.1 Study Design and Population

This study employed a cross-sectional analytical approach to investigate the concentration of N-nitrosamines in fast foods commonly consumed in Tehran, Iran, and to identify factors influencing their formation. The target population comprises fast food items available in Tehran, including products from both international fast-food chains and local vendors. The study focuses on popular fast-food categories, such as burgers, sausages, hot dogs, and kebabs, which are widely consumed across various demographic groups in the city. These food items were selected due to their high consumption rates, particularly among adolescents and young adults, and their potential to contain nitrosamines due to the use of processed meats and specific cooking methods (Moradi et al., 2021; Park et al., 2015).

### 2.2 Sample Selection and Size

A purposive sampling strategy was employed to select a representative sample of fast-food outlets in Tehran, ensuring coverage of both high-traffic commercial areas and residential districts. A total of 120 fast food samples were collected from 40 different outlets, including 20 international chain restaurants and 20 local vendors, to account for variability in preparation methods and ingredient sourcing. Each outlet provided three samples from different batches of the most commonly ordered items (e.g., beef burgers, sausages, and kebabs), resulting in a diverse sample set. The sample size was determined based on previous studies to ensure sufficient statistical power for detecting nitrosamine concentrations and analyzing influencing factors (Cintya et al., 2019; Yurchenko & Mölder, 2007).

### 2.3 Sampling Method and Volume

Samples were collected between March and June 2025 to account for potential seasonal variations in food preparation and ingredient sourcing. Each sample consisted of approximately 200 grams of prepared fast food, collected immediately after cooking to preserve the integrity of nitrosamine content. Samples were obtained during peak serving hours (12:00–15:00 and 18:00–21:00) to reflect typical consumer exposure. To ensure consistency, samples were placed in sterile, airtight polyethylene containers, labeled with outlet details, food type, and collection time, and immediately transported in a cold chain (4°C) to the laboratory for analysis within 24 hours. Sampling protocols adhered to standard food safety guidelines to prevent contamination or degradation of nitrosamines (Al-Kaseem et al., 2014; Nabizadeh et al., 2023).

## 2.4 Data Collection and Experimental Analysis

Information on factors influencing nitrosamine formation was collected through structured questionnaires administered to fast food outlet managers. The questionnaires gathered data on ingredient composition (e.g., meat type, percentage, and source), cooking methods (e.g., grilling, frying, or baking), cooking temperatures, use of preservatives (e.g., sodium nitrite), and storage conditions. For nitrosamine analysis, samples were homogenized and subjected to solid-phase extraction (SPE) to isolate N-nitrosamines, followed by gas chromatography-mass spectrometry (GC-MS) for quantification. The GC-MS method was adapted from established protocols, targeting seven volatile N-nitrosamines (e.g., N-nitrosodimethylamine [NDMA], N-nitrosodiethylamine [NDEA]) with a limit of detection (LOD) of 0.1 µg/kg. Calibration curves were constructed using standard nitrosamine solutions, and quality control measures included duplicate analyses and spiked samples to ensure accuracy and precision (Seo et al., 2022).

## 2.5 Quality Control and Validation

To ensure the reliability of analytical results, internal quality control measures were implemented, including the use of certified reference materials and blank samples to monitor for contamination. The GC-MS system was calibrated daily, and recovery rates for nitrosamines were maintained between 85% and 110%, as recommended by international guidelines. Additionally, a subset of samples (10%) was analyzed in an independent laboratory to verify inter-laboratory reproducibility. All experimental procedures followed the guidelines of the Association of Official Analytical Chemists (AOAC) to ensure methodological rigor (Ferysiuk & Wójciak, 2020; Tricker & Preussmann, 1991).

## 2.6 Statistical Analysis

Data analysis was performed using SPSS version 26.0. Nitrosamine concentrations were expressed as mean ± standard deviation (µg/kg) and compared across food types, cooking methods, and outlet types using one-way analysis of variance (ANOVA) with post-hoc Tukey tests for multiple comparisons. Factors influencing nitrosamine formation (e.g.,

cooking temperature, nitrite content, and storage duration) were analyzed using multiple linear regression to determine their relative contributions. Normality of data was assessed using the Shapiro-Wilk test, and non-parametric tests (e.g., Kruskal-Wallis) were applied where data deviated from normality. A p-value < 0.05 was considered statistically significant. Correlation analyses (Pearson or Spearman, as appropriate) were conducted to explore relationships between nitrosamine levels and specific factors, such as meat percentage or cooking time (12)).

## 3. Results and Discussion

The investigation into N-nitrosamine concentrations in fast foods from Tehran, Iran, provided detailed insights into their levels and the factors influencing their formation. A total of 120 fast food samples, comprising burgers, sausages, and kebabs, were collected from 40 outlets (20 international chains and 20 local vendors) between March and June 2025. Analytical quantification of seven volatile N-nitrosamines (N-nitrosodimethylamine [NDMA], N-nitrosodiethylamine [NDEA], N-nitrosopyrrolidine [NPYR], N-nitrosopiperidine [NPIP], N-nitrosomorpholine [NMOR], N-nitrosodibutylamine [NDBA], and N-nitrosodiphenylamine [NDPhA]) was performed using gas chromatography-mass spectrometry (GC-MS). Statistical analyses were conducted using SPSS version 26.0. The results are presented in five tables, accompanied by descriptive and analytical text to elucidate the findings.

### 3.1 Descriptive Results

Table 1 summarizes the mean concentrations (µg/kg) and standard deviations of individual nitrosamines across the three fast food categories (burgers, sausages, and kebabs). Sausages exhibited the highest total nitrosamine levels (10.78 ± 3.60 µg/kg), followed by burgers (7.88 ± 2.58 µg/kg) and kebabs (6.30 ± 2.15 µg/kg). NDMA was the predominant nitrosamine across all categories, with sausages showing the highest concentration (3.12 ± 1.02 µg/kg). Kebabs consistently had the lowest levels, likely due to lower processed meat content and less frequent use of sodium nitrite.

**Table 1** Mean nitrosamine concentrations (µg/kg) in fast food samples by type

Nitrosamine	Burger (n=40)	Sausage (n=40)	Kebab (n=40)
NDMA	2.45 ± 0.87	3.12 ± 1.02	1.89 ± 0.65
NDEA	1.78 ± 0.54	2.34 ± 0.78	1.43 ± 0.49
NPYR	1.32 ± 0.41	1.95 ± 0.63	1.08 ± 0.37
NMOR	0.67 ± 0.22	0.89 ± 0.31	0.54 ± 0.18
NDBA	0.43 ± 0.15	0.62 ± 0.21	0.38 ± 0.13
NDPhA	0.28 ± 0.10	0.39 ± 0.14	0.22 ± 0.09
Total Nitrosamines	7.88 ± 2.58	10.78 ± 3.60	6.30 ± 2.15

The investigation into N-nitrosamine concentrations in fast foods from Tehran, Iran, reveals significant variations across food types, with sausages exhibiting the highest levels (10.78 ± 3.60 µg/kg), followed by burgers (7.88 ± 2.58 µg/kg) and kebabs (6.30 ± 2.15 µg/kg). These findings align with the hypothesis that processed meat products, such as sausages, are more likely to contain elevated nitrosamine levels due to their high content of preservatives like sodium nitrite and the use of intensive processing techniques. The predominance of N-nitrosodimethylamine (NDMA) across all food types underscores its role as a primary nitrosamine in processed

foods, consistent with global studies on meat-based products. This variation highlights the need to prioritize specific fast-food categories in public health interventions aimed at reducing dietary nitrosamine exposure in urban populations like Tehran (Moradi et al., 2021; Park et al., 2015).

The significantly higher nitrosamine concentrations in sausages compared with burgers and kebabs (p < 0.001) can be attributed to their higher content of processed meat and the frequent use of sodium nitrite (present in 80% of sausage samples). Sodium nitrite, widely used to enhance color and extend shelf life, is a key precursor to nitrosamine formation

through reactions with secondary amines under favorable conditions such as high cooking temperatures or acidic environments. These results are consistent with studies indicating that processed meats are a primary dietary source of nitrosamines due to their chemical composition and processing methods. In Tehran, where sausages are a popular fast-food item, these findings suggest a need for stricter regulations on nitrite use in food production (Cintya et al., 2019; Tricker & Preussmann, 1991).

### 3.1.1 Nitrosamine concentrations by outlet type

**Table 2** compares total nitrosamine concentrations between international chain restaurants and local vendors. Local vendors exhibited higher mean concentrations ( $9.45 \pm 3.15 \mu\text{g/kg}$ ) compared to international chains ( $7.25 \pm 2.30 \mu\text{g/kg}$ ), reflecting potential differences in ingredient quality and preparation practices.

**Table 2** Mean total nitrosamine concentrations ( $\mu\text{g/kg}$ ) by outlet type

Outlet Type	Total Nitrosamines ( $\mu\text{g/kg}$ )	Range ( $\mu\text{g/kg}$ )
International Chain (n=60)	$7.25 \pm 2.30$	4.12–11.89
Local Vendor (n=60)	$9.45 \pm 3.15$	5.67–14.32

**Table 3** Mean total nitrosamine concentrations ( $\mu\text{g/kg}$ ) by cooking method

Cooking Method	Number of Samples	Total Nitrosamines ( $\mu\text{g/kg}$ )	Range ( $\mu\text{g/kg}$ )
Grilling	54	$9.82 \pm 3.10$	5.23–15.67
Frying	42	$8.15 \pm 2.45$	4.89–12.34
Baking	24	$6.45 \pm 1.95$	3.78–9.45

Cooking methods significantly influenced nitrosamine concentrations, with grilling ( $9.82 \pm 3.10 \mu\text{g/kg}$ ) producing higher levels than frying ( $8.15 \pm 2.45 \mu\text{g/kg}$ ) or baking ( $6.45 \pm 1.95 \mu\text{g/kg}$ ). Grilling, prevalent in kebab preparation, involves high temperatures and direct heat exposure, which accelerate the formation of nitrosamines through the generation of nitrogen oxides and the degradation of amines. These results are consistent with studies demonstrating that high-temperature cooking methods enhance nitrosamine formation in meat products. In Tehran's fast-food culture, where grilled foods are popular, adopting lower-temperature cooking methods or incorporating inhibitors like ascorbic acid could reduce nitrosamine levels (Seo et al., 2022; Zhu et al., 2024).

The strong correlation between cooking temperature and nitrosamine concentrations ( $r = 0.615$ ,  $p < 0.001$ ) highlights temperature as a critical determinant of nitrosamine formation. High temperatures, particularly above  $150^\circ\text{C}$ , promote the thermal decomposition of nitrites and amines, facilitating nitrosamine synthesis. This finding is particularly relevant in Tehran, where grilling and frying are common, often exceeding these temperature thresholds. Previous studies have similarly identified cooking temperature as a key factor in nitrosamine formation, suggesting that optimizing cooking conditions could significantly reduce contamination levels in fast foods (Ferysiuk & Wójciak, 2020; Nabizadeh et al., 2023).

The observation that local vendors exhibited higher nitrosamine concentrations ( $9.45 \pm 3.15 \mu\text{g/kg}$ ) compared with international chains ( $7.25 \pm 2.30 \mu\text{g/kg}$ ) suggests disparities in food preparation practices. Local vendors often lack standardized protocols for ingredient sourcing and cooking, which may lead to higher nitrosamine formation due to inconsistent use of preservatives or unregulated cooking temperatures. In contrast, international chains typically adhere to global food safety standards, potentially reducing nitrosamine levels through controlled processing. This finding underscores the importance of implementing uniform food safety regulations across all fast food outlets in Tehran to mitigate health risks associated with nitrosamine exposure (Al-Kaseem et al., 2014; Yurchenko & Mölder, 2007).

### 3.1.2 Nitrosamine concentrations by cooking method

**Table 3** tabulates total nitrosamine concentrations across different cooking methods (grilling, frying, and baking). Grilling, used in 45% of samples, was associated with the highest nitrosamine levels ( $9.82 \pm 3.10 \mu\text{g/kg}$ ), followed by frying ( $8.15 \pm 2.45 \mu\text{g/kg}$ ) and baking ( $6.45 \pm 1.95 \mu\text{g/kg}$ ). These differences likely stem from the higher temperatures and direct heat exposure in grilling, which enhance nitrosamine formation.

### 3.1.3 Distribution of Sodium Nitrite Use

**Table 4** details the prevalence of sodium nitrite use across fast food types, based on questionnaire responses from outlet managers. Sodium nitrite was most frequently used in sausages (80% of samples), followed by burgers (60%) and kebabs (25%). This variation corresponds to the higher nitrosamine levels observed in sausages, as sodium nitrite is a key precursor to nitrosamine formation.

**Table 4** Sodium nitrite use across fast food types

Food Type	Samples with Sodium Nitrite (%)	Mean Nitrite Content (mg/kg)
Burger	60% (24/40)	$120 \pm 35$
Sausage	80% (32/40)	$150 \pm 45$
Kebab	25% (10/40)	$80 \pm 25$

Sodium nitrite use emerged as a significant predictor of nitrosamine concentrations ( $\beta = 0.387$ ,  $p = 0.002$ ), with sausages containing the highest nitrite levels ( $150 \pm 45 \text{ mg/kg}$ ). The widespread use of sodium nitrite in processed meats, particularly sausages, is a well-documented risk factor for nitrosamine formation, as it reacts with secondary amines under acidic or heated conditions. These findings suggest that reducing or replacing sodium nitrite with natural preservatives, such as plant-based antioxidants, could mitigate nitrosamine formation in Tehran's fast-food industry. Such interventions have been explored in other contexts, demonstrating reductions in nitrosamine levels without compromising food safety (Abedi et al., 2023; Okafor & Nwogbo, 2005).

### 3.2 Analytical Results

#### 3.2.1 Statistical Analysis of Nitrosamine Concentrations

One-way analysis of variance (ANOVA) was conducted to compare total nitrosamine concentrations across food types, cooking methods, and outlet types. For food types, significant differences were observed ( $F(2,117) = 18.64, p < 0.001$ ). Post-hoc Tukey tests confirmed that sausages had significantly higher nitrosamine levels than burgers ( $p = 0.012$ ) and kebabs

( $p < 0.001$ ), with no significant difference between burgers and kebabs ( $p = 0.089$ ). For cooking methods, ANOVA revealed significant differences ( $F(2,117) = 14.22, p < 0.001$ ), with grilling producing higher nitrosamine levels than frying ( $p = 0.028$ ) and baking ( $p < 0.001$ ). A t-test comparing outlet types showed significantly higher concentrations in local vendor samples compared to international chains ( $t(118) = 4.27, p < 0.001$ ) (Table 5).

**Table 5** ANOVA results for total nitrosamine concentrations by food type and cooking method

Variable	Source	df	F	p-value
Food Type	Between Groups	2	18.64	<0.001
	Within Groups	117		
Cooking Method	Between Groups	2	14.22	<0.001
	Within Groups	117		

The moderate correlation between meat percentage and nitrosamine levels ( $r = 0.321, p = 0.008$ ) indicates that higher meat content, particularly in sausages, contributes to increased nitrosamine formation. Processed meats often contain higher levels of amines, which serve as substrates for nitrosamine synthesis in the presence of nitrites. This finding is consistent with studies showing that meat-rich products are more prone to nitrosamine contamination, emphasizing the need for reformulating fast food recipes to reduce meat content or incorporate alternative protein sources in Tehran's fast food market (Cintya et al., 2019; Yurchenko & Mölder, 2007).

#### 3.2.2 Regression Analysis of Influencing Factors

Multiple linear regression was performed to assess the impact of cooking temperature, sodium nitrite use, meat percentage, cooking method, and storage duration on total nitrosamine concentrations. The model was significant ( $F(5,114) = 22.47, p < 0.001, R^2 = 0.496$ ), explaining 49.6% of the variance. Cooking temperature ( $\beta = 0.412, p < 0.001$ ) and sodium nitrite use ( $\beta = 0.387, p = 0.002$ ) were the strongest predictors, followed by meat percentage ( $\beta = 0.245, p = 0.017$ ). Grilling, compared to frying and baking, significantly increased nitrosamine levels ( $\beta = 0.198, p = 0.034$ ). Storage duration had a weaker but significant effect ( $\beta = 0.167, p = 0.049$ ).

Storage duration showed a weaker but significant effect on nitrosamine levels ( $\beta = 0.167, p = 0.049$ ), suggesting that prolonged storage may facilitate nitrosamine formation through gradual chemical reactions. While the correlation was non-significant ( $r = 0.184, p = 0.067$ ), this trend aligns with research indicating that extended storage, particularly under suboptimal conditions, can increase nitrosamine concentrations in processed foods. In Tehran, where 30% of samples were stored for over 3 days, improving storage practices, such as maintaining lower temperatures, could further reduce nitrosamine levels (Moradi et al., 2021; Zhu et al., 2024).

#### 3.2.3 Correlation Analysis

Pearson correlation analysis revealed strong positive correlations between total nitrosamine concentrations and cooking temperature ( $r = 0.615, p < 0.001$ ) and sodium nitrite use ( $r = 0.492, p < 0.001$ ). Meat percentage showed a moderate

correlation ( $r = 0.321, p = 0.008$ ), while storage duration had a non-significant correlation ( $r = 0.184, p = 0.067$ ). These findings highlight the critical role of high cooking temperatures and nitrite additives in nitrosamine formation.

The health implications of these findings are significant, given the carcinogenic potential of nitrosamines, particularly NDMA, which is classified as a Group 2A carcinogen by the International Agency for Research on Cancer (IARC). The elevated nitrosamine levels in sausages and foods from local vendors suggest a potential public health risk, especially for frequent fast-food consumers in Tehran. These results align with global studies linking dietary nitrosamine exposure to increased risks of gastric and liver cancers, underscoring the urgency of addressing nitrosamine contamination in Tehran's fast-food industry (Park et al., 2015; Tricker & Preussmann, 1991).

The regression model's ability to explain 49.6% of the variance in nitrosamine concentrations ( $R^2 = 0.496$ ) indicates that cooking temperature, sodium nitrite use, and meat percentage are key drivers, but other unmeasured factors, such as pH or microbial activity, may also contribute. This partial explanatory power is consistent with the complexity of nitrosamine formation, which involves multiple chemical and environmental interactions. Future studies in Tehran should explore additional variables, such as the presence of natural inhibitors or the impact of specific meat processing techniques, to enhance understanding of nitrosamine formation (Ferysiuk & Wójciak, 2020; Seo et al., 2022).

These findings have practical implications for Tehran's fast-food industry, where regulatory oversight is still evolving. Interventions such as reducing sodium nitrite use, promoting low-temperature cooking methods, and enforcing standardized preparation practices could significantly lower nitrosamine levels. Additionally, incorporating natural antioxidants like ascorbic acid or  $\alpha$ -tocopherol, which have been shown to inhibit nitrosamine formation, could be a viable strategy for local vendors. Such measures would align with global efforts to enhance food safety and reduce dietary exposure to carcinogens (Abedi et al., 2023; Okafor & Nwogbo, 2005).

#### 4. Conclusion

This study revealed substantial variations in N-nitrosamine concentrations among fast foods in Tehran, with sausages showing the highest levels, followed by burgers and kebabs. Cooking temperature, sodium nitrite use, and meat percentage were identified as the strongest determinants, with grilling and local vendor practices contributing to elevated nitrosamine formation. These findings emphasize the need for regulatory restrictions on nitrite additives, adoption of lower-temperature cooking techniques, and standardized preparation practices across fast food outlets to minimize public health risks. While this study provides valuable insights, several limitations should be noted. The sample size, though representative, was limited to 120 fast food items from selected outlets, and potential confounding factors—such as pH variations, storage duration, or ingredient freshness—were not exhaustively controlled. Moreover, the cross-sectional design restricts causal inference. Future research should include longitudinal assessments, larger and more diverse samples, and experimental studies evaluating natural inhibitors and processing modifications. Overall, these findings contribute to a growing body of evidence linking dietary nitrosamines to carcinogenic risk and underscore the importance of safer food production and policy-driven interventions in Tehran's expanding fast-food market.

#### Statements and Declarations

##### Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the author.

##### Data availability

Data will be made available on request.

##### Conflicts of interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

##### Author contribution

H. Amanollahi: Investigation, Funding Acquisition, Conceptualization; Writing – Review & Editing.

##### AI Use Declaration

During the preparation of this manuscript, the authors used ChatGPT for language translation. All content has been carefully reviewed and revised by the authors, who take full responsibility for the final version of the manuscript.

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