

Global Food Safety Challenges and Their Public Health Consequences: A Systematic Review

**Ahmed Mohammed Ahmed¹, Israa Saad Mohammad Alshamrani², Amjad Thabet
Mohammed Alamri³, Sultan Mushabbab Omaysh Al Maythal⁴, Shahad Allan Baalqasim
Alshehri⁵, Dhafer Mohammed Ibn Saeed Al Muhmal⁶, Aishah Ahmad Awadh Alyahya⁷,
Majed Abdullah Bin Dhafer Alahmari⁸, Mohammed Ibrahim M Al Jaradh⁹, Saud Mesfer
Saud Alshahrani¹⁰**

¹Public Health Technician, Armed Forces Hospital Southern Region, Ministry of Defense Health
Services, Saudi Arabia

Email: Hm0o0di.20100@gmail.com

²Specialist - Food and Nutrition Services, Armed Forces Hospital Southern Region, Ministry of
Defense Health Services, Saudi Arabia

Email: es.1927.68@gmail.com

³Specialist - Food and Nutrition, Armed Forces Hospital Southern Region, Ministry of Defense
Health Services, Saudi Arabia

Email: Amjadtalamri@gmail.com

⁴Technician-Food Science and Technology (Food Safety), Armed Forces Hospital Southern
Region, Ministry of Defense Health Services, Saudi Arabia

Email: sultanmashbab@gmail.com

⁵Food and Nutrition Technologist, Armed Forces Hospital Southern Region, Ministry of Defense
Health Services, Saudi Arabia

Email: shahad17891@gmail.com

⁶Technician-Food Science and Technology (Food Safety), Armed Forces Hospital Southern
Region, Ministry of Defense Health Services, Saudi Arabia

Email: zmsm20@hotmail.com

⁷Specialist-Food and Nutrition, Armed Forces Hospital Southern Region, Ministry of Defense
Health Services, Saudi Arabia

Email: aishah92@hotmail.com

⁸Technician-Food Science and Technology (Food Safety), Armed Forces Hospital Southern
Region, Ministry of Defense Health Services, Saudi Arabia

Email: amjed1417m@gmail.com

⁹Public Health Technician, Armed Forces Hospital Southern Region, Ministry of Defense Health
Services, Saudi Arabia

Email: algradh2015@gmail.com

¹⁰Public Health Technician, Armed Forces Hospital Southern Region, Ministry of Defense
Health Services, Saudi Arabia

Email: Saudmsfir@gmail.com

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ABSTRACT

Background: Foodborne illness is the effect of consumption of contaminated food which can carry bacteria, viruses, parasites, chemical residues & toxins or physical hazards and can range from acute gastroenteritis to invasive infection organ damage neurological disease & cancer. Ninety-seven report 2018 WHO foodborne disease estimates for the first time in this special issue, which show that contaminated food is still an enormous global health burden, but with differential effects between populations and regions. This review addresses two related questions: how frequently are specific food-safety challenges identified in current global literature, and what are their direct and indirect pathways to public health?

Methods: A qualitative systematic review following applicable PRISMA 2020 principles (Page et al., 2021) was conducted and reported. Hazards were then classified into microbial and parasitic hazards, chemical hazards, antimicrobial resistance and food fraud, climate change and environmental effects (direct or indirect to human health). This is an opportunity to design risk-based regulation that targets the hazards that are most threatening to health, while providing smaller producers and vendors with a degree of leeway in achieving achievable standards. Future research should increase the evidence from under-represented regions, disentangle climate stress and chemical exposure impacts, enhance source attribution for AMR and assess interventions in real market scenarios.

Keywords: food safety; foodborne disease; public health; One Health; antimicrobial resistance; climate change

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1. Introduction

Food safety is a scientific discipline that describes the handling, preparation and storage of food in ways that prevent foodborne illness. Hence, it is inextricably linked to nutrition and food security, environmental health and public trust. Food can be contaminated by bacteria, viruses, parasites, chemical residues, toxins or physical hazards and cause a wide range from mild gastroenteritis to systemic disease, organ damage, neurological disease and cancer. The 2026 WHO foodborne-disease estimates show that food

contaminated continues to create a global health burden of unprecedented scale and with highly unequal population/area effect distributions (World Health Organization [WHO], 2026a, 2026b). WhyFood systems are evolving, and this is in turn increasingly shaping the problem. Globalization provides larger markets for food but opens new avenues for contamination or traceability failure through urbanization, longer supply chains, more intensive animal production, informal retail and climates hocks with higher burden of noncompliance during trade or in food waste reduction initiatives.

Hence, the evidence is a systems problem and not one of single hazard. What we call food safety failures begin upstream, ripple through processing and distribution, and are not visible until illness has set in. Global climate change has been another culprit, as earlier global analyses captured a significant burden attributed to infectious, parasitic and chemical hazards, telling different stories with more recent work emphasizing emerging routes of exposure as well as still present inequities (Have laaret al., 2015; Kirketal., 2015; WHO, 2026b). Two broad questions drive this review: which food-safety challenges are consistently highlighted in the contemporary global literature, and by which direct and indirect pathways do they impact public health? And it is not to statistically aggregate heterogeneous outcomes Instead, the review synthesises evidence across hazards, food-system drivers and health consequences to help to prioritise prevention.

2. Methods

2.1 Review design and search approach

A methodological qualitative systematic review of literature was performed following appropriate PRISMA 2020 guidelines for a broad, cross-disciplinary question (Page et al., 2021). Due to the definition of hazards, exposure pathways and health outcomes used in the relevant literature, the review protocol presented a thematic synthesis (not a meta-analysis). This included searches in PubMed and the institutional repositories of WHO, FAO and Codex Alimentarius. The last update of the search was performed in June of 2026. The search term was the combination of food safety, foodborne disease, food

contamination, public health, antimicrobial resistance, climate change, chemical hazards and food fraud with the word surveillance and One Health. Budgets associated with health losses were also calculated across the burden–outcome table as was outlined in previous work, and reference lists of larger burden papers and review articles we assessed to identify important sources.

2.2 Eligibility and synthesis

You worked out through 2010 English-language peer-reviewed studies and official institutional reports only as wider scope works that were super local, This kind of approach when talking about adjusted for global, regional or multi-country food safety challenges, or results of the mechanistic explanation to make them clear mechanism explaining clearly relevant, or at least some relevance no composite in a single local environment. The materials consisted of global burden estimates, reviews, policy guidance and drivers of food system studies. The papers excluded addressed only laboratory methods, single product tests or local outbreaks that could not be interpreted more widely. After assessing titles and abstracts as relevant, the full text of potentially eligible materials was assessed. The results gathered were categorized into microbial and parasitic dangers, chemical dangers, antimicrobial resistance and food fraud, climate change environmental change and direct and indirect impacts on public health. We used thematic synthesis to identify areas of convergence and uncertainty; no estimate of aggregated effect was calculated.

3. Results

3.1 A multi-hazard and multi-stage risk landscape

The literature reviews have repeatedly shown that foodborne hazards are associated with all steps of the farm to consumer chain. This includes agricultural water, animal health, feed, slaughter and crop harvesting, processing hygiene and temperature management, transport methods as well as commercial practices of the industry involved in food preparation at home and the adequacy of authorities to detect and respond to an incident. Microbial hazards are acute, because they immediately cause outbreaks, but the long read conclusion is that biological, chemical and governance risks are intertwined. The updated burden-of-disease assessment from the World Health Organization expands the range of risks to be considered and explicitly includes both infectious and chemical agents, while emphasizing food safety as part of a public health system rather than just an inspection task (WHO 2026b).

3.2 Microbial contamination and zoonotic transmission

The most common causes of illness are the bacteria salmonella, campylobacteria, pathogenic *Escherichia coli* and *Listeria*; norovirus and hepatitis A; food parasites. The contaminants can come from animal feces, unsafe water supplies, poor slaughter hygiene, inadequacy of cooking or a loss of temperature control in potential evils. Market ready foods and fresh products may be of particular concern, as they lack the final heating step. Enteric pathogens and parasites remain serious contributors to

Global Burden of Diseases (GBD) and disabilities, but the patterns vary markedly regionally (Khan et al. Kirk, 2015; Torgerson, 2015). Especially invaluable are data from low- and middle-income nations, since food often comes from informal or semi-traditional markets that are inexpensive and socially important, but where infrastructure and monitoring may be inconsistent. This notion of these arrangements should not be viewed as inherently unsafe and the target of an oxyformalist law. However, any effective programme must contend with practical constraints: access to water and sanitation, refrigeration, vendor training and market design. According to Grace (2015), with development, the demand for new, animal and perishable foods becomes dynamic and the food value chain lengthens. This underscores the value of implementing practical controls at critical points instead of depending only on final product testing.

3.3 Chemical hazards, toxins and chronic exposure

Chemical hazards are often much less evident than outbreaks, but can leave lasting harmful effects. Mycotoxins Pesticide residues Heavy metals Persistent environmental contaminants Natural toxins Migration of substances from food contact materials Aflatoxins and other related mycotoxins demonstrate the challenge of responding to chronic risk: crop stress and storage dictate fungal contamination, while health effects are latent, severe and difficult to attribute on an individual basis. Certain chemical toxins associated with foods are also linked to cancer, liver disease, impaired

development and other chronic outcomes (Gibb et al., 2015; Wild & Gong, 2010).

A food-safety lens is also needed for the new sustainability-oriented practices. Converging environmental goals with reuse of water, valorization of lost food, and use of recycled packaging materials or integrated farming methodologies may be challenged by microbiological, chemical, and antimicrobial-resistance hazards that are introduced in design without built-in controls vis-à-vis physical hazards. As such FAO (2024) argue that food safety should be evaluated as a co-equal performance outcome in circular agrifood systems. This is especially pertinent where polluted land, water scarcity & sub-optimal monitoring capacity, intersect.

3.4 Antimicrobial resistance, food fraud and supply-chain complexity

Antimicrobial resistance (AMR) is an indirect yet, a serious threat to food safety. Usage of antimicrobials in animals used for food and aquaculture may leave resistant bacteria to passages via food, direct animal contact, water, waste and the environment. Food is but one of several pathways; yet it is a pathway that ties food production directly into clinical risk. The WHO guidance which reiterates the need to limit the routine use of medicines important for human health in healthy food-producing animals and strengthen stewardship across production systems (WHO, 2017). Consequently, the optimal response is One Health surveillance connecting human, animal food and environmental information rather than just monitoring residues in final products.

Food fraud is another potential threat: deliberate business-to-business deception,

product tampering, misrepresentation, substitution and concealment of origin for pecuniary advantage comes into play creating potential health risks through exposures to harmful additives or hidden allergens. Furthermore, Spink and Moyer describe how food fraud, food safety and food defense concerns combine when intentional product modification occurs after normal control measures (Spink & Moyer 2011), while in complex supply chains poor motivation of inspectors due to low price negotiation power, possibly only weak enforcement and/or a lack of analysis at critical control points leads digital traceability to fall short. At the very least risk based hygiene management and supply chain transparency (Codex Alimentarius Commission, 2022; Jaffee et al., 2019).

3.5 Climate change and environmental pressures

Up to October 2023 (data dependent). Climate change may aggravate hazards that are already present and also introduce new hazards, such as through effects of temperature on pathogens and cold-chain integrity, drought on water supply, flooding on faecal and chemical contamination of water-borne disease, humidity on fungal growth and mycotoxin production. Extreme weather can simultaneously hinder inspection, transport, storage and, household preparation with contrasting effects of populations and hazards. Though not deterministic, these risks serve to highlight the need for climate-informed food-safety planning, particularly where infrastructure, electricity and laboratory capacity are low (Duchenne-Moutien & Neetoo, 2021; FAO, 2020).

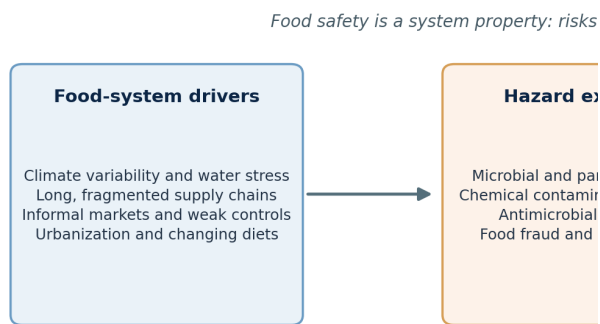


Figure 1. Food-system pathways from structural drivers to public-health consequences. Source: Author-created synthesis based on the reviewed literature.

3.6 Direct and indirect public-health consequences

Direct health impacts of hazards are dose-dependent, and vary from self-resolving diarrhoeal illness to haematological, hepatic, renal, neurodevelopmental, reproductive and even lethal effects depending on exposure route, host factors, treatment access and diagnostic delays. Vulnerable populations include infants and children, people who are pregnant or postpartum, elderly patients and patients with an immunocompromised status. At the same time, emphasis on diarrhoeal diseases, especially in young children, can overshadow other debilitating factors such as chronic parasitic infections, chemical toxicity and antimicrobial resistance (AMR) (Havelaar et al., 2015; WHO, 2026a).

Snack on your favourite flavour of dried fruit and nut mix, while fatties read newspaper article headlines about dietary shift, financial strain, access to healthcare – appearing as food safety issues playing out through food security & nutrition – lifestyle change is embodied in these larger

structures. For the providers meanwhile, the processors and vendors are also indirectly disadvantaged creating from financial losses to reputational harm to lawsuits that are subsequently diffused via the supply chain. From the health care perspective, with preventable escalating burden both on the side of workers and institutions as the lack of other options, social others result in diminished consumer confidence in food systems that negatively impact diet quality and health. Such issues pose the challenge that food safety is only a part of bigger development issues that transcend its technical nature, and improvements in food safety conversely intersects health, nutrition and equity. Grace, 2015; Jaffee et al., 2019).

4. Discussion

The main conclusion of this review is that food safety is a system-level property — a product of the interplay between hazards and processes through the various governance and regulatory domains throughout the supply chain as opposed to an inherent characteristic of any specific point in the supply chain. End-product surveillance and inspection are important, but they represent a downstream response that needs supporting upstream interventions (primary prevention), preparatory measures (secondary prevention) and responsive governance mechanisms. Food-safety management needs to be harmonised along the entire chain from farm-to-fork, including context-specific Hazard Analysis and Critical Control Point (HACCP)-style frameworks based on microbiological risk assessment; efficient laboratory and clinical networks; very rapid response and outbreak detection capacities; effective risk

communication in advance of outbreaks or effectively immediate once an outbreak occurs.

The analysis and management of transdisciplinary food-safety threats, especially multi-sectoral and interrelated ones, requires a One Health approach using integrated surveillance systems and risk assessments at the human-animal-environment interface coupled with adequate regulatory and enforcement efforts to promote the safety of foodstuffs, water resources, animals. Regulation must be risk-proportionate — taking account of the scale and extent of different hazards, as well as the capabilities of the market players who have a role to play in providing food systems: for instance dealing with lower capacity smallholders and informal traders. Unlike other groups that are formally licensed and certified, such as food industry workers or healthcare practitioners, these people may thrive better with improved hygiene infrastructure, access to clean water/sanitiser/hygienic cooling equipment, training capacity strengthening and participatory-based agriculture-specific instruction.

Future research is needed to generate more evidence on neglected and LMIC contexts, the combined effects of multiple climate change and chemical stressors, and methods for implementing source attribution of AMR and chemical hazards. Limitations of this review, however, include the nature of the topic we investigated, and its reliance on published literature which may introduce a bias towards high income countries studies. We were also strong in bringing together evidence across disciplines and geographies

as well as reporting on the outcomes following an intervention derived from a loosely consensual process rather than a pooled quantitative analysis.

5. Conclusion

Food safety issues are very complex which we see to go beyond microorganisms, we require a many sided and integrated approach. Chemical, AMR, food fraud, climate, and surveillance issues present a range of health issues from direct to indirect which we see play out in food systems and which contribute to short and long term health issues like morbidity and mortality. We do better to put in place inclusive, transparent and participatory governance which is tied to proper regulation, surveillance and enforcement also at the same time we support nutritionally sound, profitable and sustainable agri food systems.

Author Contributions (CRediT):

Ahmed Mohammed Ahmed 1: All authors contributed to the conceptualisation, methodology, investigation and formal analysis of the study.

Israa Saad Mohammad Alshamrani2: Conceptualization, Methodology, Investigation, Data curation, Validation and Writing – Review & Editing.

· Amjad Thabet Mohammed Alamri3: Investigation, Methodology, Data Curation, Formal analysis, Visualization and Writing — Review & Editing.

Contributor roles: Sultan Mushabbab Omaysh Al Maythal4: Investigation, Resources, Validation, Data Curation, Writing - Review & Editing.

· Shahad Allan Baalqasim Alshehri5 : Designed, performed and analysed the

experiment; prepared the draft of the manuscript and final revisions.

Dhafer Mohammed Ibn Saeed Al Muhmal6Institution: Investigation — Resources, Writing Review & Editing.

· Aishah Ahmad Awadh Alyahya7: Conceptualization, Investigation, Methodology, Validation, Writing - Review & Editing

Draft:· Majed Abdullah Bin Dhafer Alahmari8: Investigation, Data curation, Formal analysis, Validation, Writing – review & editing.

· Mohammed Ibrahim M Al Jaradh9: Investigation, Resources, Writing – Review & Editing

· Saud Mesfer Saud Alshahrani10: — Investigation, Formal analysis, Visualization, Validation, Writing - Review & Editing Author details Author 1.

All authors made substantial contributions to the conception and design of the work or acquisition, analysis, or interpretation of data; drafted the manuscript or critically revised it for important intellectual content; approved the final version published (usually in one go); and agree to be accountable for all aspects of the work in agreement with ICMJE criteria for authorship.

Corresponding Author:

Ahmed Mohammed Ahmed

Public Health Technician, Armed Forces Hospital Southern Region, Ministry of Defense Health Services, Saudi Arabia

E-mail: Hm0o0di.20100@gmail.com

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Corresponding Author Responsibilities:

A confirmation by the corresponding author that all authors meet the ICMJE authorship criteria The corresponding author (AW) was responsible for obtaining approval from all co-authors prior to submission, coordinating the manuscript submission and peer-review processes, responding to reviewers comments, ensuring compliance with institutional and journal policies and serves as the primary contact for all post-publication correspondence per the MODHS Publication Authorship Policy.

Approval by All Authors :

All authors made substantial contributions to this manuscript; they all have approved of the final version and given their consent for publication. All authors confirm that the manuscript is an accurate statement of their work and agree to be accountable for all aspects of the study regarding integrity and accuracy. Also, all authors declare that they meet the four authorship criteria described in 2013 by the International Committee of Medical Journal Editors (ICMJE) - namely substantial contributions to conception and design; or acquisition, analysis, or interpretation of data; participation in drafting the manuscript, or revising it critically for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work.

Accountability :

All authors take full responsibility and accountability for ensuring the integrity, accuracy, and validity of this work. Each author takes responsibility for all aspects of the study and is willing to ensure that questions related to the accuracy or integrity

of any part of the work are appropriately investigated, resolved, and documented in the literature. The authors collectively also accept responsibility for the integrity of the work as a whole and contributed equally to all aspects of this study including conception, design, execution, analysis, interpretation, reporting abstracted from ARA data to date and publication.

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Competing financial interests The authors declare no competing financial interests. All authors declare that the study was conducted in an objective and independent manner without any inappropriate external influence regarding its design, data collection, analysis, interpretation or reporting.

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Ethical Statement :

No ethical approval was required because this study is a systematic review of previously published literature and did not involve human participants, animals or identifiable personal data.

Data Availability :

Data supporting the findings of this study are available in the published articles mentioned within the manuscript. ADDITIONAL INFORMATION New datasets were not generated or analysed during the current study.

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