# Emerging foodborne risk: Impact of mycotoxins and bacteriotoxins on Food quality and public health

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## Abstract

Foodborne toxins such as mycotoxins and bacteriotoxins pose serious challenges to food safety, public health, and food trade. These toxic compounds, produced by fungi and bacteria respectively, contaminate food products at various stages of the food chain. They cause acute and chronic effects on human and animal health, including carcinogenic, neurotoxic, and immunosuppressive outcomes, demand stringent control measures. This article explores their sources, mechanisms of action, impact on food quality, detection methods and management strategies, with a focus on safeguarding public health and maintaining global food standards.

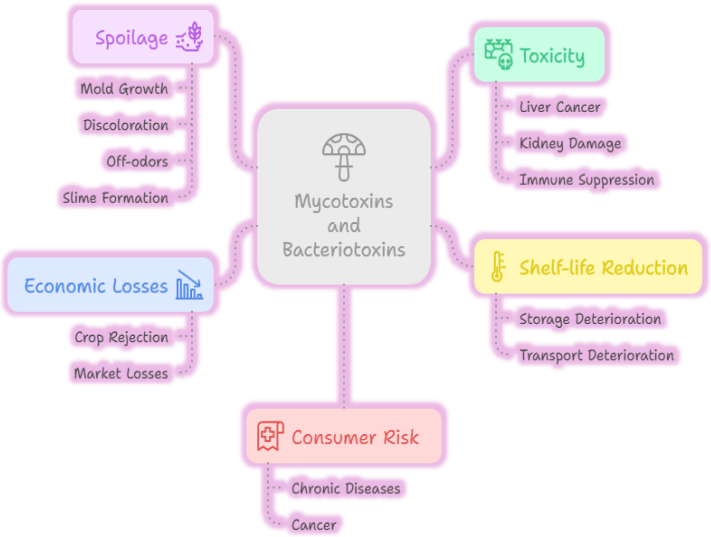
## Introduction

Food safety is a vital component of public health and agricultural sustainability. Among the many threats to food quality, toxins produced by microorganisms particularly fungi and bacteria are among the most serious. The public health effects range from acute symptoms (nausea, vomiting, diarrhea, neurotoxicity) to chronic conditions like liver and kidney disease, immunosuppression, reproductive harm, and cancer. Nearly 600 million people suffer from foodborne illnesses annually, many deaths are due to chemical toxins such as mycotoxins (WHO, food safety 2025). These toxins, mycotoxins and bacteriotoxins are low molecular weight, secondary metabolites that do not serve a primary biological function for the producing organism but are harmful to humans, animals, and even plants. These toxins can enter the food chain through pre-harvest infection of crops, post-harvest contamination during storage, or through improper food handling and processing. Contaminated foods not only compromise health but also lead to economic losses and food insecurity. Their presence can reduce food quality, spoil produce, and even render the food unsafe for consumption. In recent years, concerns over food-borne illnesses, export rejection due to toxin contamination and chronic health conditions linked to these toxins have intensified the need for effective monitoring and management strategies. This article comprehensively discusses their role in food contamination, impact on health, detection, and preventive strategies.

## Mycotoxins and Bacteriotoxins Impact on Food Quality

Mycotoxins and bacteriotoxins significantly affect food quality in various ways:

- Toxicity: These toxins can cause serious health problems like liver cancer, kidney damage, and immune suppression.
- Spoilage: Visible mold growth, discoloration, off-odors and slime formation make food unfit for consumption.
- Shelf-life Reduction: Contaminated produce deteriorates faster during storage and transport.
- Economic Losses: Crops contaminated with toxins are often rejected by buyers, both domestically and internationally.
- Consumer Risk: Long-term consumption of low levels of toxins can lead to chronic diseases like cancer.




## Mycotoxins

Mycotoxins are low molecular weight secondary metabolites produced by filamentous fungi like Aspergillus, Fusarium, Penicillium, Claviceps and Alternaria. These toxins are commonly found in cereals, nuts, spices, dried fruits and dairy products. They contaminate crops before and after harvest and have toxic, carcinogenic and immunosuppressive effects on humans and animals. Over 400 different mycotoxins have been identified, among them few are most significant.

**Major Mycotoxins and Their Characteristics**

| Mycotoxins | Fungi | Source | Effect |
|---|---|---|---|
| Aflatoxins (B1, B2, G1, G2) | *Aspergillus* spp. *A. parasiticus*, | Groundnut, maize, coconut, oilseeds | liver cancer, carcinogenicity, suppression of immune systems, hepatitis. |
| Fumonisins | *Fusarium* spp., *F. verticilloides* | Cereals, maize | Linked to esophageal cancer (McKeon *et al.*, 2024) |
| Ochratoxins | *Aspergillus*, *Penicillium* spp. | cereals, coffee, herbs, oilseeds, beef jerky, fruits and wine | Nephrotoxic, kidney and liver damage, loss of appetite, carcinogenic |
| Trichothecenes | *Fusarium* spp. & *Trichoderma, F. oxysporum* | wheat, maize | vomiting, diarrhea, immune suppression, hemorrhage, anemia, hypotension |
| Patulin | *Aspergillus terreus, Penicillium* sp. | Silage, wheat, apple, grapes, pears, cereals | Brain haemorrhage, neural disorders, skin lesions, skin cancer |
| Zearalenone | *Fusarium, F. graminearum* | Cereals, corn, silage, fodder | Carcinogenic, hormonal imbalance, estrogenic effect, reproductive problems |
| Ergot Alkaloids | *Claviceps* spp. | Found in rye | causes ergotism |

**Bacteriotoxins**

Toxic proteins or metabolites (exotoxins, endotoxins, metabolic byproducts) secreted by bacteria such as *Bacillus cereus, Clostridium botulinum* and spoilage microbes during food production or storage. These include exotoxins (secreted by bacteria) and endotoxins (released upon cell lysis). Many causes food poisoning or spoil food quality. These toxins are categorized based on their mode of action. Exotoxins: Secreted proteins affecting target cells. Endotoxins: Lipopolysaccharide components released upon bacterial lysis (Henderson, 2024).

**Major Bacteriotoxins and Their Impact**

| Bacteriotoxins | Bacteria | Source | Effect |
|---|---|---|---|
| Botulinum toxin | *Clostridium botulinum* | Found in canned foods | causes paralysis, lethal in nanogram doses |
| Enterotoxins | Staphylococcus, Bacillus | Found in dairy, rice | causes vomiting and diarrhea |
| Shiga toxin | *E. coli* | Found in undercooked meat | causes kidney failure, inhibit protein synthesis |
| Listeriolysin | *Listeria* | Found in cheese | causes meningitis (brain and spinal cord become inflamed) |
| Cholera toxin | *Vibrio cholerae* | | Cause profuse watery diarrhea by disrupting ion transport in intestines |

**Mode of Action: Mycotoxins**

Aflatoxins bind to DNA, that lead to mutations in tumor suppressor genes, particularly p53, contributing to carcinogenesis (Heliyon, 2024). Ochratoxin A interferes with mitochondrial respiration and protein synthesis, while trichothecenes disrupt ribosomal function, thereby halting cellular protein production.

**Mode of Action: Bacteriotoxins**

Botulinum toxin inhibits the release of acetylcholine at neuromuscular junctions, causing

paralysis. Shiga toxin inactivates ribosomal RNA, halting protein synthesis in intestinal endothelial cells and triggering inflammation and cell death. Superantigens like staphylococcal enterotoxin B bypass normal antigen processing pathways and directly stimulate a large number of T-cells, leading to a massive cytokine release or 'cytokine storm', which can be fatal.

**Public Health Implications**

The health consequences of consuming toxin-contaminated food range from mild to life-threatening:

**Acute effects:** Nausea, vomiting, diarrhea, abdominal cramps, neurological symptoms.

**Chronic effects:** Liver and kidney damage, immune suppression, reproductive toxicity, cancer.

**At-risk populations:** Infants, elderly, pregnant women, immunocompromised individuals.

According to WHO (2025), mycotoxins are linked to nearly 25,000–1,55,000 liver cancer deaths annually. Outbreaks of foodborne illness due to bacteriotoxins remain frequent, particularly in developing countries.

**Impact on Food Quality and Trade**

Toxin contamination severely impacts food quality, contaminated grains and food products may undergo physical degradation, such as discoloration, off-odors and textural changes, making them unappealing to consumers. Nutritionally, contaminated foods often exhibit reduced protein and vitamin content due to microbial degradation. Economically, mycotoxin contamination can lead to rejection of export shipments, loss of trade opportunities and destruction of entire harvests. The Food and Agriculture Organization (FAO & Codex, 2024-25) estimates that up to 25% of the world's food crops are affected annually by mycotoxin contamination, resulting in significant global losses.

**Detection and Monitoring Techniques**

Detection and monitoring of these toxins are crucial for ensuring food safety. High-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and liquid chromatography-tandem mass spectrometry (LC-MS/MS) are gold standard analytical techniques that offer high sensitivity and specificity. Enzyme-linked immunosorbent assays (ELISA) provide rapid, cost-effective and user-friendly detection methods, especially suitable for field testing (Heliyon, 2024). Molecular tools such as PCR are useful in identifying toxin-producing genes, while biosensors are gaining popularity due to their portability and real-time monitoring capability.

**Control and Prevention Strategies**

Prevention is better than detoxification, especially for mycotoxins which are heat-stable. Preventing contamination is far more effective and economical than detoxifying food after contamination has occurred. In the case of mycotoxins, control measures begin in the field. The use of resistant crop varieties, timely harvesting, biological control (e.g., competitive atoxigenic strains of Aspergillus) and good agricultural practices (GAPs) play a vital role in minimizing fungal infection. Post-harvest, proper drying, aerated storage, temperature and humidity control, mechanical cleaning can significantly reduce contamination risks. For bacteriotoxins, strict hygiene during food processing, adherence to Hazard Analysis and Critical Control Point (HACCP) protocols and thermal processing are essential preventive strategies. Inactivation techniques such as irradiation, chemical treatments (ammonization) and the use of microbial or enzymatic detoxifiers are under continuous research and application.

**Regulatory Framework Regulations:**

The Codex Alimentarius, jointly developed by FAO and WHO, provides international food standards. The Food Safety and Standards Authority of India (FSSAI) has specific maximum residue limits for aflatoxins, ochratoxin A and other mycotoxins in food commodities (EEA, 2025). Similarly, the European Union maintain strict regulations to ensure consumer protection. The European Union has some of the most stringent mycotoxin limits globally, prompting exporting countries to adopt better monitoring systems.

**Future Perspectives and Challenges**

- Use of nanotechnology for toxin detection and neutralization.
- CRISPR-based methods to create resistant crop varieties.
- Probiotics and dietary interventions to mitigate toxin effects.
- Climate change impact on toxin prevalence.

**Conclusion**

Mycotoxins and bacteriotoxins are significant threats to food quality, safety, public health and market value. Their management requires an integrated approach involving good agricultural practices, proper post-harvest handling, robust food processing standards, advanced detection methods and strict

regulatory compliance. Ensuring food safety is not only a technical and regulatory endeavor but also a public responsibility that demands awareness, cooperation, and action at every level of the food supply chain. Educate farmers and stakeholders is key to reducing contamination and ensuring safe food supply.

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