Biological hazards

A biological hazard is a living organism, or a substance produced by a living organism, that can cause illness when consumed through food. In the food industry, these hazards are a major concern because they are responsible for most foodborne disease outbreaks.

1. Prions

Prions are naturally occurring proteins found in animal cells. For reasons not yet fully understood, there exist **pathogenic prions**, which are simply misfolded forms of normal prions. These proteins exist in two structurally distinct forms:

- **Normal form (*PrPC*, cellular prion protein):** Found naturally in healthy organisms.
- **Abnormal form (*PrPSc*, scrapie prion protein):** Associated with transmissible spongiform encephalopathies, such as Bovine Spongiform Encephalopathy (BSE, "mad cow disease").

When abnormal prions accumulate in the brain, they trigger neuronal lysis, leading to neurological, locomotor, and behavioral symptoms. In humans, Creutzfeldt–Jakob disease (CJD) is a fatal condition with no cure, usually linked to consumption of high-risk bovine tissues, such as brain or spinal cord.

2. Viruses

Foodborne viruses are important biological hazards. Unlike bacteria, viruses cannot multiply in food because they require living host cells for replication. Nevertheless, they may survive in food and water for extended periods and remain infectious despite refrigeration or freezing. Many foodborne viruses are relatively resistant to environmental conditions, disinfection, and pH changes.

Contamination may occur through polluted water, infected food handlers, or inadequate hygiene practices at different stages of the food chain.

Norovirus

- **Family:** *Caliciviridae*

- **Clinical features:** Acute gastroenteritis characterized by vomiting and watery diarrhea within 24–48 hours post-infection, often accompanied by abdominal cramps, myalgia, and headache.
- **Transmission:** Direct (person-to-person) or indirect (ingestion of contaminated food or water).
- **Food contamination pathways:**
  - ✓ **At production:** Crops irrigated with contaminated water (leafy vegetables, berries) or shellfish from contaminated waters.

- ✓ **During handling:** Contamination occurs if an infected food handler does not follow hygiene measures.

Rotavirus

- **Family:** *Reoviridae*

- **Clinical significance:** Leading cause of viral diarrhea in infants and young children.
- **Transmission via food:** Drinking water, raw or insufficiently cooked animal and plant foods, prepared foods, and ingredients at any stage of the food chain can carry rotavirus. Contamination can occur throughout the food production and supply chain.

Hepatitis A Virus (HAV)

- **Family:** *Picornaviridae*
- **Genus:** *Hepatovirus*

- **Clinical features:** Hepatitis A causes liver disease, often with prolonged symptoms. Early signs include fever, malaise, loss of appetite, nausea, and abdominal pain, followed by jaundice.
- **Transmission:** Primarily via water or food contaminated with feces from infected individuals. Infected food handlers also represent a significant source of contamination.
- **Stability:** HAV is resistant to conventional food preservation methods, including refrigeration and freezing, making control in food systems challenging.

3. Parasites

Parasites also represent a significant biological hazard. Numerous parasites can be transmitted to humans through contaminated food and drinking water. The burden of foodborne parasitic diseases is often underestimated, mainly due to the lack of sufficiently developed and/or validated detection techniques for the various food matrices.

Parasites are unable to multiply in foods; however, they can be transmitted through the consumption of contaminated food or water. The spread of pathogenic parasites is most often associated with poor food hygiene practices or the use of contaminated water.

3.1. Routes of transmission

- The majority of foodborne parasitic infections affecting humans are zoonoses, involving vertebrate animals in their transmission cycle. These animals act as reservoirs for parasites and may serve as direct sources of contamination through the consumption of raw or undercooked meat or fish.
- The environment also constitutes an important source of food contamination. Parasites may survive for extended periods in soil or water, making plant-based foods another significant route of transmission. Vegetables and fruits can become contaminated through irrigation water, runoff from

livestock farms, the application of untreated manure, or the use of sewage sludge derived from wastewater.

3.2. Parasites commonly transmitted through food

Several parasites can be transmitted to humans via food consumption. The most relevant examples include:

Toxoplasma gondii

This protozoan parasite is mainly found in raw or undercooked lamb meat, as well as in fruits and vegetables contaminated with cat feces.

Toxoplasmosis caused by *T. gondii* may result in fever, muscle pain, headache, and marked fatigue. The infection is particularly dangerous for pregnant women, due to the risk of congenital toxoplasmosis, and for immunocompromised individuals.

***Fasciola hepatica* (Liver fluke)**

Fasciola hepatica is a flatworm that primarily infects livestock. Infected animals excrete parasite eggs into the environment, where, under humid conditions, the parasite undergoes further development involving freshwater snails of the *Lymnaea* genus.

Humans become infected by ingesting raw aquatic plants contaminated with encysted larvae (*metacercariae*). After ingestion, the larvae excyst, migrate, and develop into adult flukes that localize in the liver.

Acute infection may cause abdominal pain, hepatomegaly, vomiting, fever, urticaria, and weight loss. Chronic infection may be asymptomatic or lead to biliary complications such as gallstones, cholangitis, jaundice, cirrhosis, or pancreatitis.

Ectopic lesions may also occur in the intestinal wall, lungs, or other organs.

Echinococcus granulosus

Dogs and other wild carnivores act as definitive hosts, harboring the adult tapeworm in their gastrointestinal tract and excreting eggs through feces. These eggs contaminate soil, water, and food. Herbivorous animals (sheep, goats, cattle, camels, horses) and humans serve as intermediate hosts. Humans become infected by ingesting food or water contaminated with *E. granulosus* eggs originating from infected dogs.

The resulting disease, known as cystic echinococcosis (hydatid disease), leads to the development of one or more hydatid cysts, most commonly in the liver (causing jaundice, abdominal pain, and vomiting) and/or the lungs (leading to cough, chest pain, dyspnea, and hemoptysis).

Taenia saginata

Tapeworms are flatworms belonging to the class *Cestoda* and the family *Taeniidae*. They are cosmopolitan parasites of the human small intestine, where humans serve as the definitive host. Their life cycle includes an adult stage in humans and a larval stage (cysticercus) in specific intermediate hosts.

Taenia saginata causes taeniasis in humans following the consumption of raw or undercooked beef containing cysticerci.

Clinical manifestations typically include abdominal pain, nausea, diarrhea or constipation. Without appropriate treatment, the tapeworm may survive in the human intestine for several years.

Anisakis

Anisakis species are parasites primarily found in raw or undercooked fish and seafood, particularly marine fish such as salmon, herring, mackerel, and sardines.

They can cause **anisakiasis**, a potentially serious parasitic infection in humans, characterized by gastrointestinal symptoms including abdominal pain, nausea, vomiting, and diarrhea. Allergic reactions may also occur and can be severe in sensitized individuals.

3.3. Prevention of foodborne parasitic risks

Several measures can be implemented to control parasitic hazards of food origin:

- Strict compliance with food hygiene practices
- Adequate cooking of foods
- Proper freezing of foods when appropriate
- Ensuring the quality and freshness of food products

4. Fungi (Microscopic fungi)

Fungi are organisms that may be unicellular or multicellular. They are ubiquitous and can be found in almost all environments where a nutrient source, moisture, and oxygen are available. Among fungi, the following group is of particular importance in food safety:

4.1. Yeasts

Yeasts are microscopic, unicellular fungi with an ovoid or spherical shape. They are widely distributed in nature and are particularly associated with foods that are acidic, sweet, salty, or rich in fats.

Yeasts generally tolerate cold conditions better than heat. Most yeast species are destroyed at temperatures above approximately 77 °C. Below 10 °C, their growth is markedly slowed; however, yeast activity may still be observed at temperatures approaching 0 °C.

The majority of yeasts encountered in food products belong to the families *Saccharomycetaceae* and *Cryptococcaceae*. These families include the main yeast genera commonly found in food matrices. In general, yeasts are not pathogenic. However, their presence in foods is often undesirable due to the spoilage and deterioration they can cause.

4.2. Moulds

Moulds are multicellular filamentous fungi that can form extensive mycelial networks, which may reach considerable lengths.

They produce large numbers of highly volatile spores, allowing them to spread easily through air and water. Their growth mainly occurs during food storage stages.

Moulds may play a **beneficial role** in the food industry:

- Production of foods such as blue-veined cheeses (*Penicillium roqueforti*)
- Production of natural flavor compounds (white-rot fungi involved in wood degradation)

However, moulds can also act as **harmful microorganisms**, in several ways:

- **Food spoilage agents**

Moulds are common agents of food deterioration. In domestic and professional kitchens, *Cladosporium* species are frequently encountered. They grow optimally at ambient temperatures ranging from 18 to 28 °C and are often found in areas affected by condensation.

Nevertheless, *Cladosporium* can also grow at temperatures close to or below 0 °C and may therefore be detected on refrigerated foods.

- **Pathogenic agents**

Moulds may represent a genuine public health concern, as they can cause irritations and inflammatory reactions, allergies, asthma, pneumonia, toxic effects, and a wide range of fungal infections (mycoses).

- **Toxigenic agents**

Some moulds are capable of growing on food substrates and producing toxic secondary metabolites known as **mycotoxins**.

➢ **Definition of mycotoxins**

Mycotoxins are a diverse group of toxic secondary metabolites naturally produced by specific mould species growing on a wide range of food commodities. These low-molecular-weight compounds are chemically stable, allowing them to persist through food and feed processing. Mycotoxins can cause adverse health effects in humans and animals even at very low concentrations when exposure occurs through the diet. Some mycotoxins may also exhibit phytotoxic or antimicrobial activities.

The term *mycotoxin* was coined in 1960 following an outbreak in the United Kingdom in which 100,000 turkeys died after consuming feed contaminated with secondary metabolites produced by *Aspergillus flavus*. The term derives from *myco* ("fungus") and *toxin* ("poison"), and *mycotoxicosis* denotes the illness caused by these compounds.

➢ Origins of contamination

Two main types of contamination are recognized:

- **Primary contamination:** Occurs in the field while crops are still growing. It is predominantly associated with *Fusarium* species that infect cereals under favorable climatic conditions, particularly during warm and humid periods around flowering. Mycotoxins present at harvest cannot be removed by subsequent processing.

- **Secondary contamination:** Occurs after harvest, mainly during storage and transport. It is commonly associated with *Aspergillus* and *Penicillium* species. Inadequate storage conditions, including high moisture content, poor ventilation, and inappropriate temperatures, promote mould growth and mycotoxin production. Water activity (aw) is a key factor, as elevated levels facilitate both fungal development and toxin synthesis.

3. Major food-relevant mycotoxins

A wide range of raw materials intended for human or animal consumption may be contaminated by toxigenic moulds.

Mycotoxin	Producing Fungi	Commonly Contaminated Foods
Aflatoxins (B1, B2, G1, G2, M1)	*Aspergillus flavus*, *A. parasiticus*	Maize, peanuts, tree nuts (almonds, pistachios, walnuts), cottonseed, some spices; milk (aflatoxin M1)
Ochratoxin A (OTA)	*Aspergillus ochraceus*, *Penicillium verrucosum*	Cereals (wheat, barley, oats), coffee, dried fruits, wine, grape juice, spices
Fumonisins (B1)	*Fusarium verticillioides*, *F. proliferatum*	Maize and maize products, animal feed
Zearalenone (ZEA)	*Fusarium graminearum*, *F. culmorum*	Maize, wheat, barley, oats, rye, animal feed
Patulin	*Penicillium expansum*, some *Aspergillus* and *Byssochlamys* species	Apples, apple juice and cider, other damaged fruits

➢ **Types of mycotoxin-related intoxication**

- **Acute intoxication (mycotoxicosis):** Occurs after ingestion of highly contaminated food.
- **Chronic intoxication:** Mycotoxins are considered a major long-term health risk due to their cumulative toxic effects, which may include liver and kidney damage, immunosuppression, endocrine disruption, developmental disorders, and carcinogenicity.

Note: Mycotoxins are generally invisible, odorless, and tasteless, which prevents detection by sensory evaluation and increases the risk of chronic exposure.

➢ **Prevention and risk reduction**

As mycotoxins cannot be reliably eliminated once present in food, **prevention is the cornerstone** of risk management. Measures should be implemented throughout the food chain:

- **Field practices:** Cultivate resistant crop varieties, rotate crops, bury crop residues, control insect pests, and use targeted fungicides during flowering if necessary.
- **Harvest:** Collect crops at optimal maturity and under dry conditions.
- **Post-harvest handling:** Rapid drying to achieve safe moisture levels (e.g., <14% for maize, <7% for peanuts) is critical. Proper storage in clean, ventilated, dry silos prevents fungal growth and toxin production.
- **Physical sorting:** Remove visibly damaged or mouldy grains; avoid mixing contaminated and clean lots.
- **Storage conditions:** Keep foods dry, protected from insects, and at appropriate temperatures.
- **Consumer practices:** Buy fresh grains, nuts, and dried fruits; avoid prolonged storage; maintain a diverse diet to reduce exposure.

Efficient drying and maintaining low moisture levels are essential, as mycotoxin-producing moulds can penetrate deep into food and are not confined to surfaces.

Bacteria

These are major risks whose frequency makes them the leading cause of illnesses related to food consumption.

(See chapter on food bacteriology)