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Chapter

Food Contamination

Anna Abdolshahi and Behdad Shokrollahi Yancheshmeh

Abstract

This chapter discusses food contamination including mycotoxin contamination problems, biological, chemical, physical, and cross contamination. Food contamination challenges are generally referred to the presence of microorganisms or derived toxic substances such as mycotoxin in food that make them unsafe for human, animals, and crops. The mycotoxins can enter food throughout the food supply chain (from farm to fork). In terms of the safety of food, the presence of mycotoxin is a hazard threatening the consumer of contaminated food. Furthermore, it is necessary to know the nature, sources, distribution ways, and incidence of mycotoxin contamination in order to protect people and provide public health.

Keywords: contamination, biological, food, mycotoxin

1. Introduction

Food contamination refers to the ways that food has been depraved biologically, physically, or chemically. The contaminant could inter the food unintentionally pending agricultural production, environment, storage, transportation, sale and processing. In general, two sources of contamination are outside sources and formation in food that refer to primary and secondary contamination respectively [1]. The main criteria for contamination judgment could be potential risk and the effect it has on human health. In this regard, mycotoxins and other microbial toxins, toxic elements, radioactive isotopes, nitroso compound, polycyclic hydrocarbon aromatic, halogen containing organic compounds, pesticides residues, veterinary drug residues, etc., are major critical food contaminants [2].

Mycotoxins produced by filamentous microfungi that can cause many diseases in vertebrate animals via ingestion, absorbtion (through the skin) and inhalation routes. Mycotoxins have been found in a variety of food commodities due to the mycotoxin producer fungus are able to grow on a vast range of foods. The most pronounced contamination has been initiated from the agricultural fields during several harvesting stages including preharvest, harvest, and postharvest. Mycotoxin contaminations finally continue to the consumer table. Poor management in all stages not only can lead to rapid deterioration in nutritional value but also provides proper condition for fungal growth and also mycotoxin production. The most efficient way to control food contaminants is the implementation of Good Manufacturing Practices (GMPs) and Hazard Analysis and Critical Control Point (HACCP) that will help prevent hazards in life [3]. New approaches are based on identification of critical control point in production/processing of food that obtain

optimum condition for mycotoxin production. To minimize and control mycotoxins in food chain all environmental and climate factors must be assessed.

This chapter will review a summary of food contamination types including biological, chemical, physical and cross contamination. We will also discuss mycotoxin contamination problems regarding the main stages of food production chain.

2. Biological contamination

Biological contamination generally realizes as contamination of food or environment with microorganisms and their derivatives such as toxins. In this regard, bacteria, viruses, fungi, and parasites are potential contaminants. They are found in food, walls, water, air, clothes, etc. The biological contamination also can occur via macroscopic organisms including rodents and insects. The biological contaminants cause human diseases via three mechanisms including infection, intoxication and immunologic responses [4, 5].

2.1 Bacteria

Bacteria are small microorganisms that can grow in an ideal condition. They split and multiply so quickly [6]. Harmful bacteria, called pathogen, are recognized as hazards in safety of food. Therefore the spread and incidence of them must be controlled in food. The common sources for bacterial growth and further distribution are the air, human body, dust, pets and pests, row food (meat, milk, vegetable, etc.), soil, kitchen/factory instruments, food handlers and cloths/hands. The extrinsic factors that provide optimum conditions for bacteria to survive include food (especially protein), water (water activity), oxygen, temperature, and pH level [7]. The control of these factors can result in well preservation of food [8]. **Table 1** is illustrates major bacteria and their risks.

Major bacteria	Risk contamination
Clostridium botulinum	Intoxication, even death
Listeria monocytogenes	Infection
Salmonella spp. (*typhimurium*, *enteriditis*)	Infection
Enterohaemorrhagic *Escherichia coli*	Infection
Campylobacter jejuni	Infection
Yersinia enterocolitica	Infection
Listeria monocytogenes	Infection
Bacillus anthracis	Infection
Bacillus cereus	Intoxication
Staphylococcus aureus	Intoxication
Clostridium perfringens	Infection
Vibrio spp. (*vulnificus*, *parahaemolyticus*)	Infection
Brucella abortus, *B. suis*	Infection
Shigella spp. (*dysenteriae*)	Infection

Table 1.
The major bacteria and their risks.

2.2 Viruses

Viruses are very tiny organisms that can grow and survive only in a host cell. They are able to enter food and water due to poor hygienic conditions. Viruses can also be found in people who disrespect hygienic practices [9]. Viruses can only multiply and grow inside a living cell. They are very resistant to heat, drying, freezing, radiation, etc., and are also able to survive for a long time in food or environment. Viruses can enter food during processing, transportation through person to person contact [10]. The awareness about the importance of viruses as food contaminants would result in good hygiene practices done by consumers to minimize the transmission of viral illnesses [2]. **Table 2** shows the major viruses and their risk.

2.3 Parasites

Parasite including worms and protozoa can enter food or water. They can also infect people through these ways. They need ambient environment and proper hosts to survive. Contamination of food occurs by fecal due to poor personal hygiene of food handler, improper disposal of human feces, improper sewage treatment and utilization of untreated sewage for crop culturing [3, 11]. **Table 3** shows major Parasites and their risks.

Major viruses	Risk contamination
Hepatitis A virus	Fever, abdominal discomfort
Norwalk virus	Nausea, vomiting, diarrhea, abdominal pain (gastroenteritis), headache, low-grade fever
Rotavirus	Vomiting, watery diarrhea, fever, abdominal pain

Table 2.
The major viruses and their risk.

Major parasites	Risk contamination
Giardia lamblia	Diarrhea, abdominal cramps, fatigue, nausea, flatulence (intestinal gas), weightloss
Entamoeba histolytica	Dysentery (severe, bloody diarrhea)
Ascaris lumbricoides	Intestinal, lung infection
Diphyllobothrium latum	Attaches to intestinal wall
Cryptosporidia	Respiratory, gastrointestinal illness
Trichinella spiralis	Intestinal wall, enter the blood (to feed on it) and lymphatic system
Toxoplasma gondii	Neurological disorders, particularly schizophrenia, bipolar disorder
Taenia solium	Attaches to intestinal wall
Anisakis spp.	Anisakiasis

Table 3.
The major parasites and their risks.

3. Chemical contamination

Chemical contaminations of food are another human concern that involves numerous substances such as: agrochemicals, veterinary medicines residues, pesticides residues, environmental contaminants, heavy metals, persistent organic

pollutants, and natural toxins; which happen in food during chemical reactions at processing such as acrylamide, furan, and heterocyclic amines [12]. Other processes leading to the formation of contaminants include fermentation (e.g., ethyl carbamate, 3-monochloropropanediol) and disinfection (e.g., trihalomethanes). On the other hand, food contact materials are also kinds of chemical sources (e.g., formaldehyde, melamine, phthalates, and primary aromatic amines) that are able to leach into food. Some chemicals are naturally present in the environment, which includes ubiquitous pollutants such as dioxins and heavy metals may be increased by anthropogenic activity [13].

Some common sources of chemical contamination are:

- cleaning agents;
- unwashed fruits and vegetables;
- food containers made from non-safe polymers;
- pest control products; and
- chemicals used in equipment maintenance.

4. Physical contamination

Physical contamination refers to food that is contaminated by a foreign object during production process stages. Physical contaminants in food could come from external sources, (such as metal fragments), or internal sources (such as bone particles and pits). They can enter food accidentally during pre- and postharvesting due to poor agricultural practices and also in manufacturing, storage, transportation, or retail. Some physical contaminants are considered as food safety concerns such as glass. Sometimes a physical contaminated food can also be biologically contaminated such as the presence of a fingernail. **Table 4** provides a summary of common sources of physical contaminants in foods [12].

Sources	Contaminants
Field	Rocks/stones/sand, asphalt, metals/bullets, concrete particles, bones, wood fragments and thorns
Processing	Glass, ceramic/chards, metal fragments, staples, blades, clips, needles, keys, screws, magnet fragments, washers, bolts, screening, plastics, grease/lubricants, rubber, insulation/seal materials, nail polish, jewelry, coins, pieces of gloves, finger cots, bandages, cigarette butts, gum, bones, pits, fruit stones, nut and animal shells, medications/tablets/capsules, wood, pens, and pencils, rodents and insects
Storage and distribution	Metal, plastic, and wood fragments, insects and rodents

Table 4.
Common sources of physical contaminants in foods.

5. Cross contamination

Cross-contamination occurs in food due to the contact of a contaminated substance coming from another food via many different ways and various sources

including: Dirty clothes, Utensils, Coughing, sneezing or even touching the face and hair with food, Pests, Flies, cockroaches, mice and rats, Contacting Raw food, Garbage and waste materials [12].

6. Mycotoxin contamination problem

Mycotoxins are secondary metabolites that are produced by molds. Mycotoxins belong to biological contamination category. The majority of fungi can produce mycotoxins yet this potential is species specification [14]. Several adverse effects on humans, animals, and crops originate from mycotoxins. The contamination of food with mycotoxins is a worldwide concern. Incidence of mycotoxins depends on temperature and humidity of a region that is prone to the fungal growth. The exposure to mycotoxins could take place by ingestion and or dermal and inhalation ways without involving the producer fungi. In fact these fungal toxins are a kind of abiotic hazard originated from biotic ones [15]. The disease caused by mycotoxins is mycotoxicoses also resulted in different acute and chronic effects [16]. Generally, the contaminants could enter the food unintentionally by agricultural production, environment, storage, transportation, sale and processing. Mycotoxins are natural contaminants contribute the food chain. The mycotoxin may contaminate the food during several stages of food chain from the soil to the plate. As a matter of fact mycotoxin contamination can occur in food by infection of crops not only when directly consumed by human but also consumed as feed. However ingested mycotoxin could result in its accumulation in body organs that enter food/feed through agricultural products, meat, milk or eggs. Various foods such as cereals, nuts, spices, fruits and also their products have a potent to be contaminated with mycotoxins at high content. **Table 5** shows major mycotoxin and producer microorganism.

The foods could contaminate with fungal toxins from farm at post- and preharvest stages. The implementation of Good Agriculture Practice and Good Manufacturing Practice are efficient strategies in preventing of mycotoxin contamination [17]. However, every negligence in this field could provide proper condition for fungal growth and proliferation as well as *Aspergillus* growth and aflatoxin production in nuts [18]. Therefore, the condition of production, processing, drying, handling, storage, transportation, and marketing must be controlled. It should be considered that further mycotoxin increase is difficult if the food products are preserved or stored under preventive conditions for fungal growth and mycotoxin production especially regarding water activity and temperature. The awareness of all people either producer or consumer about the ways of mycotoxin entering the food, the main stages of food chain involving in mycotoxin contamination, the optimum condition for increase of mycotoxin contamination risk and critical control tips in this field are necessary to the prevention of mycotoxin contamination.

6.1 Agricultural production

Mycotoxins contamination of agricultural commodities can initiate from field and obtaining of conditions that conduct the fungal growth. The crops can be infected by molds at any line in the field. The production of mycotoxins due to mold growth is commonly associated with variation in weather conditions, plant stress, and humidity also inadequate feeding conditions [19]. In this regard there are three main stages that develop the mycotoxin contamination in food staff from agricultural aspect. These stages include:

Mycotoxin name	Producer microorganism
Aflatoxins	*A. flavus, A. parasiticus*, *Aspergillus bombycis*, *Aspergillus ochraceoroseus*, *Aspergillus nomius*, and *Aspergillus pseudotamari*
Ochratoxins (ochratoxin A)	*Aspergillus ochraceus*, *Aspergillus carbonarius*, *Aspergillus melleus*, *Aspergillus sclerotiorum*, *Aspergillus sulphureus*, *Pichia verrucossum*
Trichothecenes	*Fusarium* spp.
Zearalenone	*Fusarium*, *F. culmorum*, *F. graminearum*, *F. sporotrichioides*
Fumonisins	*Fusarium proliferatum*, *Fusarium verticillioides*
Tremorgenic toxins	*Penicillium*
Ergot alkaloids	*Claviceps*
Moniliformin	*Fusarium* species (mainly *F. proliferatum*)

Table 5.
The major mycotoxins and producer microorganism.

6.2 Preharvest

Mycotoxins can be produced in some natural food products due to the plants that are infected by mycotoxigenic species of molds group from farm. Preharvest practices include obtaining proper planting conditions such as soil ingredient, field qualification, crop rotation, irrigation, insect prevention, and antifungal treatment [20]. As a matter of fact the preharvest condition control is the first line of mycotoxin prevention therefore the implementation of good agricultural practices (GAP) is needful. Some important tips for preventing mycotoxins in preharvest stage are listed below:

- control of climate;
- control of fertilizer;
- control of insect, rodent, and birds;
- control of weed;
- biological control;
- control of planting date control;
- control of irrigation time;
- prevention of early splitting in nuts; and
- control of water activity and water stress.

6.3 Harvest

Mycotoxin production could intensify by any inconsideration in harvest level. The main strategies in harvesting are including utilization of efficient harvesting/collecting/transportation equipment, attention to harvesting time, control of moisture and full maturity of product, inhibition of crop damages during harvesting. The delayed harvest could influence the development of mycotoxin contamination.

The aflatoxin incidence in maize and nuts during delayed harvest were reported in many literatures. In the harvest stage it should be avoid contacting the harvested crop with the ground in order to prevent further contamination [21]. Some of major tips in order to prevention of mycotoxins in harvest stage are listed below:

- control of date of harvest;
- control of the last irrigation;
- control of storage condition;
- control of blending of harvested products;
- control of the contact with soil/ground;
- control of harvest equipment hygiene;
- control of damaging of grain; and
- sorting of defectives.

6.4 Postharvest

Mycotoxin contamination more likely could occur in the postharvest stage due to improperly handling. The high humidity during postharvest prone the dry seed to absorb moisture followed by increase in water activity that conductive to contamination. Also the combination of temperature with moisture results in the extent of mycotoxin contamination risk [21, 22]. At the postharvest stage, the observation of hygienic in all practices is necessary for safety guarantee of food products for example the use of clean transport vehicle free of any fungal growth. Consequently some tree nuts with high risk of mycotoxin contamination should be transferred to the processing plant as soon as possible after full maturity approximately within 6 h. The time of harvesting strictly have been recommended influence in mycotoxin production. Some crops when left in massive volume on the farm for a long time may present high level of mycotoxins. Some of important tips in postharvest stage in order to prevention of mycotoxins are listed below:

- rapid dehulling of crops (if it is needed);
- rapid drying of crops (if it is needed);
- separation of early splitting grain;
- control of moisture content of product;
- control of time and temperature during processing;
- control of temperature and relative humidity during storage;
- control of hygienic condition in all process;
- control of additional water content of crops after washing;

- control of packaging condition; and
- control of chemical preservatives.

6.5 Environment and climate

Environmental conditions could increase the susceptibility of crops to infection by molds also favor fungal growth consequently mycotoxin production. Wounding of crops like tree nuts by birds, mammals, insects, may eventuate significant fungal infections. On the other hand, some insects carry mycotoxin (like aflatoxin) producing fungi associated with mycotoxin contamination in crops. The environmental factors affecting this contamination such as variation of seasons, disposal close to farm regions and the rates of insect population are all influenced by climate [22, 23]. Climate condition may directly influence some agricultural product by developing structural changes in crop. In this regard the hull cracking in nuts such as pistachio so called "early split" favor the fungal growth species especially *Aspergillus* spp. The rainfall that occurs at harvesting time may accelerate the fungal growth of crops. However in some geographical regions the time of high raining and high relative humidity of weather should be considered at harvesting and storage time of crops.

6.6 Storage

To avoid further mycotoxin contamination the agricultural product should be dried or de hulled immediately. The moisture content of stored food products must be lower than critical moisture (15% moisture and preferably to <13%) content according to water activity need for fungal growth (generally less than 0.7 at 25°C). In this situation the competition of microorganism for water not only prevents further growth of fungi but also inhibits the mycotoxin production [24]. Therefore in storage stage the main preventive action must be to decrease the moisture content and also the temperature. In Storage, any migration of moisture, condensation of moisture, and leaks should not occur.

The production of aflatoxin is strongly influenced by water activity of food commodities at storage time. On the other hand the infected food commodities specially crops and also nuts are able to provide adequate inoculums for incidence of the fungus to sound ones during poor storage practices [25]. Storage management is essential in preventing fungal proliferation and mycotoxin formation in any harvested products.

6.7 Transportation

For many foods may face mycotoxin problems, the transportation conditions and time are great factors controlling the increase of mycotoxins content. During the transportation, some extrinsic factors like moisture content, relative humidity, temperature and hygienic control (cleanliness, insect control, etc.) could directly affect the safety of food. It is much emphasized that the transportation of foods under high humidity may result in mycotoxins increase. Transportation must be done in controlled conditions and any failure in this part may lead to decay of high volume of commodities.

6.8 Processing

Since mycotoxins are chemical and thermal resistant, they can be stable during heat, physical and chemical processing of food so, the prevention of mycotoxin

production in row food is a critical control point in food production chain. In terms of food safety it should be considered that most treatment of foods such as roasting, boiling, pasteurization, irradiation, freezing, drying, blanching, exhausting, boiling, curing, foaming, frying are not effective on elimination nor reduction of mycotoxin in contaminated food [3, 15, 19]. In this regard, it is better that all reduction or preventive strategies be performed before processing of food. On the other hand, these fungal toxins can also enter the human body via contaminated animal products (e.g., meat, egg, milk) due to feeding with mycotoxin contaminated feeds.

6.9 Prevention of mycotoxins

According to numerous reports about high occurrence of mycotoxins in foods/feeds they are a constant concern worldwide. Although the mycotoxin producer molds spores are present all over the environment and related toxins can be formed on crops during harvest stages, Storage, processing. Also the mold spores are present in soil and plant debris able to infect growing agriculture products simply and fast at any point of handling. However, mycotoxin contaminations cover most of economic costs including the practices of prevention and mitigation, the reduced volume of contaminated foods, animal feed contamination and reduction in animal performance or health effects. Nowadays management of mycotoxins involves all actions of prevention, regulation, control, monitoring, tracing, avoidance, decontamination, detoxification and animal treatments. Even at such total management there may be levels of mycotoxin in food products unavoidably as a continual concern [23].

The most efficient tool for mycotoxin problems is the prevention of mold growth in fields especially during postharvest practices. Additionally, environmental factors can immensely affect the production of mycotoxin by fungal species. In terms of predictive proceeding the predictive models have been developed as decision supporting systems to plan proper crop protection strategies in fields [25]. Innovative detection and diagnostic tools are also available to monitor the occurrence of mycotoxigenic fungi in fields and after harvest. When contamination is not prevented, several approaches can be employed to help remove mycotoxins from the contaminated commodities, including physical, chemical, and biological techniques. Detoxification processes should destroy or inactivate mycotoxins, by guaranteeing the nutritional value of food. Research is needed to study the fate of mycotoxins during decontamination, detoxification, and food processing. A holistic approach should be adopted to monitor, prevent, and control mycotoxigenic fungi and mycotoxins in food products.

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Conflict of interest

There is no conflict of interest.

Author details

Anna Abdolshahi* and Behdad Shokrollahi Yancheshmeh
Food Safety Research Center (Salt), Semnan University of Medical Sciences, Semnan, Iran

*Address all correspondence to: ana.abdoshahi@gmail.com

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