Food safety: Food contaminants and analysis procedures

Hanane GACEM, Djamel SADOUKI
Toxicology laboratory, Mohamed Seghir Nekkache Hospital, ALGERIA.

Summary

Food contamination is an important cause of morbidity and a significant burden to socioeconomic development worldwide; there are four main types of contaminants; biological, chemical, physical and radiological. All foods are at risk of becoming contaminated at any stage of production chain, it may happen in the orchard or field, during the harvest, after the harvest, during processing, during delivery, or in home. In many cases, it is necessary to select a suitable analysis procedure to identify each type of contaminants, for example detecting several physical contaminants by Hyperspectral imaging techniques and identifying some chemical substances by chromatography methods. In the recent years, nanotechnology have been increasingly implicated in the contaminants examination such as magnetic nanoparticles (MNP) to detect pathogenic organisms, as well as the application of nanosensors in different food contaminants analysis. Furthermore, food safety is a shared responsibility of government agencies, food producers, manufacturers, distributors, and retailers which must all protect the health of the consumer.

Key words: biological, physical, radiological, food contaminants, food chain, contaminants analysis.

1. Introduction

We can save lives by ensuring the safety of food. With every bite one eats, one is potentially exposed to illness from food contamination. Billions of people are at risk and millions fall ill every year; many die as a result of consuming unsafe food and despite the growing international awareness of foodborne diseases as a significant risk to health and socio-economic development, food safety remains marginalized. A considerable variety of contaminants are possible in food through the food chain that can render food as a potential health hazard. Food companies rely heavily on a wide range of methods to minimize contamination and to detect it when it occurs. Investigation, identification, and remediation of food contaminants are powerful means to proactively avoid safety threats to consumer health.

Food safety is a discipline describing handling, preparation, and storage of food in order to prevent food-induced illnesses, such as infections, intoxication, and allergies. Food safety refers to all hazards, whether chronic or acute, that may cause problems ranging from flu-like symptoms to serious illness or even death, to ensure food safety, rapid and accurate detection of contaminants agents is essential but food safety investigation and hazard prevention are complex and challenging. A strong, well-networked investigatory team is essential and should be equipped with a wide range of knowledge, skills, and experience to determine the precise characteristics and features of food contaminants.

2. Types of Food Contamination

There are four main sources of food contamination:
1. Physical
2. Chemical
3. Biological
4. Radiological (Wester, 2018)

2.1. Biological contaminants

If biological contaminants occur in food, they may affect human health, either by infection or intoxication by pathogens such as bacteria, viruses, parasites and prions. Many biological pathogens could be involved in the food contamination (table1). Foodborne infections are caused by swallowing live pathogens that grow within the body, usually in the intestinal tract; the major symptoms include fever, headache, nausea, vomiting, abdominal pain and diarrhea and other biological dysfunctions or even death (Chaves et al., 2017).

Table1. Biological pathogens and main implicated food

Pathogens		**Main implicated food**
Bacterial pathogens	Salmonella spp	Meats, poultry, vegetables, eggs
	Listeria monocytogenes	Milk, vegetables
	Escherichia coli	Vegetables
	Campylobacter jejuni	Chicken meats
	Bacillus cereus	Rice
	Staphylococcus aureus	Milk, dairy products
	Clostridium perfringens	Meats
	Vibrio cholerae	Water
	Shigella spp	Vegetables
virus	Norovirus	Fresh products
	Influenza virus H1N	Pork
	Hepatitis A virus	Fresh products
	Hepatitis E virus	Pork
	Influenza virus H5N1	Fowl
	Rotavirus	Water
parasites	Taenia solium, Echinococcus granulosus, Echinococcus multilocularis	Swine and raw and ready to eat products

	Toxoplasma gondii	Meat, giblet
	Cryptosporidium spp, Entamoeba histolytica	Raw and Ready to eat products
	Trichinella spiralis	Swine
	Opisthorchiidae	Fish
	Ascaris spp	Raw and Ready to eat products

Prions

Prions, infectious agents composed of protein, are unique in that they are associated with specific forms of neurodegenerative disease. Bovine spongiform encephalopathy (BSE, or "mad cow disease") is a prion disease in cattle, associated with the variant Creutzfeldt - Jakob disease (vCJD) in humans. Consuming bovine products containing specified risk material, e.g. brain tissue, is the most likely route of transmission of the prion agent to humans (WHO, 2017).

2.2 Chemical contaminants

2.2.1 Mycotoxins

Mycotoxins are naturally occurring toxins produced by certain fungi and can be found in food, they are classified as the most significant noninfectious, chronic dietary risk factor (Yu et al ., 2008).
Mycotoxins have already been detected in an extensive variety of foods, such as cereal grains, seasonings, coffee, nuts, and dried fruits. In addition, mycotoxins can be produced in any step of the food chain, in the field, during transportation, and in storage, because the fungus finds the optimal conditions for toxin production (temperature, relative humidity….).

2.2.1.1. Aflatoxins
Aflatoxins are produced by many strains of Aspergillus parasiticus, Aspergillus flavus, and Aspergillus nomius, which contaminate the agri-commodities.
Several types of aflatoxin (14 or more) occur in nature, but four – aflatoxins B1 , B2 , G1 and G2 are particularly dangerous to humans and animals, most human exposure comes from contaminated nuts, grains and their derived products. Additionally, aflatoxin M1 (AFM1), a metabolite of aflatoxin B1 (AFB1), can be found in milk in areas of high aflatoxin exposure (WHO & FOS, 2018), aflatoxins have teratogenic, and mutogenic, carcinogenic (liver cancer) effects.
2.2.1.2. Ochratoxin: Aspergillus and Penicillium are the fungi that produce ochratoxins which can lead to endemic nephropathy or kidney tumors.
2.2.1.3. Zearalenone and Fumonisin: they could be produced by Fusarium (Milicevic et al., 2015).

2.2.2. Phycotoxins

They are potent organic compounds produced by dinoflagellates, other flagellated phytoplankton, and cyanobacteria that inhabit marine, brackish, or freshwater bodies or soils. The effects of different phycotoxins range from skin irritation to respiratory paralysis (Milicevic et al., 2015).

2.2.3. Pesticides residues

Pesticides are substances or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest and weeds. There are more than 1000 pesticides used around the world to ensure food is not damaged or destroyed by pests (WHO, 2018). Each group of pesticides is designed to kill specific pests (WHO & CEH, 2018). Such as insecticides, herbicides, fungicides (table 2), rodenticides etc.

Table 2. List of the most widely used pesticides

➢ INSECTICIDES • Pyrethroids • Organophosphorus • Carbamates • Manganese	➢ FUNGICIDES • Thiocarbamates • Dithiocarbamates • Cupric salts • Tiabendazoles • Triazoles • Dicarboximides • Dinitrophenoles • Organotin compounds • Miscellaneous
➢ HERBICIDES • Bipyridyls • Chlorophenoxy • Glyphosate • Acetanilides • Triazines	

Pesticides come with a specific set of environmental concerns and health effects, even though for some pesticides, such as polychlorinated biphenyls (PCBs) and dichloro diphenyl trichloroethane (DDT), which have not been used for many years, they are very persistant and still have an impact on environment and health.

Their toxic effects are compound-specific and include several known mechanisms of action. Examples include, but are not limited to, the inhibition of acetylcholinesterases in the central and peripheral nervous system by the organophosphorus and carbamates insecticides, and the inhibition of protein and lipid synthesis by dinitroaniline and S-alkyl dialkylcarbamothiodithioate herbicides, respectively. Epidemiologic studies associated severe and irreversible neurodevelopmental deficits with mixed exposures to pesticides, especially pyrethroids, ethylene bisdithiocarbamates, organophosphates, carbamates, and chlorophenoxy herbicides (Bleotu et al., 2018).

2.2.4. Fertilizers

The worldwide use of chemical fertilizers has extremely increased and it is responsible for the "Green Revolution." Maximum food production can be achieved from the same surface area with use of mineral fertilizers such as Nitrogen (N), Phosphate (P2 O5), Potash (K2 O), they can be absorbed into the plants and enter the food chain via crops however, the largest health risk is when the chemicals flow into ground water, which is then extracted for drinking, nitrogen could generate nitrates, which decrease the quality of water and cause problems for human consumption. Other types of fertilizers, for example, phosphate and superphosphate, produce phosphoric acid and Phosphorite that rise the environmental contamination with heavy metals, such as arsenic, uranium, and cadmium. Additionally, excessive use of such fertilizers caused eutrophication problems to water bodies.

2.2.5. Antibiotics and other veterinary drugs Residues:

Antibiotics are commonly used in livestock, dairy, poultry, honey-processing industries due to their availability and cost effectiveness for Prophylactic, therapeutic, and metaphylactic purposes, the presence of antibiotics in food causes potential hazard on human health including allergic reactions, gastrointestinal disturbance, tissue damage, neurological disorders (Babapour et al., 2012).

Other veterinary drugs which are administered to live animals can remain as residues in animal tissues such as corticosteroids, beta-agonists and anabolic hormones. These drugs could affect the biological functions (in particular endocrine-disrupting).

2.2.6. Allergens:

Food industries with final products or one of their inputs containing some ingredient capable of stimulating an allergic response, such a, gelatin, lecithin and food additives. Moreover, one of the major concerns about the genetically modified plants is the possibility to cause allergic reactions (Bleotu et al., 2018).

2.2.7. Additives:

Food additives are substances added intentionally to foodstuffs to perform certain technological functions, for example to colour, to sweeten or to help preserve foods, safety of food additives is evaluated by relevant scientific data, including information on their chemical and biological properties but some food additives may cause problems for some people for instance:

Flavour enhancers (monosodium glutamate), **Food colourings** (tartrazine; cochineal; Yellow No. 5), **Preservatives** (benzoates; nitrates; sulphites), **Artificial sweetener (**aspartame) (Allergen Bureau, 2011).

2.2.8. Adulterants in food:

Food adulterant refers to foreign, unwanted and usually inferior quality substance in food, it may or not cause harm to health furthermore adulteration is not legally allowed process. In order to increase profit margins, food producers will sometimes intentionally add unlisted ingredients to food. Often, these ingredients are cheaper counterfeits of the real product, such as adding vegetable oils to extra-virgin olive oil, roasted corn to coffee, or cornstarch to onion powder or other spices. Some of these seemingly innocuous adulterants can be dangerous to those with food allergies. For example, peanut shells in cumin powder which is harmful for people who were allergic to peanuts. Occasionally, though, dangerous non-food products are added to cheapen food: adulteration of Chili powder by sudan I, Turmeric by Lead chromate, paprika with Lead oxide which is red chemical that mixed with paprika brighten its color and make it appear to be of a higher quality (FDA, 2016).

More recently, infant formula powder and milk powder was found to be contaminated with melamine, which adds nitrogen to foods and thereby increases the apparent protein content. Melamine forms crystals with cyanuric acid and caused kidney stones, renal failure and even may lead to death (Radford, 2018).

2.2.9. Heavy Metals

Heavy metals can be found naturally occurring in soil and can leach into water whereas their high level generate polluted groundwater, agricultural soils, crops and could lead to metal accumulation in fish (Bempah et al ., 2016). Metal contamination could result at various stages along the food production line (from raw contamination by industrial effluents or mining to packaging and cookware contact).

Heavy metals with potential health risks include: **Chrome** Cr, **cadmium** Cd, **lead** Pb, **arsenic** As, **mercury** Hg (especially in fish). Other metals could be mentioned such as nickel Ni, iron Fe, selinium Se. Their bioaccumulation capacity increases in the following sequence: As< Pb< Cr < Cd< Se< Hg. Heavy metals have a variety of toxic effects in humans and animals when consumed, even in low doses. Deafness, neurological, kidney damage and skin cancer are some of the critical effects caused by ingestion of these compounds (Zhao et al., 2014).

2.2.10. Emerging contaminants

The emerging contaminants can be defined as unregulated, discovered compounds in the environment on a global scale with potential concern on human health.

They are **heterogeneous group of compounds (**biotoxins, agrochemical, pharmaceutical and other industrial compounds).

During the processing of food There are multiple compounds could be formed as **acrylamides** (produced when carbohydrate-rich foods are exposed to high temperatures); **chloropropanols** (their formation in food is not fully elucidated but it is suggested that hydrochloric acid and residual lipids from the applied material are the precursors for these substances); **furans** (historically well-known but reemerging as new toxicological studies are undertaken and new exposure data and analytical methodology become available); **bisphenols** (are the core substrate to produce

bisphenol A diglycidyl ether, the main monomer used in the epoxy resin industry, which can migrate from the protective lining into food and can generate different derivatives during food storage); **phthalates** (mainly used as plasticizers) but because of their toxicity are included in the amended list of priority substances of the EU, since they are endocrine disruptors with potential neurotoxic and carcinogenic effects in humans. Other emerging contaminants can be mentioned for instance: Polychlorinated biphenyls (PCB), perfluoroalkyl substances, polybrominated diphenyl ethers, polycyclic aromatic hydrocarbons (PAH) (Kantiani et al., 2010).

2.3 Physical Hazards

Commonly known as "foreign materials," physical hazards may potentially cause harm to the final consumer. These contaminants are often found in the environment, food facilities, machinery, and employers' personal objects. Physical contaminants of food can occur at any stage of manufacture, if swallowed they can cause damage or hold potentially detrimental bacteria. The most common physical contaminants in food are; **Metals:** could be dropped from equipment such as bolt, screws, metal cans (shavings, lids) among others. **Plastic, ceramic, and glass pieces:** can be occurred from equipment (inspection belts, small wares, and buckets), facility (glass light fixtures, glass windows in doors, plastic strip curtains) or glass containers.

Other sources:

• Incomplete removal of pits or pit fragments, nut shells/bones.
• Poor design (for example, particle size of food inappropriate for consumer and therefore a choking hazard)
• Employee jewelry
• Stones, dirt, wood splinters
• Fingernails, hair.
• Insects, insect eggs, rodent droppings (FDA, 2016)

2.4. Radiological hazards

Background levels of radionuclides in foods vary and are dependent on several factors, including the type of food and the geographic region where the food has been produced. The natural radionuclides that could be in food include **Potassium-40** (^{40}K) the most common natural radioisotope, **radium-226** (^{226}Ra), **uranium 238** (^{238}U) and **thorium 232** (^{232}Th) and their associated progeny.

Some food manufacturing facilities may be located near areas with high concentrations of radionuclides, although many different kinds of radionuclides can be discharged into the environment following a major nuclear emergency, they can affect foods by either falling onto the surface of foods or through contaminated rainwater/snow, in addition to that, they could be accumulated in water, fish and seafood. A well-known example of radionuclides in food is **Iodine-131** which is distributed over a wide area, found in water and on crops and is rapidly transferred from contaminated feed into milk. However, iodine-131 has a relatively short half-live and will decay within a few weeks. Other radioisotopes could be of long-term concern if released such as **Radioactive cesium** (Cs-134, Cs-137) can also be detected early on, Cs-137 has a half life of about 30 years, (Meulenbelt et al, 2018), **Strontium-90** (Sr-90), **Strontium-89** (Sr-89) and **Plutonium (**Pu-238 / 239) can remain in the environment for a long time and could be also relatively rapidly transferred from feed to milk. They are important for uptake into the food chain and could be significant potential contributors to levels in foods. When exposed, the degree of harm to human health depends on the type and the dose of radionuclides. Long-term consumption of radiological contaminated foods can damage DNA and increase the risk of cancer.

3. Contamination along the food chain

The contamination of food is possible at any stage of food chain (figure 1); it may happen in the orchard or field, during the harvest, after the harvest, during processing, during delivery, or in home.

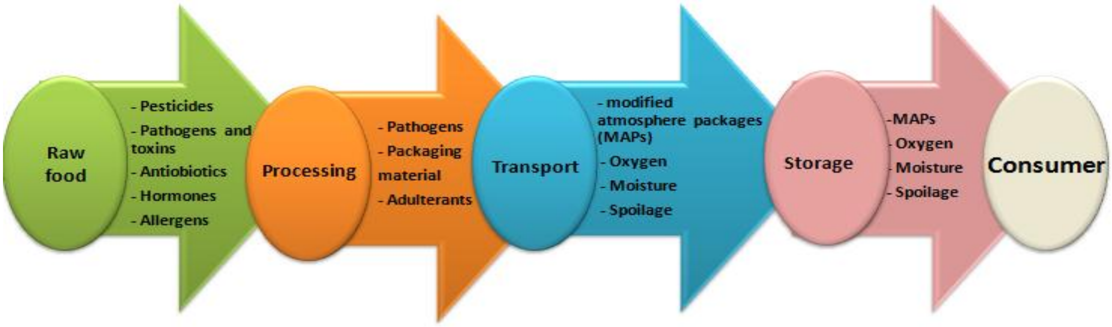

Figure1: contamination pathways

3.1. Raw Material contamination

Raw material could be contaminated, for example by high level heavy metals and pesticides residues in crops, antibiotics and hormones residues in meat and poultry, heavy metals (mercury) accumulation in fish and shellfish or even by microorganism pathogens and biotoxins.

3.2. Contamination during processing

3.2.1. Contamination due to heating steps

The use of high cooking temperatures in combination with external factors, can lead to the formation of toxic compounds (e.g., nitrosamines chloropropanols, PAHs) during heating, baking, roasting, grilling.

Frying is a dehydration process in which oil acts as the medium for heat transfer produce acrylamide, furanes or polycyclic aromatic heterocycles, 3-MCPD can be formed during the acid hydrolysis of wheat, nitrogen oxides in the drying air react with the amines in the food while heating. Nitrosodimethylamine is the most common

volatile nitrosamine in food. In dry-heat cooking, contaminants such as polycyclic heterocyclic amines (HCAs), and acrylamide can be formed. During microwave cooking many of packaging components (i.e. plasticizers, antioxidants, monomers, stabilizers, etc) can migrate from the package into the food (Nerín et al., 2016).
The contact with cookware (Teflon, aluminum, heavy metals may be released from these pots and pans) may also contaminate food (Radford, 2018).

3.2.2. Contamination during other food processing

During **fermentation** fungal toxins are also produced which cause hazardous effects on the health. Some products like ethyl carbamates are undesirable products and these are classified as process contaminants.
In addition, a nonalkylating nitroso substance could be formed in **pickles** which is linked with the tumor-advancing effect. Some other compounds like fumonisin and mycotoxins are also being identified in pickles causing kidney and liver tumors (Islami et al., 2009).

3.3. Food contamination during food handling

Food customers and handlers are one of the most important causes of insecure food. Sources of human contamination include hands, hair, wounds, breath, unshielded coughs, perspiration, and sneezes, and poor cleaning of the food surfaces and utensils. On the other hand, the contamination could be caused by cleaning processes; problems are related to residues coming from cleaning agents and disinfectants used in surfaces of food handling equipment and its transference to food.

3.4. Contamination caused by food packaging

The direct or indirect contact between the food and the packaging material can end up the transference of polymers or some substances additives (such as antioxidants, stabilizers, slipping agents or plasticizers, antioxidants, antifogging agents, antistatic agents, heat stabilizers, filling additives, pigments, and dyes among others) from the packaging to food, in a phenomenon called migration. When metallic cans are used for food packaging, corrosion phenomena in the metallic surface of the can could produce a migration of metallic ions to food, such as iron or tin (Nerín et al., 2016).

3.5. Contamination during food transport and storage

Food contamination can also take place during transportation. It can be caused from vehicle exhausts of petrol and diesel it's called cross contamination (by the vehicle used for food transportation).
During storage conditions (e.g., high temperature, sunlight exposure and humidity), food can be affected by Migration and sorption of external/internal substances

phenomena specially permanent gases such as O2, CO2 and water vapor permeation or by microbial contamination.

4. Food Safety throughout the Food Production Chain

Food safety can be achieved by a farm-to-fork approach, aiming to control hazards throughout the food production chain. Several measures should be applied on farming sites to reduce the chances of food contamination. For meat production, the following measures could be applied: diet manipulation, diet supplementation (use of probiotics, for example), vaccination, and use of good agricultural practices of the principles of HACCP, among others. For ensuring the safety of fresh produce, measures need to be applied: before planting, during production, at harvest and after harvest. All the measures are part of the code of practices for safe production of fresh fruits and vegetables and have as a basis the implementation of good agricultural practices (FAO, 2015), for example, for each pesticide are defined the series of cultivation where the use is authorized, the dose and a precise number of applications besides the delay between the last application and the harvest.

Despite the application of the aforementioned measures, key challenges for the safe production of foods at the farm include: understanding antimicrobial resistance of food-borne pathogens, the new pathogenic microorganisms and chemical substances in the food supply, appraising the impact of new technologies such as genetic engineering and nanotechnology on consumer safety, and assessment of changes in animal food production on the rise and extent of zoonosis. Avoiding the contamination of foods of animal and vegetable origin on the farm comprises an important achievement to ensure food safety.

For many food contaminants, it would be impossible to impose a zero limit on these substances. To protect human health Codex Alimentarius works to keep these levels as low as possible based on sound scientific evidence. Codex Alimentarius establishes maximum levels (MLs) of residues in food and feed.

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) support the adoption of the principles of the Hazard Analysis and Critical Control Point (HACCP) systems to improve food safety (FAO/WHO., 2006). During food processing, the application of good manufacturing practices/good hygiene practices together with HACCP comprises the best approach to the production of safe foods. The HACCP principles includes conducting hazard analysis (Principle 1), determination of critical control points (CCPs) (Principle 2), establishment of critical limits (Principle 3), monitoring procedures (Principle 4), corrective actions (Principle 5), procedures of verification (Principle 6) and establishment of record-keeping and documentation procedures (Principle 7) which provide a systematic approach to the control and identification of the hazards inherent in food processing in addition to the adoption of a more elaborate and better-integrated safety management system involving traceability throughout the entire food production chain (FAO/WHO., 2006). Food safety is also highly dependent upon distribution and retail practices. This is much more important when it comes to ready-to-eat foods. Thus, the food retail and distribution sector has also been stimulated to adopt measures to ensure food safety.

The involvement of public authorities in the elaboration of specific norms and standards for the food retail market is constantly increasing. Regulations involving HACCP include control of the cold chain in the retail food market as one of the essential factors, because this control is an efficient way of maintaining food safety.

At the consumer step, ensuring control of the top five risk factors of FBDs (improper holding temperatures, inadequate cooking, contaminated equipment, contaminated raw materials, and poor personnel hygiene) will be an important part of an effective program to ensure food safety (FDA, 2014).

The Importance of Regulatory system: For Food Safety, one essential component in the food production control system is the development of legislation. It must ensure that the food supply is protected as much as possible from hazards. A general principle of food legislation is that operators in the feed and food business have the primary responsibility for food safety and they should also keep traceability which means the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution. Official controls should be carried out regularly, on a risk basis and with appropriate frequency at all stages of the food chain on domestic produce, as well as on imports and exports. Moreover international food trade obligations should be established to guarantee the safety of the food placed on the market (WHO, 2009).

5. Food contaminants analysis

The safety of food requires control of contaminants at different stages of food chain (raw food, processing, transport, storage).

5.1. Detection of physical contaminants

Visual inspection, Multiscan Metal detection, X-ray and conventional machine vision inspection are widely used to detect physical contaminants on food production lines, moreover there is advanced techniques use Hyperspectral imaging which allows images to be colour coded according to the composition of the materials being imaged (Khan et al., 2018).

5.2. Analysis of Chemical Contaminants in Food

The main steps that are performed during a chemical analysis are the following:

1-Sampling which includes sample collection and storage.

2-Sample pretreatment by extraction, fractionation/clean-up, concentration, derivatisation.

3-Chemical analysis: several techniques could be used to analyze the contaminants (table 3) depending to their characteristics (organic/mineral, volatile or not …).
4-data handling (identification and quantification) (Ismail et al., 2017)

Table 3. Analysis for contaminants, residues, and compounds of concern in foods

Contaminants	Analysis technique
Pesticides	Multiresidue (MRMs): gas chromatography *GC* (mostly), high-performance liquid chromatography HPLC
	Single residue (SRMs): GC (mostly), HPLC, Immunoassay
Mycotoxins	HPLC (mostly) , GC, Capillary electrophoresis, Immunoassays (mostly)
Antibiotics	HPLC (mostly), GC, Immunoassays
Allergens	enzyme-linked immunosorbert assay ELISA, polymerase chain reaction PCR, Liquid chromatography–mass spectrometry LC-MS
Nitrites	Colorimetric methods, Ion-selective, Ion chromatography
Furans	Headspace GC-MS
Acrylamide	LC-MS/MS
Nitrosamines	GC-MS for volatile nitrosamines, LC-MS for nonvolatile nitrosamines
Heavy metals	Atomic absorption spectroscopy AAS, Inductively coupled plasma mass spectrometry (ICP-MS)

5.3. Detection of microorganisms in food

Viable microorganisms could be evaluated both in food and in the production environment. Many techniques are employed, for example, visual inspection could be used to detect Parasites, the culture and colony counting methods, direct microscopic techniques commonly used as standard approaches for detection of microorganisms (Bacteria and fungi). Furthermore, the polymerase chain reaction (PCR) method is also a broadly used method for the detection of pathogens in foods in particular, viruses (Vejarano et al., 2017).
Other alternatives include the use of biofunctional magnetic nanoparticles (BMNPs) combined with ATP bioluminescence, for example, for rapid detection of E. coli in pasteurized milk. Ultrasound technology is also used in food-quality characterization, which is based on the variation of flight time of the ultrasonic waves as a result of chemical changes induced by microbial contaminants. For quantitative analysis, we can use visible, near-infrared spectroscopies (Vejarano et al., 2017), Laser-induced breakdown spectroscopy (Multari et al., 2013). Moreover flow cytometry could be employed for rapid microbial analysis in food.

5.4. Analysis of Radionuclides in Foods

Several techniques could be used to analyze radionuclides in foods such as: Gamma Emitters Analysis by Gamma Spectroscopy for analysing Cs-134/137 (Máté et al., 2015), Ru-103 /106 and I-131, determination of Pu-238/239 by Alpha Spectroscopy and Analysis of Strontium-90 by Beta Counting.

5.5. Application of Nanosensors in the food Contaminants analysis

Nanobiosensor is a nanoscale device which consists at a biological material associated to transducers (optical, acoustical, electrochemical etc) which provides signal in presence of the analyte. their main advantages are high sensitivity, greatly reduced working volumes, and scope of miniaturization to provide efficient test . Furthermore they could be used in several applications such as: detection of leakage or spoilage in food (by detecting oxygen, moisture, carbon Dioxide and gaseous amine…), detection of pathogens and their products (biological pathogens, mycotoxins), the nanosensors could be also used to detect specific types of DNA. In addition to that, different variety of nanosensors are being developed for the detection of banned Dyes, adulterants (urea, melamine...), pesticides and veterinary drugs residues (Kulshreshtha et al., 2017).

For instance we can mention to **the Electronic Nose** is gas chemical nanosensors which were identified in the past few years as valuable candidate for food safety controls, e.g. early diagnosis of microbial contamination and it is able to detect microbial contamination in about 24 hours at very low inocula concentration. Furthermore there is a nanosensor similar to an electronic nose called the **“Electronic Tongue”** and works for nonvolatile analytes. E-tongues can be used to analyze the quality of foodstuffs by detecting their bitterness, sourness, or astringency (Ravichandran, 2010).

6. Conclusions

Food safety has evolved considerably in the past decades because of several factors related to the biology of microorganisms, processing conditions, social aspects, international trade, and consumer choices and lifestyles. From an analytical inspection-based approach that was deemed to assess whether a batch of product agreed with preestablished standards (focus on the final product), nowadays food safety should be anaged from farm to fork and considering risk analysis principles.

Managing food safety has become very challenging at the operational level, as food production and consumption currently involve a chain of events that must be performed adequately to ensure the food will not impair public health. The contemporary complexity of food safety can be explained by the fact that food is currently traded not only on a regional scale but also on an international scale. In addition to globalization of the food trade, other factors such as important changes in lifestyles, demographic compositions, adaptation of food-borne hazards, and changes in processing conditions and preservation methods help to explain how challenging food safety is nowadays.

Conflicts of interest
The authors declare no conflict of interest.

References

Allergen Bureau, Unexpected Allergens in Food, 2011. Available at: http://allergenbureau.net/wp-content/uploads/2013/12/Unexpected-Allergens-in-Food-18-April-2011.pdf

Babapour, A., Azami, L., Fartashmehr, J., 2012. Overview of antibiotic residues in beef and mutton in Ardebil, North West of Iran. *World Appl. Sci. J*. 19, 1417–1422.

Bempah, C.K., Ewusi, A., 2016. Heavy metals contamination and human health risk assessment around Obuasi gold mine in Ghana. *Environ. Monit. Assess*. 188- 261.

Bleotu, C., Chifiriuc, M. C., Socolov, R., Socolov, D. (2018). Introduction in Food Safety, Biosecurity and Hazard Control, Food Control and Biosecurity, 1-24.
Chaves, R.D., Alvarenga, V.O., Campagnollo, F.B., Rodriguez Caturla, M.Y., Oteiza, J.M., Sant'Ana, A.S. (2017). Food safety, *Current Developments in Biotechnology and Bioengineering*, 245-259.

FAO (Food and Agriculture Organization), Food Safety & Quality at FAO, 2015. Available from: http://www.fao.org/food/food-safety-quality/home-page/en/ (accessed 18.09.15).

FDA (Food and Drug Administration), Draft Guidance for Industry: Hazard Analysis and Risk-Based Preventive Controls for Human Food, 2016. Available at: http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ucm517412.htm.

FDA (Food and Drug Administration), FDA Retail Food Risk Factor Study: Background Information, 2014. Available from: http://www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/FoodborneIllnessRiskFactorReduction/ucm230313. htm (accessed 26.09.15).

Islami, F., Pourshams, A., Nasrollahzadeh, D., Kamangar, F., Fahimi, S., Shakeri, R., Abedi-Ardekani, B., Merat, S., Vahedi, H., Semnani, S. (2009). Tea drinking habits and oesophageal cancer in a high risk area in northern Iran: population based case-control study. *Br. Med. J.* 338, b929.

Ismail, B. P., Nielsen, S. S. (2017). Analysis of Food Contaminants, Residues, and Chemical Constituents of Concern, *Food Analysis* , 573-597.

Kantiani. L., Llorca. M., Sanchis, J., Farre, M., Barcelo, D. (2010). Emerging food contaminants: a review, *Anal. Bioanal. Chem*. 398, 2413–2427.

Khan. M. J., Khan. H. S., Yousaf. A., Khurshid. K., Abbas. A. (2018). Modern Trends in Hyperspectral Image Analysis: A Review. *IEEE Access.* 14118- 14129.

Kulshreshtha, N.M., Shrivastava, D., Bisen, P. S. (2017). Contaminant sensors: Nanotechnology-Based contaminant sensors, *Nanobiosensors* 573-628.

Máté.B., Sobiech-Matura.K., Altzitzoglou.T. (2015), Radionuclide monitoring in foodstuff: overview of the current implementation in the EU countries, *J Radioanal Nucl Chem*, 303(3), 2547–2552.

Meulenbelt, S. (2018) Assessing chemical, biological, radiological and nuclear threats to the food supply chain, Global Security: Health, Science and Policy, 3:1, 14-27.

Milicevic, D., Nesic, K., Jaksic, S. (2015). *Mycotoxin contamination of the food supply chain-health programme. Procedia Food Sci*. 5, 187–190.

Multari, R. A., Cremers, D. A., Dupre, Jo. A. M., Gustafson, J. E. (2013). Detection of Biological Contaminants on Foods and Food Surfaces Using Laser-Induced Breakdown Spectroscopy (LIBS), *Journal of Agricultural and Food Chemistry*, 8687-8694.

Nerín, c., Aznar, M., Carrizo, D. (2016). Food contamination during food process. *Trends in Food Science & Technology*, 63-68.

Radford, S. (2018). Sources of Contamination in Food. *Encyclopedia of Food Security and Sustainability*, volume 2, 518-522.

Ravichandran, R. (2010). Nanotechnology applications in food and food processing: innovative green approaches, opportunities and uncertainties for global market. *Int. J. Green Nanotechnol*. Phys. Chem. 1, 72–96.

Vejarano, R., Siche, R., Tesfaye, W. (2017). Evaluation of biological contaminants in foods by hyperspectral imaging: A review, *International Journal of Food Properties*, p 1264-1297.

Wester, P. A. (2018). Hazards, The Hazard Analysis, and The Food Safety Plan, *Analysis and Risk Based Preventative Controls*, 43-65.

WHO (World Health Organization), CEH Children's environmental health, Pesticides, 2018. Available at: https://www.who.int/ceh/capacity/Pesticides.pdf

WHO (World Health Organization), Food safety, 2017. Available at: https://www.who.int/news-room/fact-sheets/detail/food-safety

WHO (World Health Organization), FOS (Department of food safety and zoonoses), Aflatoxins, 2018. Available at: https://www.who.int/foodsafety/FSDigest_Aflatoxins_EN.pdf

WHO (World Health Organization), Pesticide residues in food, 2018. Available at: https://www.who.int/news-room/fact-sheets/detail/pesticide-residues-in-food

World Health Organization & Food and Agriculture Organization of the United Nations, FAO/WHO guidance to governments on the application of HACCP in small and less-developed food businesses, 2006 .Available from : http://www.fao.org/3/a-a0799e.pdf.

World Health Organization (WHO), INFOSAN Information Note No. 3/2009 Implementation of the WHO Global Strategy for Food Safety, 2009.

Yu, J., Payne, G.A., Campbell, B.C., Guo, B., Cleveland, T.E., Robens, J.F., Keller, N.P., Bennet, J.W., Nierman, W.C. (2008). Mycotoxin production and prevention of aflatoxin contamination in food and feed, in: Goldman, G.H., Osmani, S.A. (Eds.), *The Aspergilli: Genomics, Medical Aspects, Biotechnology, and Research Methods*, CRC Press. 457-472.

Zhao, Q., Wang, Y., Cao, Y., Chen, A., Ren, M., Ge, Y., Yu, Z., Wan, S., Hu, A., Bo, Q., Ruan, L., Chen, H., Qin, S., Chen, W., Hu, C., Tao, F., Xu, D., Xu, J., Wen, L., Li, L., 2014. Potential health risks of heavy metals in cultivated topsoil and grain, including correlations with human primary liver, lung and gastric cancer, in Anhui province, Eastern China. *Sci. Total Environ*, 470–471, 340-7.