Chapter 13
Emerging Risks Related to Food Technology

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Abstract Global food security and safety are threatened by a number of fast-occurring changes, even in the absence of natural disasters or terrorist attacks: overpopulation and urbanisation, environmental pollution, climate changes, intensive animal breeding, international trade and travel, emerging water- and food-borne diseases, antimicrobial-resistant bacteria, increasing food costs, complexity of food supply chains, malnutrition and risky food behaviour.

Food safety management tools, including food legislation, national and international standards, quality management systems, risk analysis, risk-based inspections and controls, monitoring and alert systems for food contaminants and food-borne diseases, quantitative microbial risk assessment, nutrition and toxicology studies, and elaborate food processing technologies have brought to consumers in developed countries a wide selection of safe foods.

Predictive and early warning and communication systems are being developed to increase the ability to "expect the unexpected" and take prevention measures before food hazards become real risks.

The production, processing, transportation, storage and/or distribution stages of modern food supply chains remain exposed to various types of biological or chemical contaminants, as evidenced by recent events or crises. The prion/BSE, dioxin, acrylamide, melamine, bisphenol A cases, and the numerous pathogen outbreaks illustrate this exposure. The melamine story and the international traffic of counterfeited foods and drinks show that profit-motivated fraud and adulteration are rising threats, opening potential paths for terrorist actions.

Recent food preservation, processing or packaging technologies and trends, in spite or because of their benefits (mild treatment, extended product shelf-life, "fresher" quality, RTE pre-cooked convenience) also bring safety risks at the consumer level: incomplete microbial inactivation, possible non respect of adequate storage conditions and expiration dates, undercooking, and generation of stress-resistant

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micro-organisms. Innovative technologies, such as the use of nanoparticules in foods or food contact materials, and the development of active, intelligent or sustainable food packaging entail uncertainties and safety concerns.

Natural disasters, droughts, floods, conflicts, and poverty often lead to emergency situations requiring large assistance operations with complex logistics and specific meals ready-to-eat or nutrient-supplemented foods. Containerised food processing units that could be deployed and quickly set to operate in production-disrupted areas are being developed by the World Food Programme. Other strategies against food insecurity include insurance policies for crop failures and renting of agricultural lands abroad.

Citizen perception of food safety risks and the EU consumers' "right to informed choice" explain why some technologies elicit rejection: ionising irradiation of foods, hormonal and antibiotic treatment of animals, the use of various "artificial" food additives, genetically modified crops and ingredients, cloned animals. Perceived benefits responding to consumers' needs (healthier, more nutritive, higher quality, more convenient, lower cost), "naturalness", respect of the environment and trusted information are the major factors influencing consumers' acceptance of innovative food technologies and products.

Novel foods and technologies are also subject to strict regulatory pre-market safety assessment and authorisation procedures. While necessary for protection against unexpected risks, some of these rules serve as barriers to innovation and trade, and fodder for strong political debates.

Keywords Food safety • Food hazard indicators • Quantitative risk assessment • Risk/benefit assessment • Rapid alert systems • RASFF • Predictive early warning systems • Globalisation • Climate changes • Intensive animal breeding • Water and soil pollution • Overpopulation • Drivers for emerging risks • Microbial pathogen outbreaks • Food supply chain • Counterfeited foods • Food bioterrorism • Fraud and adulterated foods • Food processing • Minimal processing • Under-processing • Over-processing • RTE foods • Food contaminants • Environmental chemicals • Acrylamide • Bisphenol A • Melamine • Dioxins • Mycotoxins • Hormonal disruptors • BSE • Antimicrobial-resistant micro-organisms • Stress-resistant micro-organisms • Food allergy • Obesity • Malnutrition • Radioactive contamination • Emerging technologies • Nanotechnologies • Active and intelligent packaging • Consumers' perception of risks • Novel food legislation

13.1 Introduction

Threats to food security and food safety have always existed, but modern technology and political governance have markedly improved this situation during the last decades, at least in many countries and for a large part of the world population. However, risks linked to chemical substances and biological agents often appear to be increasing, due to excessive use of industrial chemicals, pollution, overpopulation, climate changes, microbial adaptation, and resistance to antibiotics, etc. Such emerging challenges, whether natural or man-made, short- or long-term, are discussed in several recent books and reviews [1–15]. Similarly, while intentional food poisoning is not a new concept, food bioterrorism is a fairly recent one [16–26].

An emerging risk (to food safety) has been defined by EFSA, the European Food Safety Authority, as resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected increased significant exposure and/or susceptibility to a known hazard.

The present chapter first intends to review the main emerging risks to food safety (and security), their causes, their detection and alert systems, their potential prediction and prevention systems. A second part is devoted to emerging food safety risks related to food supply chains and to food processing, including novel food technologies.

13.2 Drivers for Emerging Risks in Food Safety and Security

13.2.1 Driver: Globalisation

Trade globalisation has many advantages, including year-round supply of fresh food at competitive prices, and wide commercial opportunities, with total annual exports of agricultural and food products exceeding US$ 1,000 billion worldwide. However, there are also several drawbacks:

- Growing global trade, migration and travel accelerate the spread of dangerous pathogens and contaminants in food;
- Complex international supply chains or networks with long transit distances and time increase exposure to contaminants and cross-contamination, and complicate food safety management;
- Such supply chains are vulnerable to agro/bio-terrorist attacks;
- One single contaminated food ingredient can lead to the recall of tons of food products in several countries, with high economic losses, possible import bans, damage to the tourist industry…

13.2.2 Driver: Potential for Climate Change

Although climate changes are highly complex and medium-long term phenomena with outcome also dependent on societal responses, some detrimental effects can already be identified:

- Water shortages cause quantity and quality problems with irrigation, process or ingredient water, plus possible shifts in production areas and cultured crops, and increased uses of agrochemicals;

- Some countries resort to purchases of agricultural lands abroad, while others take insurances against drought;
- Flooding may cause increased contamination of crops in the field, or increased exposure of food animals to zoonotic agents;
- Changes in temperatures and humidity are indeed expected to affect the distribution of plant and animal diseases, the production of mycotoxins, the spread of certain food pathogens, in addition to the current natural emergence of new pathogens and reservoirs of pathogens;
- Changes in the oceans and coastal environments may affect marine resources and seafood (e.g. increased algal toxins). Acidification of sea water could even hamper shell and bone formation;

13.2.3 Driver: Agriculture and Animal Breeding

While intensive agriculture and use of agro-chemicals will further impact on soil, water and energy supplies, with a high risk of contamination of water, food and feed crops by fertilisers and pesticides, the current trends in animal breeding could be even more devastating:

- Animal breeding [2] uses: ~75% of world agricultural areas (including pastures and feed crops), ~8% of the world water consumption, produces ~18% of total greenhouse gases, and has a low animal protein production yield (especially for beef);
- The huge current increase in intensive production (and consumption) of eggs, milk, and meat is threatening the livelihoods of a large number of small breeders;
- Large farms and herd size with enhanced contacts between animals, and their location near cities, increase the risk of zoonotic diseases;
- 3/4 of emerging human infectious diseases are due to animal pathogens (SARS, BSE, avian Flu, Q fever, parasitic diseases…);
- Antimicrobials given to animals as growth promoters and drugs contribute to induce antimicrobial-resistant micro-organisms.

13.2.4 Driver: Trends in Food Processing

In spite of their advantages in terms of sensorial and dietetic quality and convenience, the trends for mildly preserved foods (minimal heating, cold pasteurisation, "natural" preservatives, hurdle technology) and for lower salt or sugar contents increase the risk of surviving pathogenic micro-organisms, possibly stress-resistant, and of microbial spoilage of foods:

- Ready-to-eat products with long shelf-life enhance these risks;
- Manufacturers, including SMEs, must use appropriate product and process design, and HACCP;

- Consumers must treat such foods as perishable items requiring refrigeration and/or specific conditions of preparation;
- Refrigerated storage has created niches for psychrotrophs: *Listeria*, *Yersinia*… and noroviruses;
- Ready-to-cook products may be hazardous when undercooked (e.g. pizza in microwave ovens);
- Reduced packaging also increases microbial risks.

13.2.5 Driver: Overpopulation

Global population is predicted to rise from 6.6 billion people in 2008 to 7.4–7.8 billion in 2020, and the world food demand is being further enhanced by increasing affluent urban population in emerging countries (China, India). This should induce the following trends:

- Many countries with insufficient production capacity will become net food importers;
- Globally, due to climate changes and environmental constraints (water scarcity, risks of deforestation and loss of biodiversity…), the main sustainable solution will be to raise crop productivity on fertile land;
- Overfishing has already decreased seafood resources. Ocean drilling for oil will contribute to this decrease;
- Food prices should increase, and the global availability of certain foods decrease;
- Food choices will be affected, depending on country and income level, towards foods requiring less land and resources (e.g. less beef, more poultry and pork).

13.2.6 Driver: Demographics and Consumer Behaviour

Various current changes in consumers' demographics and concerns will impact on food safety:

- Life expectancy and the proportion of elderly people will increase, with a higher vulnerability to foodborne diseases;
- Changes in food composition motivated by consumer health (less salt, sugar or anti-microbial agents) may enhance microbial growth;
- Increased consumption of fresh, pre-packaged produce or other food eaten without heating has already caused pathogen outbreaks;
- Exotic food and ingredients, unusual animal species, small restaurants and catering, street vendors, may also enhance risks and errors;
- Organic food production and animal welfare may lead to reintroduction of pathogens with wildlife reservoirs (*Trichinella*, *Toxoplasma*) or increased prevalence (*Campylobacter*);

- Increased drug consumption due to overpopulation, urbanisation, aging, may result in drug contamination of surface and drinking waters;
- WHO estimated the number of overweight and obese persons, to increase to 2,300 and 700 million in 2015, with major health, social, and economic impacts.

13.2.7 Driver: Socio-economic Changes

Poverty, city overpopulation, economic crises, increasing food prices, compromise food security, but also food safety and quality:

- Cost is a major criterion for consumer's food selection, and manufacturers' margins of profits on food products are low, making it difficult for firms to target investment to food safety, possibly encouraging fraud;
- Food producers and processors may comply less with regulations (use sick animals, recycle foods, do not recall contaminated foods, neglect maintenance…);
- Low cost imports (e.g. from aquaculture and seafood, fresh produce) may originate from regions with poor sanitary practices or high pollution (oil spills, heavy metals, contaminated waters);
- Consumers may change consumption patterns: reduce the consumption of nutritious protein-rich animal foods, and of fresh vegetables and fruit; use foods past their expiration date;
- People with reduced immunity will be particularly vulnerable;
- Social and economic inequalities, conflicts, migrants, natural disasters, disrupt food security, requiring large emergency operations (with complex logistics) that do not solve the development problems. According to FAO, hunger affected 963 million persons in 2008, i.e. 17% of the world population (against 850 million persons in 2003–2005). In 2008, the World Food Programme has distributed 3.9 million tons of food to 102.1 million beneficiaries in 78 countries. Urgency operations concerned 25 million persons (15.7 in situations of natural disasters, 9.3 in conflict cases). Displaced persons and refugees assisted were 12.3 million. "Feeding America", USA largest domestic hunger relief organization, reports that in 2010 more than 37 million people, including 14 million children and nearly three million seniors, receive emergency food each year through the nation's network of food banks and the agencies they serve. The findings represent a 46% increase since 2006.

13.3 Search for Emerging Risks Through Recent Research Articles

A recent search for Food* and Risk* (in the titles, keywords and abstracts of articles) in the ScienceDirect Database at the beginning of 2010 revealed 534 relevant articles in 2009 and early 2010. The distribution of themes is shown below:

Main themes	Number of articles
Pathogenic micro-organisms and microbial food safety	72
Obesity and eating disorders	49
Exposure to environmental chemicals	45
Diet, lipids and cardiovascular diseases	41
Food allergy	29
Chemicals formed by food processing and storage	29
Diet and cancer	26
Food safety risk governance	20
Exposure to mycotoxins	18
Food-borne parasites and risks in animal-derived foods	17
Exposure to pesticides	15
Anti-oxidants	13
Functional foods	13
Shellfish poisoning	10
Perception of food safety risks and hygiene education	10
Under-nutrition and malnutrition	10

Other themes (with less than ten articles each) include (in decreasing order): salt, sodium and hypertension; vitamins; detrimental chemicals naturally present in foods; GMO and cloned animals; food irradiation; social determinants and impacts on food safety; viruses in foods; food environmental and sustainability challenges. Thirty-one articles concerned the effects of various diets.

13.4 Classical Food Safety Management Tools

The major food safety management tools are food legislation and standards, good agricultural practices (GAP), good hygiene practices (GHP), good manufacturing practices (GMP), HACCP [27], food quality and safety management standards (such as ISO 9001 and 22000) [28], and risk analysis [29, 30] (Fig. 13.1).

However, many newer food safety management tools have been implemented, such as the precautionary principle (in the EU legislation), independent food safety assessment agencies, third party certification, auto-controls and liability of food business operators, food traceability, national food inspections and controls (including at borders), risk-based controls, mandatory transparency and reporting of food incidents, mandatory collaboration with authorities, withdrawal and recall procedures for non-complying foods, prior notice of imported food shipments, registration of food facilities, food defence plans of individual food companies (against employees sabotage or terrorist attacks).

It is of interest to give here some details concerning recent trends in risk analysis, especially examples of **Quantitative risk assessment** (QRA).

One such example concerns the calculation of the probability of an allergic reaction (e.g. to peanut residues in a chocolate spread, when the same production line is used

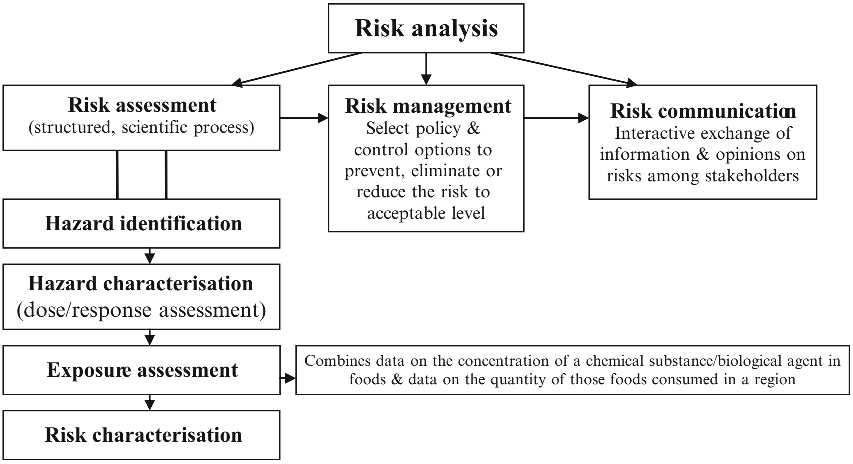

Fig. 13.1 Components of classical risk analysis. Risk is a function of probability and severity of the adverse impact of a hazard

for different products). Such a calculation would require the following estimations: (1) Proportion of the population that is allergic to the peanut allergen (perhaps 2% of adults and 4–5% of children, although there are indications that these proportions are increasing); (2) Likelihood and amount of consumption of a product (here the chocolate spread); (3) Likelihood of this food accidentally containing the allergen; (4) Concentration of allergen in this food, and minimal dose of allergen eliciting a reaction (~8 mg of whole peanut elicit a mild reaction in 10% of the at-risk population, as shown in a recent study in Nancy, France) [31]. A practical application would be to decide whether or not a label statement "may contain peanut" is necessary on the product (thus making it unavailable for allergic persons).

Another example deals with quantitative microbial risk assessment (QMRA): Modelling *Campylobacter* in the broiler meat production chain [32], so as (1) to assess the human illness incidence due to contaminated broiler meat; (2) to analyse the effects of control measures at different stages in the production chain.

The continuous introduction of *Campylobacter* in flocks implies that monitoring for the bacteria at the farm up to one week before slaughter may result in flocks falsely tested negative: once *Campylobacter* is established at the farm, the within-flock prevalence increases markedly within a week. Thus, at the point of slaughter, prevalence is most likely to be either very low (<5%) or very high (>95%).

All models show: (1.) a negligible effect of separate slaughter and processing of positive and negative flocks, (2.) the most effective intervention measures aim at reducing the *Campylobacter* concentration, rather than reducing the prevalence, (3.) during consumer handling, cross-contamination is more relevant than undercooking.

Another recent study from the Food Safety Authority Ireland showed that *Campylobacter* was often present on the external surface of poultry bags, and recommended the use of leak-proof packaging.

It can be noted that around 80% of chicken carcasses on the European market were found to be contaminated with *Campylobacter*, according to a region-wide baseline survey by EFSA in 2008. Prevalence of *Campylobacter* varied markedly among member states.

A third example, this time of semi-quantitative risk assessment, concerns setting priorities in monitoring antimicrobial resistance in meat and meat products [33], starting from prevalence data on antibiotic-resistant bacteria in populations of chicken, pigs, cattle, and calves.

The model estimated scores for the prevalence of antimicrobial-resistant *Campylobacter* spp., *Enterococcus* spp. and *Escherichia coli* in fresh meat, frozen meat, dried raw meat products and heat-treated meat products. The combination of the prevalence at retail, the human health impact and the amount of meat or product consumed gave the relative proportion of total risk attributed to each category of product: chicken (mostly fresh and frozen meat) contributed 6.7% of overall risk. Pork (mostly fresh meat and dried raw meat products): 4.0%. Beef and veal only 0.4% and 0.1%, respectively.

Another important and recent concept in risk analysis is that of **Risk/benefit health assessment of food.** This concept can be applied for example when the same food contains substances with adverse effects and substances with beneficial effects. The balance can shift towards benefit or risk depending on concentrations, intakes, subgroup of population. The calculation is complex [34]. As an example, one can mention the potential benefit of eating fish and seafood in adults versus the potential risk of neurotoxicity in infants and children due to contamination with methyl-mercury and/or persistent organic pollutants, from oil spills or other pollution sources (the question of sustainable fish stocks, and the possible presence of antibiotics in aquaculture products, could also be considered).

Other examples include human milk; vegetables (fibres and anti-oxidants versus anti-nutrients, pesticides, mycotoxins); nitrates-nitrites (NO homeostasis and antimicrobial effect versus nitrosamines); food fortification with vitamins and minerals (minimum recommended intakes versus risks of excess intakes).

13.5 Identification of Food Safety Risks: Rapid Alert Systems

Both HACCP and risk analysis focus on known hazards and use data related to specific hazard(s) and to given food chain(s). To make such data available to risk managers as soon as possible, public authorities have created rapid systems for identification and notification of food hazards and health risks (data should preferably be in standardised format).

The main rapid surveillance and alert systems are: (1) WHO International Food Safety Authorities Network (INFOSAN), (2) EU Rapid Alert System for Food & Feed (RASFF), (3) US Foodborne Diseases Active Surveillance Network (FoodNet) (and US PulseNet for DNA fingerprinting). These reactive systems identify issues mostly after their occurrence, and operate as communication platforms. Additional databases and networks from CDC (Center for Disease Control and Prevention, Atlanta, Georgia), ECDC (European Centre for Disease Prevention and Control, Stockholm), European Union, WHO (World Health Organization, Geneva), FAO (Food and Agriculture Organization, Rome), OIE (World Organization for Animal Health, Paris) are focused on hazards and/or on endpoints.

Concerning the World Health Organisation system (www.who.int), national contact points for emergencies both disseminate information from INFOSAN, and report to INFOSAN on hazards (contaminants in food and feed imports and exports) or endpoints (food poisonings). A Global Outbreak Alert & Response Network (GOARN) operates within INFOSAN.

The EU Rapid Alert System for Food and Feed (RASFF, http://ec.europa.eu/rasff) lists food safety hazards (presence of illegal substances or unacceptable concentrations of chemicals or pathogenic organisms) on its database, on a public weekly (and annual) basis:

https://webgate.ec.europa.eu/rasff-window/portal/index.cfm?event=notificationsList

Table 13.1 shows a list of alert notifications issued during a few days in June/July 2009.

Each Member State identifies hazards, in country or at EU borders, and must report them rapidly to RASFF, including measures taken regarding food safety (e.g. food recalls, rejection of imports not complying with food safety standards). RASSF sorts out the information and further transmits it to all Member States. Thus, RASFF acts as a notification, communication and alert platform.

In 2008, there were 1710 market notifications (alert or information), plus 1,389 border rejections (RASFF annual report 2008). An alert notification means that a decision (product withdrawal or recall…) must be taken by one or several Member States to avoid risks for consumers, while an information notification means that measures have already been taken to prevent the risks. Most notifications (in 2008) originated from official controls on the market, but some were due to a company's own checks or to consumer complaints. The distribution of alert notifications in 2008 by identified risks was as follows: (potentially) pathogenic microorganisms (24%), heavy metals (12%), mycotoxins (10%), migration (of chemicals from food contact materials) (9%), industrial contaminants (9%), allergens (6%), not determined (5%), pesticide residues (4%), residues of veterinary medicinal products (4%), foreign bodies (4%), food additives (3%), food composition (3%), GMO/novel food (2%), packaging defective/incorrect (2%), parasitic infestation (1%), microbiological contamination (1%), biotoxins (1%), biocontaminants (1%), bad or insufficient controls (1%). In 2008, there were 26 cases/notifications of food poisoning from bacteria, viruses, histamine, allergens, cocaine…, including 2 large outbreaks: (1) shellfish poisoning by precooked frozen mussels from Ireland (agent: heat-resistant azaspiracid algal toxin), (2) *Salmonella* in meat products from cooked beef steak strips from Ireland, later used by food processors (e.g. sandwich filling). Shellfish poisoning appears to be on the increase: there were outbreaks in 5 countries in March 2010, due to Norovirus in live oysters.

Kleter et al. [35] have analysed RASFF data for trends in food safety hazards during the period 2003–2007. As example of their findings, they listed the following

Table 13.1 Alert notifications

Date	Notified by	Ref.	Reason for notifying	Notification basis	Status
30/06/2009	Italy	2009.0831	Mercury (2.63 mg/kg – ppm) in smoked swordfish (Xiphias gladius) from Denmark	Official control on the market	Distribution on the market (possible)/ product (to be) seized
30/06/2009	Hungary	2009.0833	Deoxynivalenol (DON) (1464; 1613; 1398; 819; 2002; 1507; 2150; 1302 μg/kg – ppb) in durum groats from Hungary	Company's own check	Distribution on the market (possible)/ product (to be) withdrawn from the market
02/07/2009	Poland	2009.0845	Histamine (1433.5; 959.7 mg/kg – ppm) in frozen tuna steak from Spain	Official control on the market	Distribution on the market (possible)/product (to be) withdrawn from the market
02/07/2009	Germany	2009.0847	Aflatoxins (B1 = 11.3; Tot. = 11.3 μg/kg - ppb) in groundnut kernels from Sudan, via the Netherlands	Company's own check	Distribution on the market (possible)/product (to be) returned to dispatcher
02/07/2009	France	2009.0848	Diarrhoeic Shellfish Poisoning (DSP) toxins (positive) in frozen cooked mussels without shell from Germany	Official control on the market	Distribution on the market (possible)
03/07/2009	France	2009.0849	Escherichia coli O157:H7 in frozen beef from Germany, via the Netherlands	Company's own check	Distribution on the market (possible)/product (to be) returned to dispatcher
03/07/2009	Austria	2009.0850	Undeclared milk ingredient (casein: 1300 mg/kg – ppm) in dark chocolate bars from Italy	Official control on the market	Distribution on the market (possible)/product (to be) withdrawn from the market
03/07/2009	Austria	2009.0851	Undeclared milk ingredient (casein: 810 mg/kg – ppm) in soybeans, roasted in the Netherlands, coated with dark chocolate manufactured in Belgium and packaged in Austria	Official control on the market	Distribution on the market (possible)/product (to be) withdrawn from the market
03/07/2009	Finland	2009.0854	Norovirus (genogroup 2) in frozen raspberries from Poland	Food poisoning	Distribution on the market (possible)/product (to be) withdrawn from the market
03/07/2009	The Slovak Republic	2009.0858	Undeclared nuts (134.10 mg/kg – ppm) in wafers with cocoa cream from Bulgaria	Official control on the market	Distribution on the market (possible)/product (to be) relabelled
03/07/2009	The Nether lands	2009.0860	Benzo(a)pyrene (16.6 μg/kg – ppb) in food supplement from Germany	Official control on the market	Distribution on the market (possible)/product (to be) withdrawn from the market

chemical hazards (additives, contact materials, contaminants…): (1) Antibiotics: nitrofurans, chloramphenicol in seafoods, (2) Allergens: histamine, sulphites in seafoods, (3) Azo dyes: illegal Para Red and Sudan 4 in oils, condiments and spices, (4) Food contact substances: ITX ink component from packaging, in drinks, (5) Organic substances: formaldehyde, aromatic primary amines, diaminophenyl-methane from Chinese plastic utensils, (6) Heavy metals: Cr, Ni, Pb, Cd from Chinese and handcraft pottery, (7) Heavy metals: Hg and Cd in seafoods, (8) Pesticides: illegal isophenphos-methyl, isocarbophos in Spanish peppers; legal pesticides (dimethoate…) above MRL in fruits and vegetables.

RASFF data for 2003–2008 were screened by Nepusz et al. [36] using algorithms to analyse levels of food alert reports against a country, and reporting countries for each alert. This monitoring tool named China, Iran, Turkey, USA, and Spain as the top five offenders in food contamination (these results are from a trading EU perspective for the period considered).

13.6 Prediction (and Prevention) of Emerging Food Safety Risks: Predictive Early Warning Systems

Previously mentioned databases and systems are essential for risk and crisis management. Their retrospective statistical analysis (frequency of occurrence of hazards and risks, thresholds, algorithms) can indicate trends. However, assessment of emerging risks requires early detection or prediction, allowing preventive measures, before they become real risks. Various attempts have been made, and systems devised, for this task of "expecting the unexpected" [37,38].

Some systems are focused on specific food hazards:

- Early warning systems for moulds and mycotoxins in maize and/or wheat: computer models based on weather variables (temperature, rainfall, relative humidity), plant development stages and agronomic criteria. Indeed climate changes affect mould growth and the level and type of mycotoxins. However these systems are not very accurate.
- Predictive microbiology: it is used to understand the growth/death/survival of micro-organisms in relation to their implicit properties and interactions, and the characteristics of the food and of the processing environment. It also predicts the shelf-life and safety of foods. Example: prediction of the risk of *Vibrio* (and phycotoxins?) in shellfish from the prediction of sea water temperatures.

Some systems are focused on food imports (automatic data screening):

- New electronic screening tool for food imports (FDA, USA): Predictive Risk-Based Evaluation for Dynamic Import Compliance Targeting (PREDICT) automatically scans many databases for information that may affect admissibility determination. For example, it will check for: A product's inherent risk rating (e.g., raw seafood); If a company or product is subject to an import alert; The compliance history of relevant companies (e.g. producer, shipper, importer) and product, including recalls, inspection results, results of field exams, sample analyses of previous entries; The admissibility history of the producer, exporter, importer,consignee; Open source intelligence about the product, producer, and foreign site from which the product originates (e.g. floods, extreme heat), entry data anomalies.

The system also looks for patterns and associations. PREDICT then issues a risk score for each entry line. Based on the score, the system will either issue a "may proceed" notice or flag the entry as potentially risky and send it to an FDA reviewer for manual processing and possible examination and sampling.

Other systems may be moderately focused using data recording plus expert or stakeholder opinion, with sharing of information and knowledge to overcome problems of misinterpretation of data and ignorance of emerging risk signals:

- ECDC DIVINE-NET project monitoring food-borne viral diseases in Europe.
- EFSA's Stakeholder Consultative Platform, with web-based posting of EFSA documents, for feedback. Activities involve stakeholders to identify or prioritise food safety issues (see www.efsa.europa.eu). EFSA, the European Food Safety Authority, in charge of risk assessment, hosts ten specialised "scientific panels" and six "cooperation and assistance units", including one on emerging risks.

Moderately focused systems assess vulnerable points in the food supply chain where the introduction of (intentional) hazards is most likely to occur:

- CARVER-shock approach (adapted and described by FDA and USDA), to shield the food supply against threats of terrorist attacks and new dangers. "Critical nodes" are identified, rather than specific hazards. Multidisciplinary experts are needed, to focus on the production chain and flow diagram for a specific sector or product.

Broadly oriented systems combine food safety with other data:

- Eurostat (EU Statistical Office) (http://epp.eurostat.ec.europa.eu/) uses its database "from farm to fork" which can show trends and developments associated with various steps in the production-consumption chain in Europe. It includes results from EU food safety monitoring programmes, numbers of food inspections carried out, trade statistics, health records.
- FAO Global Information and Early Warning System on Food & Agriculture (GIEWS) is a wide information exchange system connecting governments, NGOs, research and media institutions, in which issues related to food security (crises) are shared to help policy-makers and analysts take preventive measures. Satellite observations are used to assess agricultural land status and forecast crop harvest yields.

Broadly oriented systems (strategic foresight by experts and stakeholders) consider the position of current and desirable future scenarios, and how to reach the latter with required policy changes:

- The European Community Scientific Committee on emerging and newly identified health risks has a panel of independent experts.

- The British Department for Environment, Food and Rural Affairs (DEFRA) is involved in horizon scanning: systematic examination of potential threats, opportunities and future developments at the margins of current thinking. This may explore novel, unexpected issues and persistent problems and trends .

Other predictive systems are based on a holistic approach [12,39–41]:

- EU projects: SAFE FOODS (www.safefoods/nl/), and EMRISK

(www.efsa.europa.eu/en/panels/emrisk.htm) which attempt to expand the scope of risk assessment, consider many sectors in and out the food production chain (science, technology, industry and innovation; international trade; nature and environment; government and policies; consumer behaviour; culture and demography; public health and welfare; agriculture; economy; information), and attempt to identify specific indicators and signals from these sectors [11].

An indicator is defined as a reliable and sensitive measurement or observation informing on the nature of the hazard and the source of risk. A signal is a change in such indicator, which may result in the development of a risk.

Additional recommendations for these holistic systems include: to increase transparency and accountability; to increase stakeholders' input (including consumers); to analyse both risks and benefits; to consider issues such as risk acceptability and mitigation.

In an article entitled "Selection of critical factors for identifying emerging food safety risks in dynamic food production chains", van Asselt et al. [42] first list the main indicators inside and outside food production chains.
Endogenous indicators:

Factors 1–6 relate to Food chain complexity: the higher possibility of errors in complex systems results in food safety risks.
Factors 7–10 are linked to Producers' attitude towards food safety.
Factors 11–13 show Producers' compliance to food safety regulations.
Factors 14–18 correspond to Technical innovations in the food chain.

Exogenous indicators

Factors 19–22 include Origin of raw materials; Legal requirements; Climate change; and Economic status.
Factors 23–29 are related to Consumers: Size of demand; Demand for convenience or quality; Consumer concern for health

Multidisciplinary experts were then asked to select critical indicators for each specific case, rank them, detect and analyse their signals. For this, group discussion was followed by individual ranking. Taking as case study a change from domestic (apple) to exotic (Indian or Australian mango) fruit chain on the Dutch market in 2000, the experts were asked to score a change in the listed indicators from –2 (much less change) to +2 (much more change). For each change in indicator, its subsequent consequences on food safety were also scored from –2 to +2 (markedly increased risk), as shown below [42].

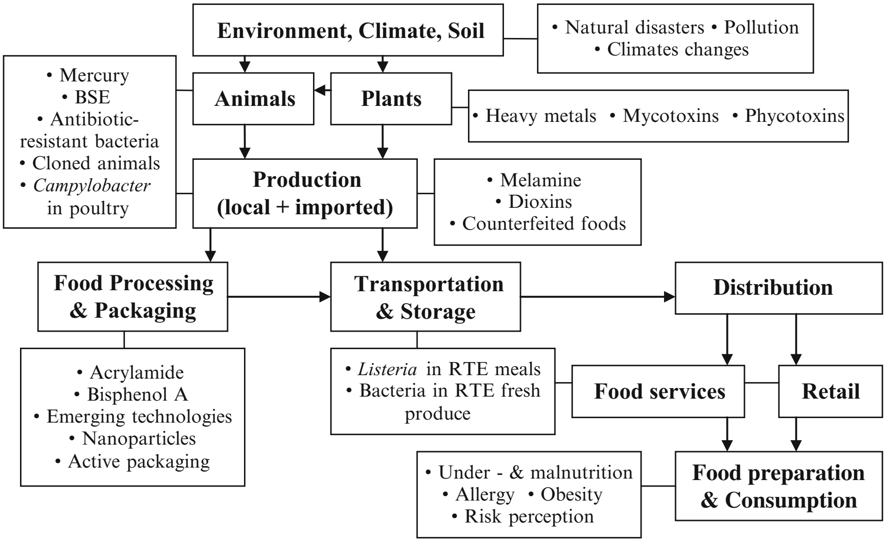

Fig. 13.2 Some safety hazards and risks in the food supply chain

Critical indicators (indicator number)	Score for change	Score for food safety risk
Logistics (5)	+2	+1
Information exchange (8)	–1	+2
Contractual agreements on quality and safety (9)	–0.5	+1
Origin of raw materials (19)	+2	+1
Legal requirements (20)	–2	+2

13.7 Safety Risks in the Food Supply Chain

Figure 13.2 summarises some of the main food safety risks in the food chain. These risks are largely due to human activities. They present a high degree of complexity and uncertainty, being related to the type of food and food attribute, type of substance, technology, region, etc.

13.8 Potential Food Safety Risks of Food Processing

They can be classified as follows:

1. Under-processing (including non homogeneity of treatment):
   - Incomplete physical removal of contaminants

- Incomplete inactivation of micro-organisms, spores, viruses, parasites (special risks for the chilled storage of foods of animal origin), plus microbial recovery and adaptation of stress-resistant microbial strains
- Incomplete inactivation of natural anti-nutrients, allergens, toxicants

2. Over-processing (including non homogeneous treatment):

- Nutrient losses or decrease in nutrient bioavailability
- Formation of toxic molecules (acrylamide, heterocyclic amines, HMF.)
- Enhancement of microbial growth (slicing, grinding, long storage…)
- Migration of chemicals from package into food (including inks…)

3. Intentional addition of unsafe substances: some food additives, nanoparticles, adulteration products, antibiotic-resistance genes, pathogens…

Some recent examples of such risks are discussed below.

13.8.1 Acrylamide in Foods (Discovered by Tareke et al. [43])

Acrylamide (prop-2-enamide; C_3H_5NO) may be formed in carbohydrate-rich foods: potatoes and cereal-based products (potato chips, French fries, bread, crispbreads, biscuits, breakfast cereals, coffee) during cooking processes such as frying, baking, roasting, microwaving at ≥120°C. Acrylamide levels observed were up to 5 mg/kg in potato chips and 2 mg/kg in biscuits. Acrylamide may also form in heated fat-rich dry foods such as nuts. The exact mechanisms of formation are unsure, but involve Maillard reactions between asparagine and reducing sugars/reactive carbonyls.

Acrylamide is also a highly reactive industrial chemical used for the production of plastics and materials. It may migrate into foods from some food contact materials.

Acrylamide is a known carcinogen to experimental animals, and may be a reproductive toxicant. Thus exposure from all sources, including diet, should be minimized (*Codex Alimentarius*, CAC/RCP 67-2009). Its primary metabolite, glycidamide, is also toxic.

In order to reduce acrylamide formation in foods, CIAA [44] has proposed a "Toolbox" showing how recipes and processes can be modified (use low sugar varieties and mixes, avoid overheating and brown colour, add asparaginase or amino acids, or an asparagine-degrading yeast). According to EFSA, from 2003 to 2006, the acrylamide levels of EU bread and potato chips has decreased, but not that of biscuits, breakfast cereals, French fries, or cereal-based baby foods. Further suggestions for the control of the acrylamide content of French fries are given by Sanny et al. [45].

The link between acrylamide and cancer risk in humans is uncertain. People have been exposed to acrylamide in their diet for a long time. Recent studies suggest that tolerable daily intakes of acrylamide for carcinogenic levels should be set at 2.6 μg/kg b.w., while the TDI for neurotoxicity is higher, at 40 μ/kg b.w. Recent Canadian, Swedish and US studies estimate the average exposure of adults to acrylamide in foods as 0.3, 0.5 and 0.4 μg/kg b.w. per day, respectively [46].

This example shows how even long-used processes can suddenly reveal unsuspected risks. It is also known that frying, grilling and barbecuing of meat and fish may form carcinogenic heterocyclic amines. The formation of furan or of acetaldehyde in some foods may be the next issue.

13.8.2 Hormonal Disruptors from Food Packaging and Containers

Some chemicals used as plasticizers in food packaging and/or plastic materials, and in cosmetics and adhesives, such as phtalates and bisphenol A are suspected of causing the increasing numbers of anomalies of the male sexual organs (low spermatozoid concentration, testicular cancers…) observed during the last 30 years in some industrialised European regions. Some of these chemicals, alone or in combination, exert anti-hormonal (anti-androgen or oestrogen-like) effects on animals. These chemicals could exert their adverse effects on the genital organs of male individuals, when these are exposed, orally or otherwise.

There were 46 RASFF notifications in 2008 concerning such chemicals (migration from food plastic items mainly from China). Strict rules have applied in the EU since July 2008: DEHP and DBP, suspected of being endocrine disruptors can only be used as plasticizers for articles that do not come in contact with fatty foods. Additional uses are authorised, with strict migration limits, for phtalates such as BBP, DINP and DIDP, which are not suspected of being endocrine disruptors.

Bisphenol A (BPA) (4,4′-dihydroxy-2,2-diphenylpropane) is used, usually in combination with other chemicals, to manufacture plastics and resins. BPA is thus present in polycarbonate food containers such as returnable beverage bottles, infant feeding bottles, tableware, storage containers. BPA residues are also present in epoxy resins used to make protective coatings for food and beverage cans and vats. During food storage, BPA may migrate in small amounts into food and drinks.

Concerning the safety of BPA, EFSA set a Tolerable Daily Intake of 50 μg/kg body weight in its 2007 risk assessment (TDI is the amount, on b.w. basis that can be ingested daily over a lifetime without appreciable risk). In an opinion published in 2008, EFSA noted that intakes of newborn infants, children and adults were well below the TDI. After exposure to BPA, the human body (including newborns and pregnant women) rapidly metabolises and eliminates BPA.

There are strong controversies about various possible toxic effects of BPA, and not only as hormonal disruptor (because of its binding to oestrogen receptors). BPA is permitted in food contact materials in the EU, USA, Japan, but some US states or EU countries have already banned its use for infant food containers. It is recommended not to heat polycarbonate baby bottles so as to reduce the risk of BPA migration into the food. Perhaps it could also be recommended not to leave bottles of mineral water in cars on hot days, although such containers are made of polyethylene rather than polycarbonate. Recent assessments of new studies on BPA can be found on the EFSA website.

13.8.3 Meat and Bone Flours, and the Bovine Spongiform Encephalopathy Crisis (from 1984)

Some technological changes in food or feed processing can have totally unexpected effects, that are not always completely elucidated. An example is given by the omission of technical steps (150°C fat rendering; hot solvent extraction; high temperature desolventisation) in the production process of "meat and bone flours" from ovine and bovine carcasses and offal. The simplified process probably failed to inactivate infectious prion proteins in these animal flours used as feed for cows. This may be the main cause for the spread of bovine spongiform encephalopathy (BSE) and the major resulting health, economic, consumption, and consumer trust crises.

Three other factors enhanced the BSE crisis: (1) the fact that the prion was a previously unknown infectious agent, with a "new" mode of transmission and action, (2) the recycling of infectious agents through successive animals, which appeared to increase "virulence", (3) profit-based fraud in the persistent use as feed of already banned meat and bone flours.

13.8.4 Fraud and Adulterated Foods

Profit-based criminal frauds have caused a number of food crises (through direct or indirect addition of toxic substances to foods or feeds):

1. Examples concerning **adulterated oils**:
   - Ukrainian sunflower oil containing mineral oil, exported to Europe (2008), leading to withdrawal from EU markets and temporary import ban, until strict controls were implemented (RASFF annual report 2008).
   - Oils from electric transformers fed to Belgian chicken (1999).
   - Spanish oil syndrome (1981), with 20,000 persons affected, and over 800 deaths, due to a denatured rapeseed oil (containing fatty acid esters of 3-(*N*-phenylamino)-1,2-propanediol), sold as edible olive oil.
2. Feeds and foods contaminated with **PCB and dioxins**.
3. Addition of **melamine** to gluten feed, soy meal and milk by Chinese firms or cooperative milk collection centres, to increase the nitrogen content, and mask milk solids dilution.

Dioxins

In 2008, there were 7 RASFF alert notifications for dioxins (present above legal limits) in foods, and 10 in feeds. An example is that of pork from Ireland, with a large trace and recall operation (from 54 countries) of pig meat and many processed pork products (RASFF annual report 2008). Dioxin-like PCBs and dioxins were found in pig meat at 100 fold the EU maximum limit of 1 pg/g fat. The source of this contamination/adulteration was as follows. Pigs from about 50 farms were fed with contaminated bakery wastes. These wastes consisted in bread crumbs which had been dried by direct contact with combustion gases. And the fuel burned to make the combustion gases had been contaminated by adding illegally oil from electric transformers (such oil generally contains PCB) (RASFF annual report 2008). RASFF gave detailed lists of distribution of possibly contaminated meats and meat products.

Codex alimentarius has developed a Code of practice for the prevention and reduction of dioxins and dioxin-like PCB contamination in food and feeds (CAC/RCP 62-2006).

Melamine (1,3,6-triazine-2,4,6-triamine; $C_3H_6N_6$)

Melamine is a chemical intermediate used in the manufacture of plastics and resins (and can leach into foods). According to EFSA, 2.5 mg melamine/kg food represent the critical level allowing to distinguish between unavoidable background presence and unacceptable adulteration. Intentionally contaminated Chinese foods or feeds contained up to 2600 mg/kg.

In the 2007 melamine gluten feed case, exports and incorporation into US pet foods had hurt (or killed) thousands of cats and dogs, without much impact on the Chinese food operators.

In the 2008 melamine milk case, 22 out of 79 Chinese producers of powdered infant formula were affected (and products were exported to 5 countries). The lack of transparency from Chinese authorities and the late recall caused kidney problems to over 300,000 infants and young children (over 50,000 hospitalised, at least 6 deaths). In spite of severe sanctions, melamine was still found in repackaged milk powder in Shanghai and Northern China firms in 2009–10.

Many Chinese composite products (biscuits, chocolate) containing contaminated milk powder were imported into the EU (but not milk powder as such, because importation is not permitted). Forty market notifications and 5 border rejections were listed in RASFF (RASFF annual report 2008). There were also news notifications from INFOSAN. EFSA estimated there was no health risk from these composite products, except in the case of an unlikely worst case scenario. Melamine toxicity risk data can be found in the EFSA scientific statement of 2008: the tolerable daily intake (TDI) has been reduced from 0.5 to 0.2 mg/kg b.w. Further EFSA assessments of studies on melamine exposure and toxicity can be found on the EFSA website.

13.8.5 Risks from Food Ingredients and Additives

The illegal production of foods and the use of non authorised food or feed additives are not single cases, but open and frequent practice in some countries with corruption, official silence and opaque supply and export channels.

In 2007, some 2000 Chinese producers and 1000 retailers had exported food ingredients and additives (with vitamins and amino acids) worth US$ 4 billion. Food and pharmaceutical companies worldwide used these ingredients and additives, probably without sufficient traceability or quality control. In 2010, some Chinese wheat flour was adulterated with pulverised lime added to bleaching agents (www.foodproductiondaily.com, April 9, 2010).

The Chinese Government is now reinforcing its legislation and inspection system. However, both the information and decision chains remain weak, and trained personnel is still lacking.

China is also a large market for foreign food ingredients and additives. The Food Ingredient China Exhibit (organised by an European Company) took place in Shanghai on March 23–25, 2010.

13.8.6 Counterfeited Foods and Drinks

The global level of fraud as counterfeiting in the food and drink industry is estimated at about $50 bn/year (www.foodproductiondaily.com, February 17 and March 24, 2009). The most frequently counterfeited foods and drinks are: fruits, conserved vegetables, baby food, milk powder, butter, instant coffee, spirits, drinks, confectionaries. Recent examples are conventionally grown vegetables sold as organic, fish sold as more premium species, canned energy drinks of unknown origin with counterfeited brand names. A picture in the French Le Monde 2 magazine (March 2010) showed the large scale destruction of counterfeited whiskies and cognacs at Zhuliao, Guangdong province, China.

Global trade and high food prices increase fraud opportunities and rewards. Counterfeiting causes high losses for food firms through damage to brands and spending on security measures. Consumers are deceived, and there is also a risk for public health.

Security measures on packaging include holograms, microdots, data codes, use-by dates, lot numbers, markers. However, counterfeiters are often able to circumvent these measures. Recent security proposals include printed pattern of fluorescent nanocrystal dots providing a fingerprint detectable under UV light, and fraud report hotlines (www.foodproductiondaily.com March 24, 2009).

13.8.7 Likely Food Targets for Terrorism (Intentional Addition of Toxic Chemicals or Biological Agents)

What are the most likely foods, feeds or drinks to tamper with? Those with easy access, large volumes, wide diffusion, short shelf-life, able to reach a maximum of people, or a specific group of people.

- Water: rivers, ponds, city reservoirs, tanks, sea salt ponds (although protected by water treatments, controls and dilution effect);

- Liquid foods: milk, fruit juices, beer, wine… (liquids facilitate an uniform diffusion of contaminants);
- Ingredients (possibly "foreign") incorporated into many foods: flours, milk powder, salt, sugar, tomato paste, peanut butter, hydrolysed vegetable proteins…
- Counterfeited foods with known and trusted brands: Coca Cola, Nescafé, baby food brands;
- Food animals (and animal feeds), which can transmit zoonotic diseases to humans through consumption of animal products.

Food ingredients are special targets because they are sourced globally, at low prices, undergo less controls, are less visible and reach multiple end-products. The situation could improve if the food industry enhanced collaboration, adopting common standards, sharing supplier audits, and establishing a clearing house of suppliers. However, specification and testing usually involve compounds which are known to be a problem for a given ingredient, such as heavy metals, mycotoxins or mould, and not intentionally added toxic substances.

13.8.8 Radioactive Contamination of Foods

The main risk comes from possible accidents in nuclear power-plants, as happened in Chernobyl (Ukraine) on 26 April 1986, with considerable quantities of radionuclides released into the atmosphere, contaminating foodstuffs and feedingstuffs in several European countries to levels significant from the health point of view. Measures were adopted to ensure that certain agricultural products were only introduced into the EU according to common arrangements. A Regulation is being presently amended, laying down maximum permitted levels of radioactive contamination (in Bq/kg) of foods and feeds following a nuclear accident or any other case of radiological emergency. Such levels depend on the nature of radioelements present (Sr-90, I-131, Cs-134, Cs-137, Pu-239, Am-241…) and on the food category (infant food, dairy produce, liquid foodstuffs, other foodstuffs except "minor foodstuffs") [47]. Because of the 30 year decay period of radioactive caesium, the EU trade in wild game, wild berries, wild mushrooms, and carnivorous lake fish of regions affected by the Chernobyl accident is still monitored and subjected to maximum permitted levels [48]. FAO, WHO and the International Atomic Energy Agency (IAEA) have also developed maximum levels of radioactivity permitted for the international trade of foods.

In a radiation emergency situation, the availability of uncontaminated food and food raw materials to consumers and to the entire production chain is a serious challenge, especially during the growing season. Hypothetical contamination scenarios and exercises are recommended for preparedness. Short-term countermeasures differ from longer-term remediation. The most frequently cited countermeasures are: food and feed restrictions, clean feeding of animals (with feed additives to bind caesium in the GI tract of ruminants), shallow ploughing of the soil, addition of ammonium ferric hexacyano-ferrate (AFCF, reduces the transfer of caesium from the soil to rye grass and clover). In all cases, measurements of radioactivity, determination of the types of radionuclides, and general information and advice to all stakeholders are required [49].

13.9 Safety of "Emerging" Food Technologies

This section starts with a brief survey of recent food technologies and their potential food safety risks. Obviously these technologies also have beneficial effects, and some of them are widely used in the food industry.
"New" physical treatments (often "minimal", or low temperature)

- High pressure pasteurisation: incomplete microbial inactivation, no spore inactivation, microbial recovery; some chemical reactions.
- Pulsed electric fields: no spore inactivation, non homogeneity and arcing; electrochemical reactions; metal transfer from electrodes.
- Cold plasma (dielectric barrier discharge at atmospheric pressure and ~30°C) (possible use for surface disinfection): free radicals, oxidations.
- Light pulses and UV: non homogeneity (surface only); photo-oxidative reactions.
- Ultrasound: low efficiency for microbial inactivation (but safe cleaning).
- Ohmic heating: under/overheating, metal transfer from electrodes.
- Microwaves: non homogeneity of heating and possible power reduction over time of domestic ovens.
- Ionising radiation: free radicals, oxidative reactions, consumer distrust (there is a pending US petition for surface irradiation of meat carcasses).

"New" chemical or combined "hurdle" treatments (often "minimal", and low temperature)

- Modified atmosphere: can delay microbial growth, but tend to over-extend shelf-life and storage time.
- Anti-microbial agents (and "hurdle" processing): incomplete microbial inactivation; microbial growth only delayed in storage; sub-lethally injured cells may give antimicrobial-resistant, acid-resistant, osmotic-resistant… or virulent strains through adaptation mechanisms; natural flora inactivation reduces competition against pathogens; potential reactivity or toxicity of some antimicrobial agents; possible use to conceal poor hygiene practices.

Examples are given by the decontamination of poultry, pork or beef carcasses by washing or spraying with solutions of: Cl_2, ClO_2, hypochlorite, acidified sodium chlorite, trisodium phosphate, organic acids (lactic, acetic), H_2O_2, O_3, electrolysed H_2O, lactoferrin… Few of these antimicrobials are presently authorised in the EU.

The efficiency and safety of some innovative anti-microbials remain to be determined:

(1) Bacteriophages against bacterial pathogens. These "bacteria-eating" viruses could be an effective way of eliminating specific food pathogens in meat and

milk products. They tend to persist longer than their hosts (replicating best on growing bacteria) and behave as inert particles in the environment. Their long term anti-bacterial activity is reduced on dry surfaces and their persistence in food varies with each bacteriophage and with the conditions of application (pH, moisture, temperature…). Refrigeration temperatures improve their persistence.

Their specificity vis à vis bacterial species, their persistence, or their ability to prevent food recontamination by pathogens is generally unknown.

In 2006, FDA accepted the GRAS status of a Listex P100 preparation of bacteriophage (obtained using *Listeria innocua*) to be used in foods to protect against *Listeria monocytogenes.*

(2) Yeasts against moulds and mycotoxins. As announced in the IFT Weekly Newsletter of Feb. 3, 2010, S. Hua from ARS-USDA found that spraying pistachio trees with the yeast *Pichia* inhibited incidence of *Aspergillus flavus* in pistachios by up to 97%, compared to unsprayed trees. The yeast can also be sprayed on the harvested or stored crop. It may also protect other crops against some microbial strains.

13.9.1 Listeria Risks in Ready-to-Eat Foods

The critical risk areas for this type of processed foods are:

- When these foods are targeted to vulnerable persons, such as people above 60, pregnant women and immuno-compromised persons;
- When the food composition supports the growth of *Listeria monocytogenes*. Risks are increased if pH > 4.5 and/or Aw > 0.91 (low salt content). These conditions correspond to current trends;
- Several preparation steps are also critical: the training and education of operators; cleaning operations; the slicing of meat products; packaging. The practice of HACCP is necessary;
- Current trends for minimal processing are risky for subsequent food preservation: cook-chill; moderate or cold pasteurisation, e.g. with high pressure; antimicrobial chemicals such as lactate, acetate, bacteriocins, lactoferrin, carvacrol, thymol;
- It is imperative that storage temperature be kept ≤4°C in distribution and at home. Consumers' respect of expiration date is critical. Current trends for long shelf-life increase risks.

QMRA can be used to predict efficiency of different risk mitigation options. *Codex Alimentarius* has also issued guidelines for the control of *Listeria* in RTE foods (CAC/GL 61-2007).

13.9.2 Pathogen Outbreaks in Fresh Fruit and Vegetable Produce

Fresh produce has become a frequent vehicle of foodborne illnesses (~13% of reported outbreaks with an identified food source, in the USA) [15]. This is only partly explained by the current increased consumption of fruits and vegetables, or by better outbreak detection.

Salad greens, lettuce, sprouts, and melons are leading vehicles, with norovirus, *Salmonella* and *E. coli* O157 as most frequent pathogens. The initial contamination comes through irrigation water and fertilizers. Major outbreaks are associated with fresh-cut, bagged produce (18 outbreaks in the US in 1998–2006, mostly due to leafy greens) [15]. Increased surfaces from cut, shredded, diced and/or peeled tissues release liquids and nutrients, enhance microbial attachment and growth, and interfere with disinfectant (mainly Cl_2) washes. Poorly controlled refrigerated distribution channels further increase risks.

13.9.3 Nanotechnologies

The definition of nanotechnologies is not very precise: use of substances on a very small scale (≤100 nm, obtained by assembly of molecules or downsizing). "Engineered nanomaterials" (ENM) or "nanoparticules" are already used in ingredients, additives, fertilisers, pesticides, drugs, packaging.

ENM have specific physico-chemical properties: small size increases diffusivity; high surface area enhances binding, reactivity, possibly recognition. Structure, size distribution, chemical composition, surface charge may also confer unique functionalities for food uses:

1. as food ingredients and additives: increased solubility, dispersibility, stable emulsions without emulsifier, improved texture;
2. as delivery systems for bioactive compounds: molecular traps (e.g. emulsion droplets, edible solid lipid or carbohydrate polymer particles) for protection and targeted delivery of nutrients (lycopene, phytosterols), higher availability of nutrients (Fe, Zn) for food supplements;
3. in innovative packaging: more protective or intelligent packaging: reactive nanoprobes responding to environmental changes, alerting of use-by date, temperature, pathogens, toxins; anti-bacterial coatings (e.g. silver particles) for food-contact surfaces (refrigerator…).

In plastic polymer or biopolymer films and coatings, nanoparticules may act as "fillers" to enhance barrier properties against gas migration (O_2, CO_2, H_2O vapour and/or flavours), with positive impacts on the shelf-life of fresh or processed foods. Mechanical strength and resistance to abrasion or thermal stress of films or coatings may also be improved. Nanofillers may consist of clays (montmorillonite, i.e. magnesium aluminium silicate; kaolinite), carbon-based nanotubes or graphene nanosheets.

Degradable bio-nanocomposites may also be used: starch-clay mixes, cellulose, polylactic acid, chitosan, proteins.

Current usage of nanoparticules in food/feed is increasing, but not well documented as there is no industrial inventory or public database.

There are broad uncertainties over the safe use of nanoparticules for foods and health implications of exposure [50]. Their small size increases their ability to move unexpectedly in the body. Adhesive and reactive surfaces may cause various interactions. In its Scientific Opinion of 2009, EFSA estimates that existing risk assessment methods can be applied, on a case/case basis. Data on non nano chemicals cannot be extrapolated to their nano equivalents, because formulation to the nanosize may change their properties. There are considerable limitations and uncertainties: (1) on detecting, characterising and "dosing" ENM; (2) on their absorption, distribution, metabolism, and excretion; (3) on their toxicology and environmental impact. ENM could undergo changes in the gastro-intestinal tract. Insoluble ENM may be retained and accumulate. Soluble ENM may pass through membranes, including the brain barrier, together with adsorbed substances. Little knowledge exists on their chronic exposure and carcinogenicity following oral intake. Their possible impact on the nutritional value or bioavailability of food constituents also remains to be studied. The presence of nanoparticles as contaminants in food and feed also deserves to be considered.

EFSA Scientific Opinion indicates data needed from nanotechnology applicants for risk assessment. Stakeholders have been consulted in view of future legislation. Main challenges rest with: workplace safety, distinction of natural and engineered nanoparticles, cost; food safety, uncertain legislation, including possible labelling requirements. EFSA presently (2010) prepares a guidance document on how to assess potential risks related to certain food-related uses of nanotechnology. The European Council wants "nanofoods" to be included in the future revised Novel Food Regulation.

13.9.4 Active and Intelligent Food Packaging

While "classic" packaging should be as inert as possible, these new packaging intentionally interact with the food or its environment, either ("active") to extend shelf-life with maintenance of quality, or ("intelligent") to give indication on, and monitor, the food freshness (time-temperature indicator, ripeness indicator, biosensors…). Active packaging contain deliberately incorporated components intended to release or absorb substances into or from the food or its environment (release antimicrobials, antioxidants; absorb O_2, C_2H_4…). Such packaging could be combined with tamper-proof or identity-ensuring systems. While highly promising, these new packaging are not yet widely used.

The main safety issue (as for classic packaging) is migration of chemicals and their degradation products into the food. Nano sizes could increase risks. A new Regulation (450/2009/EC) specific to active and intelligent packaging introduces safety evaluation by EFSA, with an authorisation scheme, focusing on migration data of chemicals and their toxicological properties. The efficiency of such packaging to perform the claimed function should be demonstrated in real foods. This is critical when it should prevent microbial growth, or reveal the presence of pathogenic bacteria or toxic contaminants. Their proper use should be explained to consumers by way of labelling.

The acceptance of active or intelligent packaging may be limited. Consumers may perceive systems for the extension of shelf-life as detrimental to food freshness. Time-temperature and other indicators of stressing conditions may induce consumers to select only newly displayed items. Complex packaging may also convey a negative carbon footprint image. Retailers and consumers may thus make a negative cost/benefit analysis.

Radio frequency identification (RFID) tags stuck or printed on food packages represent a type of intelligent labelling (without direct interaction with the food), replacing bar codes, that may change food sales and marketing, allowing a mobile phone to show food composition and nutritional adequacy; refrigerators to signal expiry dates and send automatic reorders; robot ovens to select cooking conditions…. RFID tags may also permit some intrusion into consumers' habits. Their reliability and resistance to tampering are not yet fully established.

13.10 Some Additional Challenges

A "Paradox of Progress" is often quoted concerning the food chain in Western Europe. In spite of renovated institutions (EFSA) and food law (Regulation EC/178/2002), stricter safety and quality standards (GMP, ISO 9001, HACCP), and intensified quality control and monitoring, the number of reported food safety incidents has increased (partly due to improved detection methods and systematic surveillance and reporting), and consumers' trust in food safety has decreased.

Several agro-food technologies tend to elicit consumer rejection (and in some cases strong political debates):

- Ionising irradiation of foods;
- Hormonal (and antibiotic) treatment of animals to hasten growth and increase meat or milk production (banned in the EU);
- Various food additives (consumers' request for "clean labels");
- Excessive use of crop fertilisers and pesticides (consumers' request for organic foods);
- Genetically modified food crops and food ingredients (in the EU);
- Genetically modified animals (including cloned animals).

There are indeed difficulties in matching the fast pace of innovation in food production and processing with risk assessment methodologies (pathogen testing, allergen testing, toxicology evaluations, environmental impact) [51].

The consumer "right to informed choice" is well established in the EU. Mandatory labelling for irradiated foods and GM foods have discouraged manufacturers and retailers to place such foods on the market, despite their potential advantages.

Consumers' perception of risks is an important challenge. Several factors influence consumer's acceptance of innovative food technologies and products [52]. Perceived benefits responding to consumers' needs (e.g. healthier, more nutritive, higher quality, lower price foods) are the major positive determinants.

Many consumers perceive new food technologies as riskier than traditional ones. "Tampering with nature" (e.g. genetic engineering) seems to be a predictor of perceived risk, while nature and naturalness are positive values. Consumers who value organic foods assess GM foods and irradiation more negatively. Chemical transformations, additives, "artificial" ingredients and gene modifications are perceived as most distant from nature, while physical transformations and genetic selection appear as less deviant.

Consumers often rely on general attitudes for judgment. Social amplification may increase the perception of risks for processes that are considered as safe by experts and policy makers. Information on risk strongly influences its perception, while familiarity with foods is more important for the perception of benefits.

Since most consumers have limited knowledge of risks or benefits of novel technologies, trust is a crucial determinant of acceptance. Consumers trust more easily operators with shared values, such as consumers' associations. Independent scientists are more trusted than national food control authorities or the food industry. Information given to consumers through labels, public debates or the media can amplify perceived risks if they do not come from a trusted source. Unintentional or deliberate misinformation often induces a fear of very low probability risks.

The technology used to create a food may dissuade consumers from buying, especially if they assume more profit to producers than to them, and if the technology deviates from naturalness. To change prior suspicious cultural and social attitudes of consumers, it is recommended to build trust, demonstrate tangible benefits, and show association with natural processes.

Legislation on novel foods and new technologies represents another issue. Depending on the category of stakeholders, it may be considered as a necessary protection against emerging food safety risks, or as a major barrier to innovation and trade.

European Regulation 97/258/EC on Novel Foods and Food Ingredients subjects each novel food to a severe pre-market safety assessment and authorisation procedure. It also specifies labelling rules to inform the consumer of any characteristics making the novel food no longer "equivalent" to an existing food, or having health or ethical implications.

According to the Regulation, there are several categories of novel foods: (1) a food not used significantly for humans in the EU before 1997; (2) a new or modified molecular structure or ingredient isolated from animals, plants, micro-organisms, fungi, or algae; (3) a food or ingredient subjected to a new process, or issued from a new production or breeding process, resulting in significant changes in composition, structure, nutritive value, metabolic effect and/or level of undesirable substances.

This classification includes some "functional foods" (which are also subject to Regulation 2006/1924/EC on Nutrition and Health Claims made on Foods). It excludes (because other rules apply) food additives, flavourings, enzymes, extraction solvents, vitamins and minerals, and (since 2003) genetically modified foods and ingredients.

Although a simplified "notification" procedure can be used for a novel food "substantially equivalent" to an existing food, Regulation 97/258/EC exerts strong constraints (costs, delays) on food business operators, detrimental to: (1) traditional foods from third countries, (2) innovative foods, (3) new technologies.

A revised European proposal (COM 2007.0872 of 14 Jan. 2008) is being discussed, maintaining high health protection, with additional objectives: (1) promote a more favourable legislative environment for innovation and competition in the food industry, (2) consider the particular needs of traditional food from third countries (avoid unjustified barriers to trade), provided these foods have a 25 years safe history of use in their country of origin. Food business operators and importers will be responsible for the safety of these foods, (3) clarify and facilitate implementation, with a single EU harmonised, centralised and shorter procedure for assessment (by EFSA) followed by authorisation (by the European Commission). Post-market monitoring by food business operators may be required, (4) give a wider choice of safe novel foods to the consumers.

13.11 Conclusions

Even in the absence of natural disasters or terrorist attacks, global food security and safety are threatened by a number of fast-occurring changes: overpopulation and urbanisation, environmental pollution, climate changes, intensive agriculture and animal breeding, international trade and travel, emerging water- and food-borne diseases, antimicrobial-resistant bacteria, increasing food costs, complexity of food supply chains, malnutrition and risky food behaviour.

Food safety management tools including food legislation, national and international standards, quality management systems, risk analysis, risk-based inspections and controls, monitoring and alert systems for food contaminants and food-borne diseases, quantitative microbial risk assessment, nutrition and toxicology studies, elaborate food processing technologies, have brought to consumers in developed countries a wide selection of safe foods.

Predictive and early warning and communication systems are being developed to increase the ability to "expect the unexpected" and take prevention measures before food hazards become real risks. Some 500 research articles listed in 2009 under food* + risk* by the ScienceDirect database also give partial indications on emerging risks.

Indeed, recent events or crises indicate that the production, processing, transportation, storage and/or distribution stages of modern food supply chains remain exposed to various types of biological or chemical contaminants. The prion/BSE, dioxin, acrylamide, melamine, bisphenol A cases, and the numerous pathogen outbreaks (*Listeria*, VTEC *E. coli*, *Campylobacter*, norovirus, parasites, shellfish toxins…) illustrate this exposure. The melamine story and the international traffic of counterfeited foods and drinks show that profit-motivated fraud and adulteration are rising threats, opening potential paths for terrorist actions.

Recent food preservation, processing or packaging technologies and trends, in spite or because of their benefits (mild treatment, extended product shelf-life, "fresher" quality, RTE pre-cooked convenience) also bring safety risks at the consumer level: incomplete microbial inactivation, possible non respect of adequate storage conditions and expiration dates, undercooking, generation of stress-resistant micro-organisms. Innovative technologies, such as the use of nanoparticules in foods or food contact materials, and the development of active, intelligent or sustainable food packaging entail uncertainties and safety concerns.

Natural disasters, conflicts, or poverty often lead to emergency situations requiring large assistance operations with complex logistics and specific meals RTE or nutrient-supplemented foods. Other strategies against food insecurity include insurance policies and renting of agricultural lands abroad.

Citizen perception of food safety risks and the EU consumer "right to informed choice" explain why some technologies elicit rejection: ionising irradiation of foods, hormonal and antibiotic treatment of animals, the use of various "artificial" food additives, genetically modified crops and ingredients. Perceived benefits responding to consumers' needs (healthier, more nutritive, higher quality, more convenient, lower cost), "naturalness", respect of the environment and trusted information are the major factors influencing consumers' acceptance of innovative food technologies and products.

Novel foods and novel technologies are also subject to strict regulatory pre-market safety assessment and authorisation procedures (European Regulations 97/258/EC on novel foods and food ingredients, and 1924/2006/EC on nutrition and health claims made on foods). While necessary for protection against unexpected risks, some of these rules are questioned in terms of barriers to innovation and trade, and objects of strong political debates.

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