ENSURING FOOD SAFETY FOR FOOD SECURITY

GARANTIZAR LA SEGURIDAD ALIMENTARIA PARA LA SEGURIDAD ALIMENTARIA

Gaspar Ros[1]. Catedrático de Nutrición y Bromatología, Universidad de Murcia

Recibido: 2-2-2022
Aceptado: 24-3-2022

Abstract
Security challenges within anthropology must include food security as a key aspect since it is the basis of another series of anthropological challenges. Ensuring food safety for food security is an increasingly complex task due to its size and complexity. Although technological advances are solving the problems that are generated, the threats arise as new situations determined by social, demographic, ecological and natural resource changes, which in the face of a growing population do not always allow an evaluation with sufficient anticipation. This challenge to achieve global food security presents aspects to be assessed, such as global social trends in food consumption (mega-cities and mega-regions; increasing population aging and personalized foods and diets; global food production, food security and climate change; internet of food (IoF) and digital food), current and emerging risks in food safety (biological risks: from bacteria to viruses and antimicrobial resistance; chemical contamination: unintentional and intentional: allergens and intolerances; new technologies and food safety), and advances in technology and food safety (the role of food companies in ensuring food safety: packaging and traceability; risk assessment tools such as predictive microbiology for hazard estimation, and evaluation chemical risk and safety assessments, omics and big data ”; transparency and sustainability in communication and public perception of food safety). This complexity and determining factors must be constantly reviewed for global food security.
Keywords: Food safety, food security, agenda 2030, food trends, food regulation, food safety communication.

[1] E-mail: gros@um.es

Resumen

Los desafíos de seguridad dentro de la antropología deben incluir la seguridad alimentaria como un aspecto clave ya que es la base de otra serie de desafíos antropológicos. Garantizar la inocuidad de los alimentos para la seguridad alimentaria es una tarea cada vez más compleja por el tamaño y la complejidad que adquiere. Si bien los avances tecnológicos van solucionando los problemas que se generan, las amenazas surgen como nuevas situaciones determinadas por cambios sociales, demográficos, ecológicos y de recursos naturales, que ante una población creciente no siempre permiten una evaluación con la suficiente anticipación. Este reto para conseguir una seguridad alimentaria global presenta aspectos a tener valorar como las tendencias sociales globales en el consumo de alimentos (mega-ciudades y mega-regiones; creciente envejecimiento de la población y alimentos y dietas personalizados; producción global de alimentos, seguridad y cambio climático; internet de los alimentos (IoF) y alimentos digitales), los riesgos actuales y emergentes en seguridad alimentaria (riesgos biológicos: de bacteria a virus y resistencia antimicrobiana; contaminación química: no intencional e intencional: alérgenos e intolerancias; nuevas tecnologías y seguridad alimentaria), y los avances en tecnología y seguridad alimentaria (el papel de las empresas alimentarias en garantizando la inocuidad de los alimentos: elaboración de envases y trazabilidad; herramientas de evaluación de riesgos como la microbiología predictiva para la estimación de peligros, y evaluación de riesgos químicos y evaluaciones de seguridad; ómicas y "big data"; transparencia y sostenibilidad en la comunicación y la percepción pública de la inocuidad de los alimentos). Esta complejidad y factores determinantes deben ser permanentemente revisados para el aseguramiento alimentario global.

Palabras clave: Seguridad alimentaria, seguridad alimentaria, agenda 2030, tendencias alimentarias, buena regulación, comunicación sobre seguridad alimentaria.

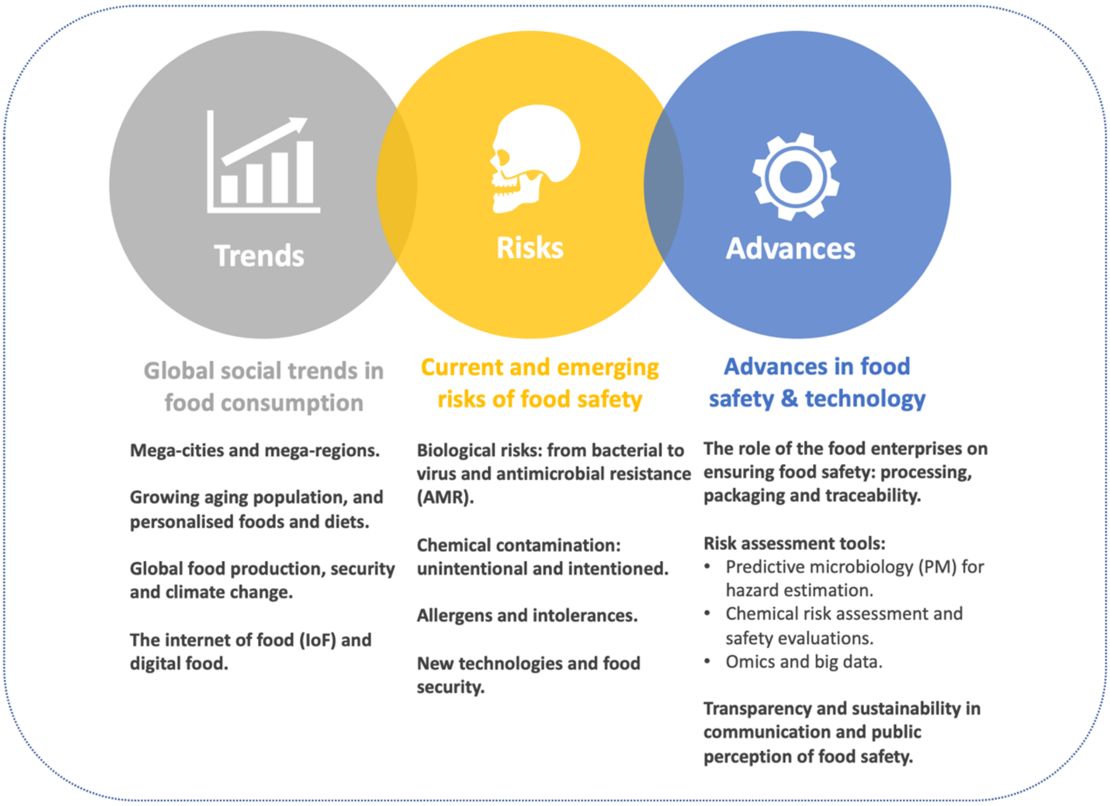
1. Introduction

More than 820 million people suffer from daily hunger and this number has been slowly increasing in the past three years (FAO, 2019), and almost 2 billion people face some form of food insecurity, and in some area's particular groups such as women, children and indigenous groups remain vulnerable to hunger or undernutrition. At the same time the world is also facing the growing threat of overweight and obesity assuming epidemic proportions. Sustainable nutrition and food security are front and centre on the global agenda and key themes within the United Nations Sustainable Development Goals -SDG- (UN, 2015). To face SDG Goal number 2, "Zero Hunger", the world will need to feed around 9 billion people by 2050 and to do so through safe sustainable food chains (Godfray *et al.*, 2010). Demand for protein-rich foods such as meat and dairy could more than double from current needs with the global middle class estimated to grow from about 450 million in 2005 to 2.1 billion in 2050 (van der Mensbrugghe *et al.*, 2009). The need to reduce the complexity of and drive improvements in the efficiency and effectiveness of food chains has never been greater.

2. The 2030 Agenda and the SDGs.

2030 Agenda and its accompanying 17 SDGs (UN, 2015) have been widely praised for a strong articulation of an environmental dimension, in addition to breaking new ground with goals on inequality, economic growth, energy and peace. The SDGs are the result of a comprehensive participatory process, unparalleled in the history of global development (Doane, 2016). 2030 Agenda has been praised by experts and interest groups as a means to stimulate a radical shift in world affairs (Banik and Miklian 2017). However, SDGs have also been criticized for their unrealistic ambitions and lack of focus (King *et al*., 2017). For instance, how low-income countries and conflict-prone fragile states will be able to plan, coordinate and finance development programs in line with the SDGs and aligned with their national interest. Governments must therefore develop the capacity to identify mere profit-making initiatives that can thwart overall social and economic development. Additionally, there are a long list of threats that limit the ensuring of food safety and security that are summarized in Figure 1, and that will be reviewed as a key determinant to reach the main goal of global food safety.

Figure 1. Summarized threats that limit the ensuring of food safety and security.



3. Threats that limit the ensuring of food safety and security

As mentioned, one of the key challenges of the World in 2050 will be global food security, not only to produce but also to provide access to enough of the right foods to meet the nutritional requirements of the global population (Franklin and Andrews, 2012). To understand the complexity of this challenge we will follow King *et al.* (2017) description of the key issues that determine food safety.

3.1. Global social trends in food consumption

Mega-cities and mega-regions

The population behaviour and distribution are concentration to becomes more effective in big cities and regions. It is also linked to a wider opportunity to find more labour opportunities and to reach a wellbeing status for the population. The side effect is the rural depopulation (emptied of the rural areas) and the growth of the middle-income consumers. The global middle class is estimated to grow from about 450 million in 2005 to 2.1 billion in 2050, corresponding to 8.2–28.4% of the global population (van der Mensbrugghe *et al.*, 2009) and will be accompanied with higher purchasing power, higher consumption and a greater demand for processed food, meat, dairy, and fish, all of which add pressure to the food supply system (Godfray *et al.*, 2010). In addition, there will be a growing demand for convenience and pre-cooked and ready-to-eat meals. A major increase in the number of people living in cities, could facilitate a higher proportion of the population having access to modern food chains including modern retail systems such as supermarkets and with these, more formalised and regulated food safety. This could improve food safety and decrease foodborne illness. Alternatively, more people living in close proximity could increase foodborne disease in cases where humans can act as a vector, or where microbiologically or chemically contaminated food is distributed widely as a result of large-scale manufacturing and distribution.

Growing aging population, and personalised foods and diets.

There is a clear fact that the population is growing in the world, but at the same time is getting old, and the wellbeing led to the population to be more selective to avoid the harmful products and request healthier ones. For that reason, the food industry is focused on innovation to meet consumers' new demands, keeping highly sensory, healthy, specific to their nutritional needs and are easy to prepare (King *et al.*, 2017). Additionally, ethical consumer's demand, request seasonal, locally grown and organic and/or sustainable food products. This represents an increasing challenge for the food industry, as trends become cumulative, in that consumer "want it all" at the same time (King *et al.*, 2017). To meet the requirements from consumers and retailers, the food industry develop foods in the limits of the food technology with no preservatives or lowering salt concentrations, that may bring the pH closer to neutral making it suitable for 'ambient storage' (Parkin *et al.*, 2007), but assuming some important risks related with microbial growth or spoilage. The so called "extra-safe" food products, such as irradiated, sterilized, or pasteurized foods, is one possible solution proposed to address this dilemma targeted to higher-risk populations exposed to these foods (Doyle *et al.*, 2015). Foodborne illness is known to affect vulnerable populations, including the aged, more severely. With a rapidly aging populace and a growing population of immunocompromised persons, the deleterious impacts of outbreaks are likely to become more significant from a public health perspective. The equivalency of new less traditional food preservation technologies will require safety to be designed in, and based on risk management principles. Because of this demand, the convergence between science and medicine, gastronomy and industry is today more necessary than ever (King *et al.*, 2017).

Also, personalised diets focus on nutritional aspects to prevent or alleviate (not to cure diseases) people of certain diseases (mostly non communicable disease, NCD), although some practices may create unintended food safety issues. For instance, a totally empirical approach could be dangerous and more systematic research is needed including the use of nutrigenomics, metabolomics and toxicogenomics. The challenge of delivering personalised nutrition in a personalised manner to the masses will require novel, less heavily processed foods that preserve heat labile nutrients (King *et al.*, 2017).

Global food production, security and climate change.

Global food production has changed in the past decades to meet the increased demand for food. It is clearly associated with the growing human population worldwide, the industrial-scale and centralized production systems (including large-scale farming, intensified animal production, and large-scale food processing and distribution (King *et al.*, 2017). However, these systems will be constrained by the Earth's finite resources (Godfray *et al.*, 2010). There is also a need to stop the many negative environmental effects of food production on the environment such as the release of greenhouse gases, environmental pollution due to nutrient run-off, water shortages due to over-extraction, soil degradation and the loss of biodiversity through land conversion or inappropriate management and, ecosystem disruption due to the intensive harvesting of fish and other aquatic foods. It is also now widely recognized that food production systems and the food chain in general must become fully sustainable (Godfray *et al.*, 2010).

In addition, climate change is a current global concern that also rise with globalization of the food supply with, for example, increased greenhouse gas emissions associated with increased production and food transport (Godfray *et al.*, 2010). While there is continuing controversy about the magnitude of its effects, in general, weather conditions have become more variable with extreme weather events increasing in regularity and intensity (Stewart and Elliott, 2015). Climate change is likely to create new safety issues or exacerbate existing issues to the point where, at least temporarily, we may need to reassess our tolerance to risk and safety limits in order to allow time for our regulatory environments and food chains to cope and adjust. This may entail temporal adjustments to increase tolerable levels of many contaminants (microbial, chemical, and radiation) presently established for the human food chain. The global expansion of livestock production and encroachment of wildlife habitats by invasive agricultural land use, have also emphasised the need for increased awareness around the potential for emerging zoonotic viruses in food production areas; especially where bats and primates are in contact with humans (Locatelli and Peeters, 2012).

The internet of food (IoF) and digital food

IoF expands for the Internet of Things (IoT) which aim is to introducing artificial intelligence to physical devices such as computers and mobiles, and the production of foods. When we talk about the food and beverage industry, it has a huge impact in the food industry, with a important number of applications in the food industry such as management of the industry equipment, smart refrigerators, reduce the energy consumption, stock management, reduce logistics charges, data analytics report and give an update related to customers or food safety regulations, achieving quality regulations set up by different organizations and institutes. So IoF is a new trend and a useful tool that will help for food safety in the food industry as well at the retailers and at home. Also, digital food, such as 3D printing of food, is becoming an important trend to obtain food items and maybe a transforming the food industry. With 3D printing of food, 'everyone' can become a food manufacturer (Pallottino *et al.*, 2016, Sun *et al.*, 2015, Yang *et al.*, 2017) with the potential to create new combinations of ingredients, at higher-than-normal water activities, reduced acidity or lower/zero levels of preservatives, or moreover without any risk assessment being undertaken as normally would be the case in the manufacture of such foods. It could be argued that everyone can currently 'cook up' whatever combinations of ingredients using the tools in a conventional home kitchen without any formal risk assessment or training in food safety management (King *et al.*, 2017). Food safety needs to be an important consideration in the uptake of 3D printing for food. Regulatory environments and food safety management systems will need to evolve to take into account advances in digital processing, including such things as personalised nutrition, e-commerce and 3D printing. Whilst empowering consumers, such innovations and technologies have the potential to circumvent established mechanisms of providing consumer protection (King *et al.*, 2017).

3.2. Current and emerging risks of food safety

Biological risks: from bacterial to virus and antimicrobial resistance (AMR)

In order to keep food supply safe, it is essential to underline the real importance of food safety regarding good hygiene practices by all from stable to table, particularly handwashing. Classical food poisoning represents a crossover between infectious diseases and toxin-mediated illness, as many bacteria elaborate toxins to produce symptoms. Some cases of food poisoning involve colonization and reproduction of bacteria in the gastrointestinal tract, while others arise from pre-formed toxins in food. Bacterial food poisoning may be short-lived and self-limited (e.g. *Bacillus cereus, Staphylococcus aureus*); or prolonged, with severe symptoms, complications, and sequelae (e.g. *Campylobacter spp., Escherichia coli, Shigella spp*.). These bacterial are still an important issue, although food poisoning may also result from viral, fungal, or chemical contamination. The bacterial or virus food poisoning a concept that we have to consider is that there are also Emerging and Re-Emerging Infectious Diseases (EIDs), infections that have newly appeared in a population or have existed previously but are rapidly increasing in incidence or geographic range. Emerging foodborne pathogens are often zoonotic in origin and may include Gram-negative and Gram-positive bacteria, parasites, and viruses. Previously established foodborne pathogens may re-emerge as more virulent pathogens after the acquisition of new virulence factors, including antibiotic resistance determinants.

Virus is becoming of interest although there are not references to prevent and control food production. Most problems with foodborne viruses arise due to contamination of food products during manual handling in combination with subsequent minimal processing of foods (Koopmans and Duizer, 2004). Viruses survive well in the environment and are much more resistant than bacteria to some of the current procedures used to mitigate bacterial infections during food processing, preservation and storage (Baert *et al.*, 2009, Koopmans and Duizer, 2004; Li *et al.*, 2015). It is therefore of paramount importance that we gain a better understanding of how a combination of technologies may be used to inactivate foodborne viruses. Enteric viruses are major contributors to foodborne disease, with norovirus (NoV) and hepatitis A virus (HAV) being the most significant. Globally NoV accounts for the largest number of cases of foodborne disease (Ahmed *et al.*, 2014, WHO, 2015b). While HAV infection attributed to food is in the range of around 5% (FAO/WHO, 2008), HAV is associated with more serious illness. Virally contaminated food and water generally display no organoleptic changes. The ability to detect virus particles, which are often present in low numbers in contaminated food, is also hampered by the fact that there are no universal or rapid culture-based methods available for the cultivation of foodborne viruses. In the absence of culture methods, harmonized methods are required for the molecular detection of foodborne viruses; especially for NoV and HAV (Stals *et al.*, 2012). Changes in food processing and consumption patterns that lead to the worldwide availability of minimally processed high-risk foods (Koopmans *et al.*, 2002) and the increasing import of products from HAV-endemic regions to non-endemic countries (Todd and Grieg, 2015), pose a significant issue. It is clear that we need better surveillance of foodborne viruses, especially in ready-to-eat (RTE) foods. However, it is not clear whether routine monitoring of food specimens for viral contamination will be feasible and given the difficulty of excluding food handlers likely to be shedding virus at any one time, infections from foodborne viruses are likely to increase in significance in the future (Carter, 2005).

Two particular viral issues are under the focus: Avian influenza virus (AIV) and COVID-19. Regarding AIV, their potential mutate capacity in the far within chicken to became easily transmissible and zoonotic from human to human, requires a One Health approach to guarantee farm-to-table food security and to prevent AIV contaminated products from reaching the food chain (Harder *et al.*, 2016). Regarding COVID-19, WHO has stated that there have been no reports of transmission of COVID-19 through food. Therefore, based on current epidemiological support, this virus is not foodborne.

Antimicrobial resistance (AMR) threatens the effective prevention and treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses and fungi. AMR occurs when bacteria, viruses, fungi and parasites change over time and no longer respond to medicines making infections harder to treat and increasing the risk of disease spread, severe illness and death. As a result, the medicines become ineffective and infections persist in the body, increasing the risk of spread to others. Antimicrobials - including antibiotics, antivirals, antifungals and antiparasitics - are medicines used to prevent and treat infections in humans, animals and plants. Microorganisms that develop antimicrobial resistance are sometimes referred to as “superbugs”.

The rates of antimicrobial resistant bacteria causing serious and life-threatening infections are rapidly rising (WHO, 2014). This development is accelerated by selection pressures from the use and misuse of antimicrobial drugs (Holmes *et al.*, 2016, WHO, 2014). The rapid transmission of resistance genes between bacteria, combined with an increasingly connected world, further accelerates the spread of resistant strains on a global scale (Holmes *et al.*, 2016). The potential for antimicrobial resistant livestock pathogens to pass their resistance onto human pathogens, represents an alarming concern for the treatment of human infections with antibiotics that may already be rendered ineffective. To support the global surveillance of AMR, in May 2015, the WHO set up the Global Antimicrobial Resistance Surveillance System (GLASS) to establish a global standardized approach to the collection, analysis and sharing of data (WHO, 2015a). However, this initiative will not capture and provide insight into the use of antibiotics by all smallholder farmers, who are estimated to account for more than 90% of all farms worldwide (Lowder *et al.*, 2014). The preservation of antimicrobial efficacy and appropriate use of key agents and processes in the animal production environment is critical to ensuring we keep pace with the increasing global demand for protein food sources (Shaban *et al.*, 2014). In order that AMR does not derail food security and severely undermine human disease control, scientists and industry must foster innovation and research in the development of new measures and solutions to avoid the emergence and spread of antibacterial resistance.

Chemical contamination: unintentional and intentioned

Exposure to chemical hazards (agrochemicals, environmental/industrial contaminants, processing/storage derived contaminants, contact-material derived contaminants, biotoxins, or microplastics among others) is rising steadily as global population and pollution are increasing (King *et al.*, 2017) than can contaminate the food supply chain at any point, that also may be persistent and bio-accumulate in animals and humans, in the food chain. Acute impact on health is no so common and it largest impact on human health is through low-level repeated exposure. This makes the link between exposure and ill-health very difficult to establish, but there is increasing concern that chemical exposure may play a major role in the ethology of many disorders (Bergman *et al.*, 2013). The problem also is that the number of contaminants is growing and is more precise as analytical methodology improves and the capacity to determine new metabolites is more accurate. In addition, the climate change and global food transport also add to the complexity of this problem, as traditional and emerging contaminants are now appearing in regions never seen before (Zhu *et al.*, 2013).

The intentional adulteration of food for economic benefit is a global phenomenon that has occurred throughout history (Wilson, 2008). Food fraud for EFSA or Economically Motivated Adulteration (EMA) for FDA is about “any suspected intentional action by businesses or individuals for the purpose of deceiving purchasers and gaining undue advantage therefrom, in violation of the rules referred to in Article 1(2) of Regulation (EU) 2017/625 (the agri-food chain legislation)”. These intentional infringements to the EU agri-food chain legislation may hinder the proper functioning of the internal market and may also constitute a risk to human, animal or plant health, to animal welfare or to the environment as regards GMOs and plant protection products (Morin and Lees, 2013). Scandals such as the "rapeseed oil" fraud intended for industrial use (1981) affected about 20.000 people and led to between 370 and 835 fatalities in Spain, dioxin in Belgium resulting in massive economic losses (1999), milk adulterated with melamine in China resulting in more than 50.000 sick babies and around six fatalities (2008), and more recently, methanol poisoning from the sale of illegal spirits which caused around 59 casualties in the Czech Republic and Poland (2012-2014), horse meat in beef products (2013), fipronil in eggs (2017) and the slaughter of sick cows (2019) have also drawn worldwide attention (Morin and Lees, 2013). Against what happen to unintentional contamination, is often harder to detect and confirm as the motive is always to evade detection and adulterants are often employed that have a high degree of similarity to the product being adulterated. According to the EMA Incidents Database, fish and seafood are by far the most impacted food category followed by dairy products, and oils and fats (King *et al.*, 2017). The FDA Food Safety Modernization Act (FSMA) contains a final rule aimed at preventing intentional adulteration from acts intended to cause wide-scale harm to public health, including acts of terrorism targeting the food supply (FDA, 2011). However, a global whole-of-system approach with multidisciplinary input from scientists (e.g., testing methods), regulators (e.g., policy frameworks) and industry (e.g., simplification of supply chains), will be required (King *et al.*, 2017).

Among the intentioned contamination is the Food Contact Materials (FCMs) and their associated health risks. Food contact materials are all materials and articles intended to come into contact with food, such as packaging and containers, kitchen equipment, cutlery and dishes. These can be made from a variety of materials including plastics, rubber, paper and metal. General requirements for all food contact materials are laid down in Framework Regulation (EC) 1935/2004. Good Manufacturing Practice for materials and articles intended to come in contact with food is described in Regulation (EC) 2023/2006. There are also EU regulations for specific materials: ceramics, regenerated cellulose film, plastics, recycled plastics and active and intelligent materials. In addition, some directives cover single substances or groups of substances used in the manufacture of food contact materials. Food contact materials must not transfer their components into the foods in unacceptable quantities (migration). This relies on insuring that during contact there is no migration of unsafe levels of chemical substances from the material to the food. EFSA adopts and publishes scientific opinions and provides scientific advice for risk managers on the safety of substances used or intended to be used to manufacture materials which come into contact with food as well as the safety of related processes (e.g. recycling of plastics). The most important materials are bisphenol A, plastics and plastic recycling, non-plastic food contact materials, and active and intelligent packaging substances

Allergens and intolerances

EFSA's Panel on Dietetic Products, Nutrition and Allergies (NDA) points out that the prevalence of food allergies is difficult to establish because of a scarcity of studies available for some geographical areas and the use of different methodologies to gather prevalence data. However, using food challenges as a criterion for diagnosis, the prevalence of food allergies across Europe has been estimated at around 1% for both, adults and children (EFSA, 2014), and other authors (Leung *et al.*, 2014) consider that food allergies affect approximately 3.5-4.0% of the world's population and are increasing in developed and developing countries (Prescott *et al.*, 2013). The complexity in protection of food-allergic consumers lies in the fact that, unlike bacterial or viral contamination which negatively affects everybody, the presence of allergens is only relevant to a susceptible segment of the population; of which the outcome of consumption could potentially be fatal (King *et al.*, 2017). Most developed countries mandate labelling of the most common allergenic foods, as well as ingredients derived from those foods in accordance with the 1999 Codex Alimentarius (Codex) guidelines (Codex Alimentarius, 1999). Precautionary allergen labelling (PAL), also called advisory labelling, refers to the voluntary labelling to indicate that one or more regulated allergens could be unintentionally, but unavoidably, present in a product, and thus pose a risk to susceptible consumers. At the EU Any allergens present must be emphasised in the list of ingredients, for example by using a different font, letter size or background colour. In the absence of a list of ingredients, the indication of allergens must include the word ‘contains' followed by the name of the allergen (Regulation (EC) No 1169/2011). However, in the vast majority of countries, the use of PAL is not regulated by legislation and a formal risk assessment is not performed (Allen *et al.*, 2014). To this end, the VITAL (Voluntary Incidental Trace Allergen Labelling) Program of the Allergen Bureau of Australia & New Zealand (ABA), was created to provide a standardized allergen risk assessment process for the food industry. In addition, uncertainty over the risk posed to allergic individuals by even minute residual traces of allergen has prompted many food manufacturers to provide advice as to the potential for unintentional contamination with allergens during manufacture in the form of Precautionary Allergen Labelling (PAL) (King *et al.*, 2017). More than 170 foods have been identified as potentially allergenic and novel food sources are now being explored in an effort to solve the future food insecurity problem (Houben *et al.*, 2016, Verhoeckx *et al.*, 2016), and dietary patterns between countries can also lead to differences in allergenicity to specific foods (Lee *et al.*, 2008)

New technologies and food security

Different new technologies are in our life at an early stage of development and per se have no influence on food security but there are some potential impacts pending on their uses. Regulation is also an issue on debate and need further development. Technologies such as TALENs (transcription activator-like effector nucleases) or CRISPR/Cas9 (clustered regularly interspaced short palindromic repeat), allow directed modification of specific DNA sequences at their normal chromosomal locations, with an impact on the animal and plant products that although may occur naturally, or by traditional breeding methods (Carroll and Charo, 2015), but that with these genome editing technologies became a potential food safety risk. These advanced technologies bring to the debate of the nineties and early twenty-first century about the transgenic food production, now normalized, legislated and assumed by the consumers. Transparency of use and accuracy of outcomes may pave the way for sensible policies for their regulation and use (Editorial, 2016). Effective risk communication efforts out to the public related to the whole area of whole genome editing is definitely needed (King *et al.*, 2017).

Another emerging technology is based on small size, the nanotechnology (nano sized are around 100 nm or less in size.), which as penetrate every aspect of food production (Hannon, *et al.*, 2015), but it has centred on novel food packaging materials or enhance the nutritional value of a product, and there are a number of commercial products currently available (Bumbudsanpharoke and Ko, 2015). The approval of products sold in Europe is the responsibility of the EC and Member States. EFSA would not be in a position to know about what is on the market as it is not our responsibility, but the technology exists for some applications, and products may be available from outside of Europe that could contain nano sized substances either in the product or its packaging. However, due to a lack of specific regulations and harmonization in the nanotechnology area, it is difficult to approximate its overall use worldwide (Coles and Frewer, 2013). Regulation is not within the remit of EFSA, which provides independent scientific advice to risk managers. It is the responsibility of risk managers to consider appropriate measures and assess existing legislation, in light of EFSA's opinions. Wide diversity exists in the current status of regulations and legislation on nanomaterials in food packaging by country (Bumbudsanpharoke and Ko, 2015). There must be international cooperation in the pursuit of nano-safety, since nanoparticles may well be difficult to detect in imported packaged goods. As the opportunities for the use of nanoparticles in the food production industry are infinite, more research in this space is warranted through a combined effort of food regulators, authorities and industry at a local and global scale.

3.3. Advances in food safety and technology

The role of the food enterprises on ensuring food safety: processing, packaging and traceability.

Food manufacturers are continuously challenged by consumer expectations for products that are pathogen-free and minimally processed, in a globalised food market where supply chains are getting longer (King *et al.*, 2017). Recent food preservation, processing or packaging technologies and trends, although have clear benefits (mild treatment, extended product shelf-life, "fresher" quality, RTE pre-cooked convenience), also bring potential safety risks to the consumer level: incomplete microbial inactivation, possibly not respecting proper storage conditions and expiration dates, undercooking, and generation of stress-resistant microorganisms (Cheftel, 2011). This emphasizes the need to develop and implement novel food processing and preservation methods to improve food safety throughout the food chain (King *et al.*, 2017). In addition, not all technologies are equally accepted by consumers such as food irradiation that is highly controversial (Siegrist *et al.*, 2006) or high-pressure processing (HPP) (Hurtado *et al.*, 2015). Combined with processing is food-packaging which challenges it to extend packaged food self-life maintaining safety and quality. This innovation is linked to smart packaging that refers to packaging systems with embedded sensor technology used with foods, pharmaceuticals, and many other types of products. It is used to extend shelf life, monitor freshness, display information on quality, and improve product and customer safety (Siró, 2012). As regulatory agencies move towards outcome-based regulations, it will become increasingly necessary for the food industry to have a variety of inactivation technologies and smart packaging at their disposal and rely safety to the consumers.

For consumers and food industry, food traceability (FT) is essential to provide confidence about the food safety. FT is the ability to track any food, feed, or substance destined for consumption through all stages of the supply chain. Within the EU, there is increasing demand from consumers, businesses and institutions to have more transparent, direct access to information about where and how food is produced, processed, packed, transported and distributed. FT is crucial to ensure that food products are safe for consumers to eat to prevent contaminated food from reaching consumers, and to enable targeted withdrawals of products (thus minimising waste and disruption to trade). An increase in global trade of food items, has led to a heightened need to be able to trace affected products internationally and domestically when there is an incidence of foodborne illness or animal or plant disease. Traceback is essential during the initial stages of an outbreak, to quickly identify the potential source of the outbreak. Timely identification of the source of the outbreak can result in the outbreak being stopped in its tracks. This results in smaller outbreaks, a reduction in spoiled food due to the rapid identification of the right food involved in the outbreak, prevention of future outbreaks due to the ability to trace a problem back to a herd or a farm and, an enhanced ability to quickly implement measures to identify and eliminate the problem at its source. Many developed countries have implemented new legal requirements for traceability, and exporting countries are under pressure to comply with the regulations set up by importing countries. Charlebois *et al.* (2014) examined existing global food traceability regulations in 21 major OECD countries and found that none of the countries had an electronic tracking system for all commodities, highlighting the need for more advanced traceability systems for other domestic and imported products.

Risk assessment tools

Predictive microbiology (PM) for hazard estimation

PM involves knowledge of microbial growth responses to environmental factors summarized as equations or mathematical models, and has demonstrated a broad utility within the food industry and can aid in quantitative risk assessment and decision-making during Hazard Analysis for Critical Control Point (HACCP) planning, estimation of the shelf-life of foods and in the design or reformulation of food products (McMeekin *et al.*, 2002). Predictive microbiology models are commonly used to quantify the human exposure of bacteria through the ingestion of foods. To translate these concepts into food safety levels, risk-based metrics are used as a systematic approach to food safety based on hazard identification and control. Transfer of the knowledge of predictive microbiology into real world food manufacturing applications will continue to rise with the development of open, community driven and web-based predictive microbial model repositories (Plaza-Rodríguez *et al.*, 2015).

Chemical risk assessment and safety evaluations

As well as microbiological risks, evaluation of chemical ones have advanced and has developed as an important tool for food safety evaluation. Chemical risk-based approaches are based on reliable exposure estimates, taking into account uncertainties in exposure assessment. Of equal importance is the elucidation and appropriate consideration of the mode of action (MOA), which needs to be put into perspective with an appropriate estimate of consumer exposure (King *et al.*, 2017).

A hazard-based element also is intrinsic to the so-called threshold of toxicological concern (TTC) concept, which provides a generic approach to the safety assessment of chemicals with no or insufficient toxicological data (Barlow, 2005). TTC is a concept that refers to the establishment of a level of exposure for all chemicals, whether or not there are chemical-specific toxicity data, below which there would be no appreciable risk to human health. The European Food Safety Authority (EFSA) and WHO embarked on a project to review the current approach and proposed some modifications (EFSA/WHO, 2015).

The ability to accurately determine the concentration of a particular contaminant in a food matrix is critical for the evaluation of potential risk to the consumer. As a result, innovative analytical approaches are continuously being developed as a response to the ever-growing number of contaminants already present in food or emerging risks threatening to enter the food supply chain. The main pursuit of many analytical approaches revolves around obtaining a higher sensitivity for difficult-to-detect contaminants and, a reduction in cost and analysis time per sample (King *et al.*, 2017).

The determination of suitable biomarkers in human/animal biological fluids (e.g., serum, plasma, urine, breast milk and others) or in tissue biopsies has also allowed for more accurate population exposure estimates for hazardous contaminants. It requires detailed knowledge of the metabolism of the respective compound to focus on specific metabolites as quantitative exposure indicators (Eisenbrand, 2015).

The integration of omics data into mechanistic predictive models also holds the promise of providing more accurate predictions under specific physical and chemical changes and extending the model outside the range of space bounded by observations (Pérez-Rodríguez and Valero, 2013).

Omics and big data

Genomics (including metagenomics), transcriptomics and proteomics are rapidly transforming our approaches to detection, prevention and treatment of foodborne pathogens. Microbial genome sequencing in particular has evolved from a research tool into an approach that can be used to characterize foodborne pathogen isolates as part of routine surveillance systems. Genome sequencing efforts will not only improve outbreak detection and source tracking, but will also create large amounts of foodborne pathogen genome sequence data, which will be available for data mining efforts that could facilitate better source attribution and provide new insights into foodborne pathogen biology and transmission. While practical uses and application of metagenomics, transcriptomics, and proteomics data and associated tools are less prominent, these tools are also starting to yield practical food safety solutions (Bergholz *et al.*, 2014). One of the most promising applications of metagenomics is the ability to detect and identify previously unknown pathogens in food matrices and food-associated environments, including viruses. The CDC estimates that around 80% of foodborne disease cases in the U.S. are caused by unspecified agents (Scallan *et al.*, 2011), indicating that a better foodborne disease surveillance system is required to address the current knowledge gap concerning unknown and unidentified foodborne agents (Aw *et al.*, 2016).

Big data

The continuing progress in genomics, transcriptomics, proteomics, and metabolomics in combination with novel tools in bioinformatics and system biology, has brought about promising new avenues toward improved toxic hazards characterization and this is expected to be further developed in the years to come. While whole animal toxicity studies remain the centrepiece of current regulatory frameworks, animal welfare concerns, high cost, and questions around the ability to accurately predict in-vivo tissue functions in humans have fuelled interest in alternative approaches. For example, current alternative techniques in development include microfluidic organs-on-chips (Bhatia and Ingber, 2014), 'omics' techniques (e.g., transcriptomic fingerprinting of appropriate cell cultures) (Pielaat *et al.*, 2013) and computational estimation methods for predicting acute and chronic systemic toxicity (Lapenna *et al.*, 2010).

Big data represents high volume, high velocity, high veracity, and/or high variety information assets that require new forms of processing to enable enhanced decision-making, insight discovery and process optimization (Wiedmann, 2015). Most uses of large datasets and big data analytics in food safety and quality to date focus on providing improved root cause and retrospective analyses, but development and use of predictive analytics in food safety is likely to grow quickly in the near future (Wiedmann, 2015).

There is a definite and important need for the industry to take action to prepare to take advantage of big-data tools and solutions for food safety and quality dilemmas. Data integration and ownership will be some of the most important challenges that the food industry will need to address. Big data processing and consequent outcomes will need to be shared amongst producers, retailers, health authorities and regulators.

Transparency and sustainability in communication and public perception of food safety

Who is responsible of food safety issues to the consumers? This is a complex question, because on one hand the health authorities have the independent scientific information but the media (professional and not professional) are faster to communicate such an information at the time that imprecise. The globalization of news (e.g., TV, Internet) has resulted in the ability for news to spread quickly and cause unfavourable economic consequences for producers (King *et al.*, 2017). The media is widely reported as amplifying and misrepresenting the risk posed by food incidents, diminishing trust in the food supply (Henderson *et al.*, 2014). For this reason, consumers may have a negative perception due, among several reasons, to the fact that information is not always reliable if coming from the media, or not clear enough if coming from the authorities. Nevertheless, this situation has prompted calls for increasing the transparency of risk assessment in the EU food chain. In January 2018, the European Commission published the report that identifies some shortcomings, such as the lack of transparency of EFSA risk assessments and national authorities' inconsistent interpretation and enforcement of existing EU food regulations. It also points at persisting regulatory gaps, and insufficient EU action to tackle nutrition issues and misleading food labelling practices. A general plan for risk communication has been adopted, ensuring a comprehensive communication framework throughout the risk analysis process, combined with open dialogue amongst all interested parties. The benefits of social media for food safety risk communicators include speed, accessibility and interactive capacity when raising awareness about an issue or during crisis communications, and may lead to a social amplification of risk perception, wherein risks assessed by technical experts as relatively minor elicit strong public concerns (Chapman *et al.*, 2014). Misinformation and false assertions may be easily disseminated via social media with or without malicious intent and be widely believed (Chapman *et al.*, 2014). Of particular concern is the significant and expanding role of "influencers"; individuals (often with no background in food safety or food science) communicating about food safety issues through online social media and significantly influencing public perceptions of food safety. The challenge for influencers in online social media is to be conscientious about providing balanced, complete, and accurate food-related information to consumers (Byrd-Bredbenner *et al.*, 2015). This may be easier said than done. Care needs to be taken, as the public may avoid certain foods which are not risky and eat other foods that are of a high risk, especially in high-risk households (King *et al.*, 2017).

Conclusions

Ensuring food safety for food security is not an easy challenge for the future, considering the wide range of trends in the population growth, behaviour and environmental determinants. In the future, the world will need to feed over 9 billion people, requiring substantially increased efforts towards dependable, safe and sustainable food production, and without food safety, we cannot have food security and achieve the SDGs. Food security, in fact, may be seen as a prerequisite for societal development, and food safety systems will need to accommodate the needs of developed and developing economies. Technological development has to adapt also to future societal requirements of food security, safety and sustainability, at all levels of the food chain. Analytical specificity and sensitivity, the acknowledge of bioavailability from the matrix, the magnitude and frequency of exposures or precise biomarkers, are major determinants to assess the exposure to evaluate the risk assessment. Novel techniques, such as metabolomics, enable us to picture the totality of metabolites, the metabolome, in a given body fluid or compartment, and among new technologies WGS will be used extensively, to speed up trace-back outbreaks apply to faster detection and targeted control of outbreaks globally. This will allow the collection of comprehensive analytical information about specific food intakes and their biological impact. A big challenge arises from consumer understanding, both of food safety risks and/or perception of novel/emerging processing technologies which could reduce food safety risks. Efforts should also be intensified to create more harmonized and equivalent food safety standards and regulations, mechanisms to do this more quickly than is currently the case with unified and global databases. As mentioned, the trends, the risks and the advances in food safety and technology are here to overcome the challenge to ensure food safety for food security, keeping an eye on the unpredictable factors such as political or social factors. A flexible and responsive approach will be needed to adequately address the food challenges of the future.

References

Ahmed, S. M., Hall, A. J., Robinson, A. E., Verhoef, L., Premkumar, P., Parashar, U. D. and Lopman, B. A. (2014). Global prevalence of norovirus in cases of gastroenteritis: A systematic review and meta-analysis. *Lancet Infectious Diseases*, 14 (8) 725-730. Doi: 10.1016/S1473-3099(14)70767-4.

Aw, T. G., Wengert, S. and Rose, J. B. (2016). Metagenomic analysis of viruses associated with field-grown and retail lettuce identifies human and animal viruses. International *Journal of Food Microbiology*, 223, pp. 50-56. Doi: 10.1016/j.ijfoodmicro.2016.02.008.

Baert, L., Debevere, J. and Uyttendaele, M. (2009). The efficacy of preservation methods to inactivate foodborne viruses. *International Journal of Food Microbiology*, 131 (2–3), pp. 83-94. Doi: 10.1016/j.ijfoodmicro.2009.03.007.

Banik, D. and Miklian, J. (2017) “New Business: The Private Sector as a New Global Development Player”, Global Policy.

Barlow, S. Threshold of Toxicological Concern (TTC) – a tool for assessing substances of unknown toxicity present at low levels in the diet (2005).

Bergman, Å., Heindel, J. J., Jobling, S., Kidd, K. A. and Zoeller, R. T. (2013). Endocrine disrupting chemicals-2012.United Nations Environment Programme and the World Health Organization, Geneva, Switzerland.

Bergholz T. M., Moreno Switt A. I. and Wiedmann M. (2014). Omics approaches in food safety: fulfilling the promise? *Trends Microbiol.* May; 22(5): 275-281. Doi: 10.1016/j.tim.2014.01.006.

Bhatia, S.N. and Ingber, D. E. (2014). Microfluidic organs-on-chips. *Nature Biotechnology*, 32 (8), pp. 760-772. Doi: 10.1038/nbt.2989.

Bumbudsanpharoke, N. and Ko, S. (2015). Nano-food Packaging: An overview of market, migration research, and safety regulations. *Journal of Food Science*, 80 (5), pp. R910-R923. Doi: 10.1111/1750-3841.12861.

Byrd-Bredbenner C., Cohn M. N., Farber J. M., Harris L. J., Roberts T., Salin V., Singh M., Jaferi A. and Sperber W. H. (2015). Food safety considerations for innovative nutrition solutions. *Ann N Y Acad Sci. Jul*;1347:29-44. Doi: 10.1111/nyas.12779.

Carroll, D. and Charo, R. A. The societal opportunities and challenges of genome editing *Genome Biology*, 16 (1) (2015), pp. 1-9. Doi: 10.1186/s13059-015-0812-0.

Carter, M. (2005). Enterically infecting viruses: Pathogenicity, transmission and significance for food and waterborne infection. *Journal of Applied Microbiology*, 98 (6), pp. 1354-1380. Doi: 10.1111/j.1365-2672.2005.02635.x.

Chapman,B., Raymond, B. and Powell, D. (2014). Potential of social media as a tool to combat foodborne illness. *Perspectives in Public Health*, 134 (4) (2014), pp. 225-230. Doi: 10.1177/1757913914538015.

Charlebois, S., Sterling, B., Haratifar, S. and Naing S. K. (2014). Comparison of global food traceability regulations and requirements. *Comprehensive Reviews in Food Science and Food Safety*, 13 (5) (2014), pp. 1104-1123. Doi: 10.1111/1541-4337.12101.

Cheftel, J.C. (2011). Emerging risks related to food technology. *NATO Science for Peace and Security Series A: Chemistry and Biology* (2011), pp. 223-254. Doi: 10.1007/978-94-007-1100-6_13.

Coles, D. and Frewer, L. J. (2013). Nanotechnology applied to European food production – a review of ethical and regulatory issues. *Trends in Food Science & Technology*, 34 (1), pp. 32-43. Doi: 10.1016/j.tifs.2013.08.006.

Doane, D. (2016) "We Won't Conquer the Mountains of the SDGs Without Humility", The Guardian, https://www.theguardian.com/global-development-professionals-network/2016/jul/07/sdgs-progress-stay-humble. Accessed 20 Nov 2019

Doyle, M. P., Erickson, M. C., Alali, W., Cannon, J., Deng, X., Ortega, Y., Smith, M. A. and Zhao, T. (2015). The food industry's current and future role in preventing microbial foodborne illness within the United States. *Clin Infect Dis.* Jul 15; 61(2):252-259. Doi: 10.1093/cid/civ253.

EFSA (2014). Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific Opinion on the evaluation of allergenic foods and food ingredients for labelling purposes. *EFSA*

Journal, Volume12, Issue11. November, 3894. Doi: 10.2903/j.efsa.2014.3894

EFSA (2015). Outcome of the public consultation on the draft scientific opinion of the EFSA panel on contaminants in the food chain (CONTAM) on acrylamide in food. *EFSA Supporting Publications*, 12 (6). Doi: 10.2903/sp.efsa.2015.EN-817.

EFSA/WHO (2015). Threshold of toxicological concern approach: Conclusions and recommendations of the EFSA/WHO expert workshop. DRAFT for public consultation. https://www.efsa.europa.eu/sites/default/files/consultation/150212%2C0.pdf.

Eisenbrand, G. (2015). Current issues and perspectives in food safety and risk assessment. *Human & Experimental Toxicology*, 34 (12), pp. 1286-1290.Doi: 10.1177/0960327115598408.

FAO (2019) State of Food Security and Nutrition in the World, https://www.fao.org/publications/card/es/c/CA5162EN/.

Franklin, D. and Andrews, J. (2012). Megachange: The world in 2050, Vol. 105, John Wiley & Sons.

Godfray H. C., Beddington J. R., Crute I. R., Haddad L., Lawrence D., Muir J. F., Pretty J., Robinson S., Thomas S. M., Toulmin C. (2010). Food security: the challenge of feeding 9 billion people. *Science*. 2010 Feb 12;327(5967):812-818. Doi: 10.1126/science.1185383.

Hannon, J. C., Kerry, J., Cruz-Romero, M., Morris, M. and Cummins, E. (2015). Advances and challenges for the use of engineered nanoparticles in food contact materials. *Trends in Food Science & Technology*, 43 (1), pp. 43-62. Doi: 10.1016/j.tifs.2015.01.008.

Harder, T. C., Buda, S., Hengel, H., Beer, M. and Mettenleiter, T.C. (2016). Poultry food products—a source of avian influenza virus transmission to humans? *Clinical Microbiology and Infection*, 22 (2), pp. 141-146. Doi: 10.1016/j.cmi.2015.11.015.

Henderson, J., Wilson, A., Meyer, S. B., Coveney, J., Calnan, M., McCullum, D., Lloyd, S., Ward, P. R. (2014). The role of the media in construction and presentation of food risks. *Health, Risk & Society*, 16 (7–8), pp. 615-630. Doi: 10.1080/13698575.2014.966806.

Holmes, A. H., Moore, L. S., Sundsfjord, A., Steinbakk, M., Regmi, S., Karkey, A., Guerin, P.J., Piddock, L. J (2016). Understanding the mechanisms and drivers of antimicrobial resistance. *Lancet*. 2016 Jan 9;387(10014):176-87. Doi: 10.1016/S0140-6736(15)00473-0.

Houben, G., Burney, P., Chan, C. H., Crevel, R., Dubois, A., Faludi, R., Klein Entink, R., Knulst, A., Taylor, S. and Ronsmans, S. (2016). Prioritisation of allergenic foods with respect to public health relevance: Report from an ILSI Europe Food Allergy Task Force Expert

Group. *Food Chem Toxicol*. Mar; 89:8-18. Doi: 10.1016/j.fct.2015.12.028.

Hurtado, A., Picouet, P., Jofré, A., Guàrdia, M.D., Ros, J.M. and Bañón, S. (2015). Application of high pressure processing for obtaining "Fresh-Like" fruit smoothies. Food and Bioprocess Technology, 8 (12), pp. 2470-2482.

King, T., Cole, M.B., Farber, J.M., Eisenbrand, G., Zabaras, D., Fox, E.M., & Hill, J. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. Trends in Food Science and Technology, 68, 160-175. Doi: 10.1016/j.tifs.2017.08.014.

Koopmans, M. and Duizer, E. (2004). Foodborne viruses: an emerging problem. *Int J Food Microbiol*. Jan 1;90(1):23-41. Doi: 10.1016/s0168-1605(03)00169-7.

Lapenna, S., Gatnik, M. F. and Worth, A. P. (2010). Review of QSA R models and software tools for predicting acute and chronic systemic Toxicity: Publications office of the European Union Luxembourg.

Lee, B. W., Shek, L. P. -C., Gerez, I. F. A., Soh, S. E. and Van Bever, H. P. (2008). Food allergy–lessons from Asia. *World Allergy Organization Journal*, 1 (7) (2008), pp. 1-5. Doi: 10.1097/WOX.0b013e31817b7431.

Leung, P. S. C., Shu, S. -A. and Chang, C. (2014). The changing geoepidemiology of food allergies. *Clinical Reviews in Allergy & Immunology*, 46 (3), pp. 169-179. Doi: 10.1007/s12016-014-8411-5.

Li, D., De Keuckelaere, A. and Uyttendaele, M. (2015). Fate of foodborne viruses in the "Farm to Fork" chain of fresh produce. *Comprehensive Reviews in Food Science and Food Safety*, 14 (6), pp. 755-770. Doi: 10.1111/1541-4337.12163.

Locatelli, S. and Peeters, M. (2012). Non-Human Primates, Retroviruses, and zoonotic infection risks in the human population. *Nature Education Knowledge*, 3 (10), p. 62

Lowder, S.K., Skoet, J. and Singh, S. What do we really know about the number and distribution of farms and family farms worldwide? (2014). Background paper for The State of Food and Agriculture 2014

McMeekin, T.A., Olley, J., Ratkowsky, D.A. and Ross, T. (2002). Predictive microbiology: towards the interface and beyond. *Int J Food Microbiol*. Mar; 73(2-3): 395-407. Doi: 10.1016/s0168-1605(01)00663-8.

Morin, J. F. and Lees, M. (2013). FI Handbook on Food Authenticity Issues and Related Analytical Techniques. ISBN electronic version 978-2-9566303-1-9.

Pallottino, P., Hakola, L., Costa, C., Antonucci, F., Figorilli, S., Seisto, A., and Menesatti, P. (2016). Printing on food or food printing: A review. *Food and Bioprocess Technology*, pp. 1-9. Doi: 10.1007/s11947-016-1692-3.

Parkin, M., Shepherd, J., Hall, R. and Hill, J. (2007). Meeting the needs of markets and customers - ensuring the regulatory building blocks are in place. *The Australian Journal of Dairy Technology*, 62 (2), pp. 116-121

Pérez-Rodriguez, F., and Valero, A. (2013). Predictive microbiology in foods. R.W. Hartel (Ed.), Predictive microbiology in foods, Springer, pp. 1-10

Pielaat, A., Barker, G., Hendriksen, P., Hollman, P., Peijnenburg, A. and Ter Kuile, B. (2013). A foresight study on emerging technologies: State of the art of omics technologies and potential applications in food and feed safety. *EFSA Supporting Publications*, 10 (10). Doi: 10.2903/sp.efsa.2013.EN-495.

Plaza-Rodríguez, C., Thoens, C., Falenski, A., Weiser, A. A., Appel, B., Kaesbohrer, A. and Filter, M. (2015). A strategy to establish Food Safety Model Repositories. *Int J Food Microbiol*. Jul 2; 204:81-90. doi: 10.1016/j.ijfoodmicro.2015.03.010.

Prescott, S. L., Pawankar, R., Allen, K. J., Campbell, D. E., Sinn, J. Kh, Fiocchi, A., Ebisawa, M., Sampson, H. A., Beyer, K., Lee, B. W. (2013). A global survey of changing patterns of food allergy burden in children. *World Allergy Organ J.* Dec 4; 6(1): 21. Doi: 10.1186/1939-4551-6-21.

Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC.

Regulation (EC) No 2023/2006 of 22 December 2006 on good manufacturing practice for materials and articles intended to come into contact with food.

Regulation (EC) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

Regulation (EC) 1381/2019 of the European Parliament and of the Council of 20 June 2019 on the transparency and sustainability of the EU risk assessment in the food chain.

Scallan, E., Griffin, P. M., Angulo, F. J., Tauxe, R. V., Hoekstra, R. M. (2011). Foodborne illness acquired in the United States-unspecified agents. *Emerg Infect Dis.* 2011 Jan; 17(1): 16-22. Doi: 10.3201/eid1701.091101p2.

Shaban, R.Z., Simon, G.I., Trott, D.J., Turnidge, J. and Jordan, D. (2914). Surveillance and reporting of antimicrobial resistance and antibiotic usage in animals and agriculture in Australia.

Siegrist, M., Keller, C., and Kiers, H. A. L. (2006). Lay people's perception of food hazards: Comparing aggregated data and individual data. *Appetite*, 47 (3), pp. 324-332. Doi:

10.1016/j.appet.2006.05.012

Siró, I. (2012). Active and intelligent packaging of food Progress in food preservation Wiley-Blackwell.

Stals, A., Baert, L., Van Coillie, E. and Uyttendaele, M. (2012). Extraction of food-borne viruses from food samples: A review. *International Journal of Food Microbiology*, 153 (1), pp. 1-9. Doi: 10.1016/j.ijfoodmicro.2011.10.014.

Stewart, L.D. and Elliott, C.T. (2015). The impact of climate change on existing and emerging microbial threats across the food chain: An island of Ireland perspective. *Trends in Food Science & Technology*, 44 (1), pp. 11-20. Doi: 10.1016/j.tifs.2015.04.007.

Sun, J., Peng, Z., Zhou, W., Fuh, J.Y.H., Hong, G.S. and Chiu, A. (2015). A review on 3D printing for customized food fabrication. *Procedia Manufacturing*, 1, pp. 308-319. Doi: 10.1016/j.promfg.2015.09.057

Todd, E. and Grieg, J. (2015). Viruses of foodborne origin: A review. *Virus Adaptation and Treatment*, 7, pp. 25-45. Doi: 10.2147/VAAT.S50108.

UN (2015). Transforming our world: The 2030 agenda for sustainable development.

UN (2019). The Sustainable Development Goals Report 2019, https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf

van der Mensbrugghe, D., Osorio-Rodarte, I., Burns, A., and Baffes, J. (2009). Macroeconomic environment, commodity markets: A longer term outlook. Paper presented at the Expert Meeting on How to feed the World in 2050 FAO Headquarters, Rome, Italy.

Verhoeckx, K., Broekman, H., Knulst, A. and Houben, G. (2016). Allergenicity assessment strategy for novel food proteins and protein sources. *Regulatory Toxicology and Pharmacology*, 79, pp. 118-124. Doi: 10.1016/j.yrtph.2016.03.016

WHO. Antimicrobial resistance global report on surveillance. (2014)

WHO, (2015). WHO. Global antimicrobial resistance surveillance System: Manual for early implementation.

Wiedmannm, M. (2015). Can big data revolutionize food Safety? Food quality and safety. Retrieved from http://www.foodqualityandsafety.com/article/can-big-data-revolutionize-food-safety/

Yang, F., Zhang, M. and Bhandari, B. (2017). Recent development in 3D food printing. Critical Reviews in Food Science and Nutrition, 57 (14), pp. 3145-3153. Doi: DOI: 10.1080/10408398.2015.1094732.

Zhu, N., Fu, J., Gao, Y., Ssebugere, P., Wang, Y. and Jiang, G. (2013).

Hexabromocyclododecane in alpine fish from the Tibetan Plateau, China. Environmental Pollution, 181, pp. 7-13. Doi: 10.1016/j.envpol.2013.05.050.