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FROM FARM TO FORK AND FURTHER:

RESEARCH TACKLING THE GRAND
CHALLENGE OF FOOD SAFETY IN
EUROPE

THE HAGUE CENTRE FOR STRATEGIC STUDIES AND TNO



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TNO and The Hague Centre for Strategic Studies (HCSS) program Strategy & Change analyzes global trends in a dynamic world affecting the foundations of our security, welfare, and well-being.

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THE GRAND CHALLENGES PROJECT

Over the past century, Europe has become more and more prosperous. We are healthier, richer, safer, and live longer than ever before. But there is a downside to this success: it poses new challenges that threaten our future well-being. Ironically, many of these challenges are the price we pay for progress. Our economic growth comes at the cost of a changing climate and resource scarcity; new technologies breed new types of international organized crime; modern lifestyles lead to new diseases; increasing life expectancy puts pressure on public finances; and new production patterns lead to food safety concerns. Policymakers, researchers, companies, and citizens in Europe need to look at ways to deal with these trends. The Grand Challenges project aims to further the debate by exploring how we can use research and development to tackle the most pressing societal challenges to Europe's future. In six separate reports, we highlight grand challenges on six key issues. We show how these challenges may impact Europe's future and look at the potential of applied science to address these challenges and create new opportunities for European societies.

MANAGEMENT SUMMARY

Food in the European Union has never been safer and we have never had such advanced systems protecting us against food safety risks. Europe has some of the lowest rates of known food-borne illnesses in the world. Despite this, biological, chemical, allergenic and physical hazards are still present. Food safety has been described as a major concern shared by all Europeans in the context of the EU's forthcoming research framework program, Horizon 2020.¹ New and more complex challenges keep emerging, as evidenced by the deadly outbreak of E. coli in 2011. As food safety problems of the past, including basic hygiene, become easier to address, future risks become harder to manage. This paradox of progress lies at the heart of this report. In what follows, we demonstrate the need for scientific and technological research to address three key risk categories which, if left unaddressed, threaten to become the food safety crises of tomorrow.

Europe's most salient food safety risks are changing in origin and nature. In the first part of the report we examine a wide range of foresight studies to look at the drivers behind our new challenges. The most important ones are:

- **Globalization:** the food chain has become so long and complex that it is better described as a food network. We get our food from a widening variety of distant places, many with less stringent food safety practices. As a result, there are more points in this network at which food can become contaminated. Monitoring this is becoming ever more difficult.
- **Changing consumption and production patterns:** an increasing demand for meat creates a need for more intensive farming, which raises the risk of zoonotic diseases. Furthermore, intensive farming often involves more

1 European Commission, 'The EU Framework Programme for Research and Innovation.', January 10, 2012, http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020

extensive use of antibiotics; these will become less effective as bacteria become resistant.

- **Innovation:** consumption of more exotic and varied food and the development of novel proteins to alleviate the demand for meat mean a wider range of molecules to which people can be allergic, resulting in serious and even life-threatening reactions.

These drivers give rise to three issues of concern:

- **Antibiotic resistance:** bacteria are becoming resistant to the medications we use to drive them out. In other words, our arsenal against bacterial diseases is shrinking. This is a serious problem, as people who get ill from drug-resistant bacteria tend to suffer worse and for longer than those infected with other strains.
- **Chemical hazards:** food occasionally reaches supermarkets contaminated with toxic chemicals. There may be other chemical hazards we are unaware of, and we do not yet know the long-term effects of many chemicals present in our food.
- **Allergenicity:** allergies are a rising problem in Europe, with 2-3% of the population thought to suffer from food allergy, a figure even higher among children. There is currently no standard guidance on how to indicate the risk level of allergens. This creates uncertainty and risk for allergy sufferers, undermining their quality of life with potentially disastrous consequences.

These challenges pose the question of which countries are best equipped to effectively prevent food-borne illnesses and tackle these future food safety challenges. To answer this question, we present a map that shows how countries score on four key food safety indicators. It reveals that the long-standing EU members such as Spain and Italy perform well in addressing food safety risks. Newer members of the EU do less well, with Bulgaria and Cyprus achieving lower scores.

In the second part, we look at how research is involved in tackling food safety. We begin by looking at the number of projects and researchers in countries spearheading food safety research. Our analysis reveals a heavy concentration in the US. However, when we look at a measure indicating the relative research focus on food safety expressed by the number of food safety researchers as a percentage of the total number of researchers in all

disciplines, it becomes clear that a number of EU Member States also perform well. A similar picture emerges when we express the number of food safety researchers as a ratio of a country's total research budget. We also pinpoint 45 of the world research 'centers of excellence' for food safety. The majority of these are in the US and Europe.

When looking at food safety research funded by the EU, we find that increasing funds are allocated to three emerging research areas: detection and tracing methods to better identify contaminations; modeling to provide better understanding of the contents and structure of food; and 'intelligent' packaging, which uses new systems to indicate the safety of food.

Also of interest is the private sector involvement in food safety research. Here, safety generally plays second fiddle to more lucrative areas of innovation which aim to make food more appealing or last longer. We nonetheless find a high degree of involvement of the private sector in EU-funded research on food safety. This often concerns firms that are suppliers of food safety technologies or buyers who can make use of them.

Finally, in the third part we assess the extent to which current research tracks are meeting our future food safety needs. We return to the key risk categories highlighted above and point to areas of future research which will be crucial to meeting the grand challenge of food safety:

- On **antibiotic resistance**, research is needed to develop new methods for assessment, tools for monitoring, and products such as vaccines, all of which will ease demand for antibiotics. Scientific guidelines for the rational and socially responsible use of antibiotics would also be of great benefit. In addition, surveillance and epidemiological data are vital in mapping and forecasting the spread of disease and making more efficient use of the antibiotics we do use.
- For identifying **chemical hazards**, methods to detect toxic chemicals in our food are currently expensive and inefficient. They require extensive and often unnecessarily detailed analysis of the myriad of substances within a food product, while requiring a great deal of time, animals and resources. They are also limited to known hazards, so they cannot expect the unexpected. Research ought to focus on developing methods of assessing the presence and safety of a vast array of chemicals within

complex food products. The ongoing research on detection can help by making tests more financially feasible and increasing the number of targeted substances.

- Research and regulation are badly needed in order to stop **food allergy** from plaguing the lives of Europeans in the future. Rational criteria based on scientific research are indispensable in addressing the lack of standard methods and requirements for the assessment and signaling of the presence and chances of contamination of allergens.

These research areas can have visible impact on food safety in Europe in years to come by potentially reducing the number of food-borne illnesses due to improved consumer and supplier capabilities in the prevention, management and identification of contaminated or dangerous foods. By identifying the challenges of the future and addressing them in the present, research can help ensure the safety of our food from farm to fork and further.

INTRODUCTION

Europe's food has never been safer, yet new risks are emerging which were of less concern before. Our grasp of basic food hygiene has turned our attention to food safety risks of increasing complexity. This story of success leading to ever tougher challenges has been referred to as a 'paradox of progress'.² This report explores the multiple food safety challenges facing European countries and how research and technology can contribute to improving food safety.

BACKGROUND

European food risk management is, by many standards, highly advanced. An extensive and complex system of governance is supported by the European Food Safety Authority (EFSA), which works in combination with national food regulators in the Member States. A Rapid Alert System is in place for coordinating warnings across the Union. Ever more exacting regulations are under constant scrutiny and revision. As a result, Europe has some of the lowest rates of known food-borne illnesses in the world, with developing countries relatively far worse hit by the effects of unsafe food.³

Despite this, European citizens' confidence in the food they eat is periodically shaken by fears that what they eat could do them harm. These scares can be exacerbated by the media, however they also reflect risks genuinely present in the European food chain which are caused by various drivers and have potentially lethal effects on Europeans' health. These drivers are closely linked to trends of increasing prosperity, globalization,

2 European Commission, 'The Paradox of Progress,' European Commission, 06 2011, http://ec.europa.eu/research/fp6/index_en.cfm?p=5.

3 World Health Organization, 'Food Safety and Foodborne Illness,' *Media Centre*, March 2007, <http://www.who.int/mediacentre/factsheets/fs237/en/index.html>.

and scientific advancement. They replace rudimentary tasks, such as basic hygiene, with complex, elusive challenges such as increasingly intricate food chains (better described as networks); antimicrobial resistance; food allergies; and unidentified and undetected harmful chemicals.

In eliminating or mitigating these risks, research is crucial. Adequately responding to these challenges will require the use of various instruments, from improved regulation to better education and the use of technology. New and developing methods to prevent, detect and remove harmful agents at every point of the food chain are essential to ensuring a safe food supply. The role research can play in tackling the challenge of food safety for Europe is increasingly recognized. This is illustrated by Europe's new Framework Programme Horizon 2020, which lists 'ensuring food security and safety' as a major concern shared by all Europeans and one of the main challenges for research to focus on.⁴

STRUCTURE AND SCOPE

The objective of this report is threefold. First, we outline the main forms which food safety risks take (biological, chemical, allergenic and physical). We look at specific risks which, if left unaddressed, could materialize as outbreaks or even crises in the future.

The risks, their associated drivers and their potential effects are detailed based on evidence from academic journals, news reports and health agency websites. Second, we provide an overview of ongoing food safety research that focuses on developing technologies to mitigate the risks discussed in the first section. Third, the report identifies avenues for future research and concludes with an assessment of the most promising research opportunities based on the specific risks identified in the first part.

4 European Commission, 'The EU Framework Programme for Research and Innovation.:'; Scottish Parliament, 'Horizon 2020 Inquiry,' *Scottish Parliament*, November 30, 2011, <http://www.scottish.parliament.uk/parliamentarybusiness/CurrentCommittees/45921.aspx>.

BOX 1 KEY TERMS

Food Safety: when food safety risks are eliminated or mitigated or if food is already safe by design, thus limiting potential health damage.

Food Safety Risks: potential causes of negative food-related health effects which informed consumers are unable to avoid. These risks are biological, physical, chemical and allergenic. In each of these cases, the risk is that food can contain one or more contaminants which damage the health of the consumer. When these risks materialize by making people ill, an outbreak may be recorded.

Outbreak: the European Food Safety Authority defines this as 'incidences of two or more human cases of the same disease or infection in which the cases are linked or are probably linked to the same food source.'⁵

This report deals exclusively with negative health effects which result when otherwise safe food is contaminated. The focus of this report is on research into technological measures aimed at improving food safety by avoiding, eliminating, or mitigating biological, physical, chemical, and allergenic risks. We are chiefly concerned with the risk of direct exposure to food which causes disease. Beyond our scope therefore are health risks related to malnutrition, which includes undernutrition (and its consequences such as deficiencies), overnutrition (and its consequences such as hypertension and obesity) or nutritional imbalances. Though research in these fields is important, such safety issues arise from normative choices. They can therefore be considered risks that informed consumers are able to avoid. We also recognize that many risks are associated with the food industry in an indirect way, for example the concerns surrounding avian influenza which could be passed from farm animal to human and then from human to human. Similarly, the outbreak of hantavirus in the US highlights food as one possible transmission route.⁶ We set aside these outbreaks of disease because they are only indirectly or partially related to food.

5 European Food Safety Authority and European Centre for Disease Prevention and Control, 'The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2010,' *European Food Safety Authority Journal* 10, no. 3 (11 2012): 2597.

6 Centers for Disease Control and Prevention, 'How People Get Hantavirus Pulmonary Syndrome (HPS),' *Centers for Disease Control and Prevention*, August 29, 2012, <http://www.cdc.gov/hantavirus/hps/transmission.html>.

1 FOOD SAFETY CHALLENGE IN EUROPE

This part looks into food safety in Europe and starts with an overview of the current situation in section 1.1. On the basis of a selection of indicators, a map was created showing the overall status of food safety in Europe. This is followed by an overview in section 1.2 of some of the important changes in our society which are driving changes in food safety. Then in sections 1.3-1.6 we examine in detail the types of risks and how they are evolving. This allows us to identify specific risks which need to be addressed by future research. This part concludes by combining the drivers with the types of risk to identify three major areas of risk likely to require attention in the future.

1.1 CURRENT AND FUTURE FOOD SAFETY SITUATION

To assess which countries are performing best in preventing their citizens falling victim to food-borne illnesses, we have created a 'Food Safety Performance Monitor'. We looked at four key indicators of performance in terms of *vulnerability*, *measures taken* and *outcomes*. The combination of these indicators results in a food safety performance score, shown on the map in Figure 1.⁷ The map shows a considerably better food safety situation among states with longer-standing membership to the EU when compared to those who joined in 2004 and 2007. Spain and Italy perform particularly well.⁸

7 More details on our methodology can be found in Appendix 1.

8 For a more detailed analysis of the results, see the HCSS Food Performance Monitor, available at <http://projects.hcss.nl/monitor/>.

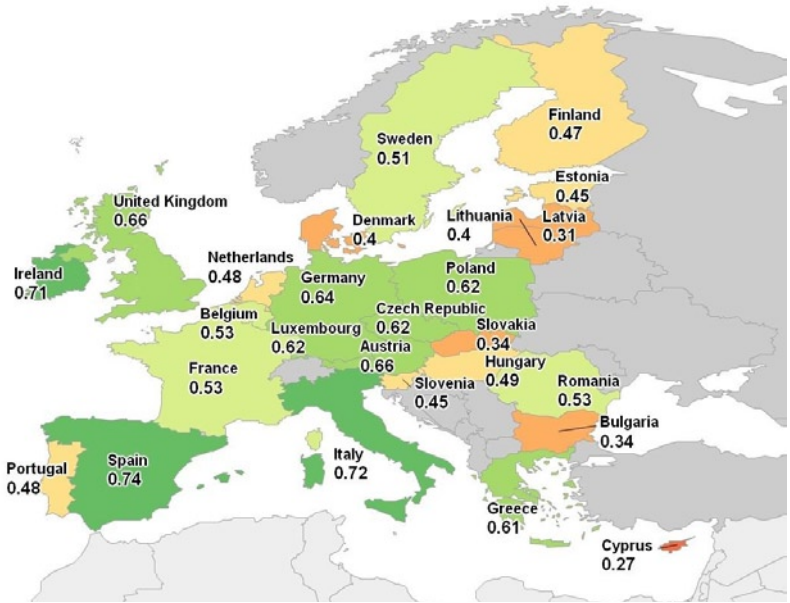


FIGURE 1 OVERALL FOOD SAFETY PERFORMANCE IN EUROPE. HIGHER SCORES INDICATE BETTER PERFORMANCE.

In the future, food safety is likely to be affected by three major trends. These are globalization, changing production practices, and innovation.

As a result of **globalization**, the risks of contamination become more serious as the complexity of the food supply chain—better referred to as a network—increases. In the coming years, food transportation networks are likely to become ever more international. Changing **production** patterns will also exacerbate certain risks. Changing methods such as increasingly intensive farming also present new risks and therefore require different priorities for ensuring food safety. **Innovation** within the food sector is ongoing and new production methods, ingredients, and additives are under constant development. The more of these are introduced, the greater the chances of some kind of chemical or allergenic hazard passing undetected into food.

1.2 BIOLOGICAL RISKS

In food safety there are four key areas of risk: biological, chemical, allergenic and physical. In the following paragraphs we will explore each in detail. Biological risks are one of the four risk categories identified. This section looks at biological risks in their various forms, how they come about and key drivers and trends going forward. Biological food safety risks are by far the most recognizable and are referred to in common parlance as 'food poisoning'. They are caused by bacteria, viruses, fungi and other microorganisms. When they materialize, they are usually characterized by symptoms such as nausea, vomiting, and diarrhea. Though often fast-acting and short-lived, biological food-borne illnesses can be fatal. Bacterial contamination is believed to be at the source of 90% of all known food-borne illnesses.⁹ Europe has made considerable advances in managing these, however new problems are emerging. As the global food market becomes ever more complex and farming practices intensify, there is mounting concern as opportunities for biological contamination increase. Meanwhile its resistance is growing against existing methods used to eliminate it, thus driving an increase in associated illnesses worldwide.¹⁰

There are three main forms of biological contamination: bacterial, viral and other biological. We briefly describe these three before looking at the key drivers and trends in biological risks.

BACTERIAL CONTAMINANTS

Food always contains bacteria and people handling it can also contaminate it if they do not (and occasionally even if they do) take certain precautions. Most bacterial risks are eliminated by cooking or other processing of food, however some persist. Contamination can take a number of different forms.

9 Asociación de Investigación de la Industria Agroalimentaria, 'BIOLISME,' 18 2012, http://cordis.europa.eu/projects/rcn/96290_en.html.

10 World Health Organization, 'Initiative to Estimate the Global Burden of Foodborne Diseases,' *Food Safety*, 2012, http://www.who.int/foodsafety/foodborne_disease/ferg/en/index1.html.

Examples include salmonella and listeria, both of which contaminate foods such as eggs and cheese, causing hundreds of outbreaks every year.¹¹

VIRAL CONTAMINANTS

Though less common than bacterial risks, illnesses caused by viruses often occur, usually within three days of consuming contaminated food, causing mostly short-lived illnesses in otherwise healthy individuals. People with diminished resistance, such as the elderly and those with other health conditions, are more likely to experience complications. Viral outbreaks can then spread from person to person and become epidemics no longer directly related to food. Viral outbreaks are associated with contamination of food with fecal matter, particularly in fresh-cut fruit and vegetables.¹² As an example, one of the most common viruses behind food-borne illness is norovirus, a major cause of gastroenteritis.

OTHER BIOLOGICAL CONTAMINANTS

In addition to bacterial and viral contaminants, other forms of biological risks occasionally present themselves in the form of parasites, fungi and other pathogens. One notable example is prions, a form of 'infectious protein' only recently identified from the bovine spongiform encephalopathy (BSE) 'mad cow disease' crisis (see Box 2 for more details).

KEY DRIVERS AND TRENDS

Biological risks are affected by the drivers identified in section 1.2 in many ways. **Globalization** is lengthening chains and the distance food travels, so more opportunities are available for bacteria to enter food. The complexity of the food industry is also increasing, making it ever more difficult to identify and arrest contaminations when they occur.

Production techniques and foodstuffs intended to be more nutritious or appetizing are on the rise. Some of these provide ideal conditions for bacteria to thrive, thus presenting a higher risk. There is therefore a potential tradeoff between safety and desirability. Rising demand for meat

11 European Food Safety Authority and European Centre for Disease Prevention and Control, 'The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2010.'

12 Ibid.

is associated with increasingly intensive farming, which also plays a role as it can create conditions which facilitate the spread of disease. World meat production is predicted to be double its present level by 2050.¹³ The EU is expected to both increase its meat production and become a net importer of every type of meat except pork and poultry by 2020.¹⁴

Antimicrobials (drugs which kill or inhibit microorganisms in animals and humans) are an important part of food production trends. They have been invaluable in improving human and animal health but they are not without their drawbacks. In the form of antibiotics, they are used in farmed animals to promote growth, reduce waste caused by diseased animals and prevent the transfer of zoonotic disease. They are also associated with the rise in intensive farming, where animal-to-animal transmission of disease is more likely. Antibiotics are often wrongly used to treat viral infections, a manifest misuse since they have no benefit at all, but they still contribute to the problem of antimicrobial resistance in bacteria.¹⁵ The more they are used, the more antibiotics lead to the development of resistant bacteria, which can then enter the food chain. As such, antibiotics can be described as a 'societal drug' as the implications of their use go far beyond the immediate benefits of their direct effects.¹⁶ People who become ill from resistant bacteria do not respond to standard treatments and tend to be hospitalized more frequently and for longer than those infected with ordinary bacteria. This is a serious and rising problem, particularly for the European Union, where over 25,000 lives are lost every year to bacteria which do not

13 Neil Marchant, 'The Identification of Future Global Food Risks' (presented at the Food Standards Agency Event: The Identification of Future Global Food Risks, The Royal Society, London, 2012), 43, <http://www.food.gov.uk/multimedia/pdfs/ffrtranscript.pdf>.

14 Directorate-General for Agriculture and Rural Development, *Prospects for Agricultural Markets and Income in the EU 2011-2020* (European Commission, December 2011), http://ec.europa.eu/agriculture/publi/caprep/prospects2011/fullrep_en.pdf.

15 American College of Physicians, 'Antibiotic Resistance,' *American College of Physicians*, 2012, http://www.acponline.org/patients_families/diseases_conditions/antibiotic_resistance/.

16 World Health Organization, *Tackling Antibiotic Resistance from a Food Safety Perspective in Europe*.

respond to available antibiotics.¹⁷ Research is badly needed if we are to stay one step ahead—and not one step behind—this worrying trend.

BOX 2 EXAMPLES OF BACTERIAL RISKS

2011 saw one of the worst ever outbreaks of *Escherichia coli* (*E. coli*). At the origin of this outbreak was accidental contamination and the cultivation of bean sprouts at temperatures which allowed *E. coli* to proliferate. These sprouts were then served raw in various eateries, leaving the bacteria fully active. This particular strain of *E. coli* (O104:H4) was particularly virulent, causing severe food poisoning symptoms and HUS (hemolytic-uremic syndrome, characterized by bloody diarrhea and kidney failure). Those affected did not respond to major types of antibiotics (penicillins and cephalosporins), highlighting the issue of antibiotic resistance. By the final weeks of the outbreak, 4075 cases in sixteen countries were recorded and 50 lives were lost.¹⁸ Virtually every case had been in Germany prior to becoming ill. Yet the outbreak was initially blamed on cucumbers originating from Spain, prolonging the investigation and delaying the arrest of the cause. This is evidence of the problem of globalization and complexity in the food chain.

Of the 'other biological risks' mentioned above, the example most strong in the EU's collective memory is the Bovine Spongiform Encephalopathy (BSE) crisis.¹⁹ When the disease proliferated among cattle during the early 1990s, it was traced to the production process: intensive farming of cattle. Meat and bone meal from infected cows was being routinely recycled and fed to healthy cows, thus spreading the

17 Ibid.

18 World Health Organisation, 'Outbreaks of *E. Coli* O104:H4 Infection: Update 30,' 22 2011, <http://www.euro.who.int/en/what-we-do/health-topics/emergencies/international-health-regulations/news/news/2011/07/outbreaks-of-e.-coli-o104h4-infection-update-30>.

19 World Health Organization, 'Food Safety and Foodborne Illness.'

pathogen.²⁰ During the crisis almost half a million infected animals entered the food chain.²¹ Consuming beef from BSE-infected cows is now known to cause variant Creutzfeldt-Jakob disease (vCJD) in humans. There is no cure or effective treatment and the disease is invariably terminal. Because of its dramatic neurodegenerative symptoms and tendency to affect younger patients, 'mad cow disease', as BSE and vCJD are colloquially known, induced public outcry.²² From October 1996 to March 2011, 216 cases of vCJD were reported in the EU. Virtually all of these were related to the consumption of contaminated bovine products.²³ The two diseases are now better understood and the risk has diminished considerably, however changing and intensifying farming practices mean that other risks could still surface in the future, and a relaxation of the ban on recycling animal carcasses to make feed has raised concerns of a similar crisis emerging.²⁴

1.3 CHEMICAL RISKS

Chemical food safety risks can occur when harmful substances such as pollutants or pesticides enter the food chain or are formed within food naturally or during processing. Humans are constantly exposed to many of these, but at certain levels they become dangerous for health. Long-term exposure to certain chemicals can result in a wide range of symptoms. For example, dioxins can impair the immune, endocrine, nervous, and reproductive systems. They are also known to cause several types of

20 Unlike other biological risks, BSE is not caused by a virus or a living organism, rather a protein in a misfolded form known as a prion, which causes healthy proteins to convert to the diseased form in a chain-reaction effect which, over a long incubation period, causes exponential worsening of the infected individual's condition.

21 BBC News, 'CJD Deaths 'May Have Peaked', *BBC News*, November 23, 2001, <http://news.bbc.co.uk/2/hi/health/1671737.stm>.

22 Ibid.

23 World Health Organization, 'Variant Creutzfeldt-Jakob Disease,' *WHO*, February 2012, <http://www.who.int/mediacentre/factsheets/fs180/en/>.

24 Robert Will, 'Public Health and European CJD Surveillance,' accessed August 29, 2008, http://ec.europa.eu/food/animal/diseases/strategy/docs/Public_health_E_CJD_Surveillance_en.pdf.

cancer.²⁵ If food were to be contaminated at a sufficiently high level for a sufficient period of time, there is a risk that such symptoms would present themselves in consumers.

We currently have limited understanding of many of the ways in which food can become contaminated: we can trace some errors and cases of intentional adulteration, but chemical hazards which form naturally or during processing and cooking are much harder to identify. Current technology only allows us to find them if we know what they are and how to specifically look for them. Of the myriad of substances contained within a given complex food product, a high percentage are usually unknown.²⁶ As a result, detection of chemical hazards is often late and may not even occur at all.

Our knowledge is also limited as to the long-term effects of many of these chemicals and the precise levels of exposure that can be considered a significant risk to human health. The onset of related symptoms may take years or even generations to occur. Many illnesses and public health problems associated with chemical exposure through food may not be identified as such. There is therefore deep uncertainty as to the full scale of health impacts caused by chemicals in food.

KEY DRIVERS AND TRENDS

Several factors identified in section 1.2 drive chemical risks to our food safety. First, **globalization** once again plays a role here. As the food chain becomes more complicated, there are ever more points at which contamination could occur and escape attention when it does. Different countries have different food safety standards. The EU's standards are generally much more exacting than those of its trading partners. The risks associated with products imported from countries with less stringent regulations will become ever more important as our trade with those countries increases.

25 World Health Organisation, 'Dioxins and Their Effects on Human Health,' *WHO*, May 2010, <http://www.who.int/mediacentre/factsheets/fs225/en/index.html>.

26 M. Rennen et al., *Toxicological Assessment of Complex Chemical Mixtures Using the Threshold of Toxicological Concern Concept* (Zeist, Netherlands: TNO, n.d.).

A second trend is the development of **innovative** food ingredients, additives and processing techniques. Although this is an important way in which food firms maintain their competitiveness, food safety innovation tends not to be as profitable as it is only salient when negative. Extolling the improved safety of a product may suggest to consumers that the firm's previous products were unsafe.

BOX 3 EXAMPLES OF CHEMICAL RISKS

Contamination of food with hazardous chemicals is discovered periodically, leading to withdrawals and investigations. In 2005, 470 types of food product were withdrawn in the UK after they were found to contain the carcinogenic (cancer-causing) dye Sudan I. In 2007 the European Commission issued a health warning to Member States over the thickening agent guar gum, which was found to be contaminated in India with pesticide dioxins.

Chinese food is bedeviled by scandal after scandal, particularly relating to chemical adulterations.²⁷ The most significant of these involved melamine intended to disguise fraudulently diluted milk in protein tests—a cost-cutting measure which led to the death or hospitalization of hundreds of infants. Europe feels the impact of China's food safety difficulties: Chinese food is by far the largest cause of notifications to the European Rapid Alert System for Food and Feed (RASFF) in terms of alerts, information and border rejections.²⁸ These cases relate to the challenge of detecting unexpected contaminants. Moreover, they highlight the driver of globalization: though chemical contaminations

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- 27 Morgan Figuers, 'Apologies for Food Safety in China,' *China Digital Times*, March 9, 2007, <http://chinadigitaltimes.net/2007/03/apologies-for-food-safety-in-china/>; Patti Waldmeir, 'China Milk: Not so Bright,' *Financial Times*, June 28, 2012, <http://blogs.ft.com/beyond-brics/2012/06/28/china-milk-not-so-bright/#axzz252PzGVPh>; Nicholas Zamiska, 'Who's Monitoring Chinese Food Exports?,' *The Wall Street Journal*, April 9, 2007, <http://online.wsj.com/article/SB117608207682763704.html>.
- 28 Rapid Alert System for Food and Feed, *2011 Annual Report* (Luxembourg: European Commission, 2012), http://ec.europa.eu/food/food/rapidalert/docs/rasff_annual_report_2011_en.pdf.

occur in the EU, our increasing exposure to food from abroad makes regulation much more difficult and detection much more necessary.

As late as 2002 it was inadvertently discovered that acrylamide, a potential carcinogen, was being formed during certain commonplace processes such as the frying of potatoes.²⁹ This led to a number of further studies and interest from the media, examining the risk posed by the quantity of acrylamide that Europeans were regularly consuming and how to reduce it. This included a large-scale study of heat-generated food toxins under the EU's Sixth Framework Programme (FP6), involving 24 partners in 14 countries.³⁰ Evidence is inconsistent over the number of actual cases of cancer caused by acrylamide, however our previous unawareness of its presence raises questions about what other chemicals may be present within our food as a result of production processes and the possibility that innovation could mean new ones enter the food chain in the future.

1.4 ALLERGENIC RISKS

Though often overlooked, allergenic risks are very much part of the overall picture of food safety and are of mounting concern in Europe. The number of people with a food allergy is thought to be between 2 and 3% of adults and somewhat higher in children.³¹ This means that the problem of allergenic food safety could reach a very large scale if not properly addressed. The risk of allergenic contamination should be taken just as seriously as any other. When talking about allergenic risks in relation to food safety, it is important to distinguish between allergies, allergens, and allergic reactions. See Box 4.

29 Edén Tareke et al., 'Analysis of Acrylamide, a Carcinogen Formed in Heated Foodstuffs,' *Journal of Agricultural Food and Chemistry* 50, no. 17 (July 17, 2002): 4998–5006, doi:10.1021/jf020302f.

30 Kerstin Skog, *Heat-generated Food Toxicants: Identification, Characterisation and Risk Minimisation* (Lund: Lund University, April 12, 2007).

31 TNO, *Food and Nutrition Update* (Zeist, Netherlands, June 2012).

BOX 4 FOOD ALLERGY KEY TERMS

An **allergic reaction** (effect) occurs when the body responds in an adverse manner to a chemical—almost always a protein—which is normally harmless.

The chemicals which are capable of provoking such reactions are known as **allergens** (risk).

An **allergy** is a condition which allows allergens to cause allergic reactions.

This category of risks is different to the others in that it only applies to those who are allergic. However the consequences can be severe, causing potentially serious allergic reactions, such as blocked airways and inflammation. It can also have a negative impact on the quality of life of allergy sufferers and those around them.

Food containing allergens is often widely available and the allergen may be in many ingredients. Foods can also be contaminated, leaving allergens present in trace form. There is also a possibility that genetic modification can insert genes which code for allergenic proteins not previously present in the unmodified organism.³² In addition, consumer uncertainty is substantial, since there is no standard guidance as to how manufacturers must indicate the presence of allergens, whether known or inadvertent.³³ In some industries, such as perfume, the use of certain potential allergens is prohibited by EU law. However in food this is both unfeasible and undesirable; such constraints would only make food production much more complex and costly and reduce variety and choice for consumers. There are also no established methodologies for assessing potential contamination and no guidelines on disclosing it. This means allergy sufferers are ill-equipped to assess the safety of the food they consume. Warnings currently range from overly cautious ('may contain traces' for a negligible risk) to recklessly minimal (no warning at all when one is due).³⁴

32 Nordlee et al., 'Identification of a Brazil-nut Allergen in Transgenic Soybeans,' 14 1996, <http://www.ncbi.nlm.nih.gov/pubmed/8594427>.

33 TNO, *Food and Nutrition Update*.

34 *Ibid.*

KEY DRIVERS AND TRENDS

Allergenic risks are subject to many of the same trends as biological and chemical ones. As a result of **globalization**, the food chain is diversifying, exposing Europeans to many new allergens which could damage their health. Another rising trend is for new and **innovative** protein sources to be developed as alternatives to meat. This also increases the range of possible allergens in consumers' diets. In both these cases, there is a rising risk that allergic and not-yet-allergic consumers could be exposed to allergens.

BOX 5 EXAMPLES OF ALLERGENIC RISKS

There is a plethora of cases where people have been exposed to allergens and suffered severe health consequences and even deaths, of which there are around 10 per year in the UK alone. This in turn has been known to induce panic among the public and increasingly disproportionate measures to protect against allergens.³⁵ One case involved the anaphylactic shock and subsequent death of a British teenager after eating a product which had previously caused him no harm.³⁶ In this case it appears that the product was indeed contaminated with an allergen from a foreign source, highlighting the issue of complexity in the food industry.

1.5 PHYSICAL RISKS

Food production processes occasionally allow physical contaminants into food, for example bones, shards of plastic and other foreign objects and, in extreme cases, small animals such as mice.³⁷ These physical risks are generally well managed: producers can virtually eliminate the risk with basic quality control practices such as eyesight and metal detectors. Furthermore, consumers will see or feel most contaminants before they can cause harm. Physical risks do not constitute an issue of rising

35 BBC News, 'Warning of Nut Allergy 'Hysteria',' *BBC News*, December 10, 2008, <http://news.bbc.co.uk/2/hi/health/7773210.stm>.

36 BBC News, 'Allergic Teenager Died After Chicken and Chips Takeaway,' *BBC News*, 15 2011, <http://www.bbc.co.uk/news/uk-england-merseyside-14936175>.

37 BBC News, 'Firm Fined After Dead Mouse Found in Loaf of Bread,' *BBC News*, 27 2010, <http://www.bbc.co.uk/news/uk-england-oxfordshire-11419498>.

importance in food safety and are therefore not a matter of concern for the rest of this report.

1.6 THE NEED FOR RESEARCH

In closing this chapter, we combine the drivers presented in section 1.2 with the risk areas examined to identify three key issues which demand increasing attention.

- First, in biological risks, **antimicrobial resistance** will be made more challenging by globalization and increased meat production (see section 1.2). Legislation and regulation will not always be a viable countermeasure, as a lot of production will take place abroad, so research is needed to develop ways of tackling this trend.
- Second, in chemical risks, **unidentified chemical hazards** must be addressed within the context of changing production techniques and new innovative products (see section 1.4). Research is therefore needed to find new and more efficient ways of filling the gaps in our knowledge.
- Third, in allergenic risks, **allergies** are also likely to become increasingly burdensome as a consequence of more diversity from globalization and innovation in the food industry (see section 1.5).

Research can help address the issues of how to identify these risks and alert consumers. This is the focus of the next two chapters, where we first look at what research is happening at the moment and then identify key future research areas for tackling the food safety challenges identified in this chapter.

2 FOOD SAFETY RESEARCH

The purpose of this chapter is to look at ongoing food safety research. So far, we have identified some key areas of pressing concern. Solving these issues will partly be a political challenge, requiring a comprehensive strategy involving legislation, regulation, governance, and education. But technology can also make an important contribution. Developing more efficient and effective methods to prevent, detect, and remove harmful agents at every point of the food chain will all be essential in tackling food safety issues of our future. This chapter provides insight into where these developments may be taking place.

In section 2.1, a number of **countries** are identified as world leaders on the basis of data on the number of organizations involved in food safety research, the number of ongoing projects on food safety and the number of food safety researchers. We also consider how the scale of a country's food safety research might relate to its food safety performance as identified in our GeoRisQ Monitor in section 1.1.

In section 2.2, top food safety research **institutions** are identified by the number of food safety researchers, with some added based on their focus or participation in research projects of particular interest to this report.

Next, section 2.3 looks at research projects funded by the **EU**. The focus of this analysis is limited to research projects developing technologies that aim to mitigate food safety risks and to advance food safety. We identify three main areas of research, namely, detection and traceability, more advanced packaging solutions, and modeling. These connect to the risk areas examined in the first part (biological, chemical, allergenic and physical). They also have a certain link to the research priorities we identified in paragraph 1.7 (antimicrobial resistance, unidentified chemical risks and allergies). In chapter 3 we assess the extent to which this is the

case before highlighting further research areas which will require increasing attention in years to come.

Finally, in section 2.4 we look at **private sector** research and its involvement in various aspects of food safety.

2.1 LEADING COUNTRIES

This section looks at countries in terms of their food safety research activities. We cover three aspects: organizations, projects and researchers. For each, we look at numbers to give an idea of the scale and intensity of research in those countries.

ORGANIZATIONS

Figure 2 shows a worldwide overview of food safety organizations. The bigger the circle, the more research organizations there are in a specific country. In general, the developed world (US, EU, Japan, Australia, New Zealand) clearly stands out. This appears to confirm the existence of a paradox of progress: as these countries have more and more advanced food production and citizens have plentiful access to food, the complexity of food safety problems to be solved increases, and so does the need for more research. Another observation is that China appears to be lagging behind. It will be interesting to see if its rapid development and frequent food safety problems (see section 1.3) lead to an expansion of its food safety research program.

The map also shows a high concentration of organizations in Europe, significantly overshadowing the rest of the world.³⁸ Most of these agencies are Member-State government departments. The US follows, again with mainly government departments, but also a small number of universities and private organizations.³⁹ One explanation for the apparent lower number of US organizations funding research is that where European countries have individual national research programs, the US operates at a federal level. This explanation is supported by the data on the actual number of projects.

³⁸ Data on the organizations funding this are drawn in this part from the US Department of Agriculture's database of research projects on food safety.

³⁹ United States Department of Agriculture, 'Food Safety Research Funding Agencies Map,' Food Safety Research Information Office, July 19, 2012, <http://fsrio.nal.usda.gov/research-projects-database/food-safety-research-funding-agencies-map,>

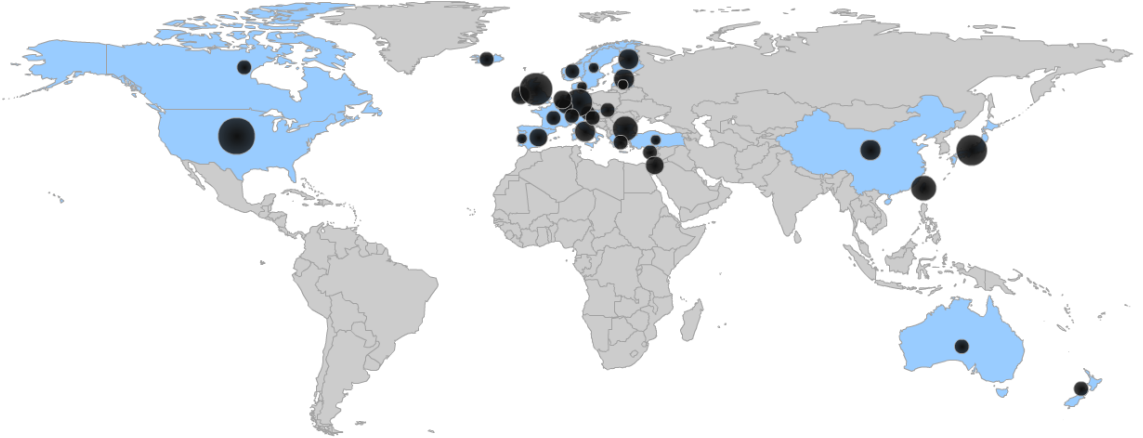


FIGURE 2 ORGANIZATIONS FUNDING FOOD SAFETY RESEARCH⁴⁰

PROJECTS

Still looking at the scale of research, we move from the number of organizations to the number of studies underway. Here, the picture is reversed and the center of gravity is not in Europe, but the US. The best available international data come from the US Department of Agriculture (USDA)'s Food Safety Research Information Office. It catalogues over 7000 projects,⁴¹ of which the vast majority are taking place in the USA. Of the total number of projects, 1582 are funded by agencies in Europe; 354 of these are funded by EU organizations themselves.⁴²

40 United States Department of Agriculture, 'Research Projects Database,' *Food Safety Research Information Office*, 19 2012, http://fsrio.nal.usda.gov/nal_web/fsrio/advsearch.php.

41 These projects include everything related to food safety and thus do not exclude projects whose focus is other than technology.

42 United States Department of Agriculture, 'Research Projects Database.'

Figure 3 paints a broad picture of where most food safety research projects occur. The resulting picture does however depend partly on the inclusion of projects in the database. Thus, one reason for the higher number of projects in the US may be that projects based in the US are simply better at registering their activities with the USDA. Nonetheless, the data are still useful as an indication of projects which have taken the initiative to register their activities.

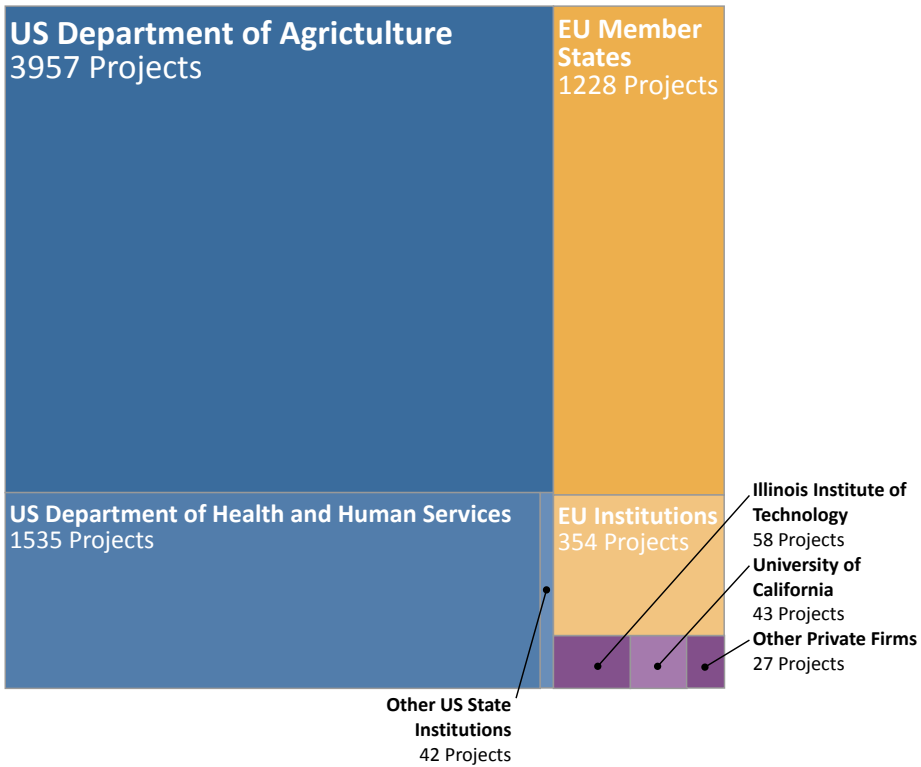


FIGURE 3 NUMBER OF FOOD SAFETY-RELATED RESEARCH PROJECTS IN USDA DATABASE⁴³

43 Ibid.

RESEARCHERS

Finally, in addition to organizations and projects, the countries leading food safety research in terms of scale can also be identified by looking at the number of researchers involved with food safety research per country. Figure 4 shows this for the countries with the highest numbers of researchers. We also look at the number of food-safety researchers relative to the number of researchers from other disciplines and to Gross Expenditure on R&D. This gives an idea of the intensity of the research. Table 1 illustrates this for the EU Member States, plus the four non-EU countries also in the top 10 for highest number of researchers.

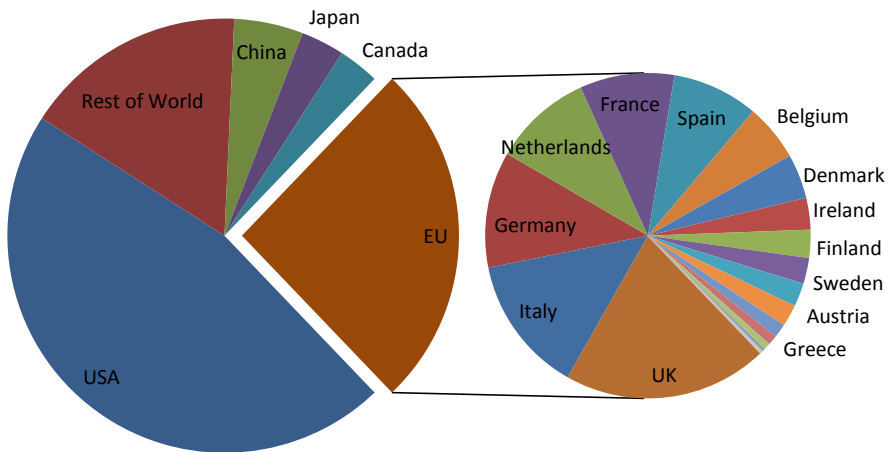


FIGURE 4 SHARE OF FOOD SAFETY RESEARCHERS⁴⁴

44 Maven Semantic, 'Search for Medical Professionals and Organisations,' *Maven Semantic Medical Database*, 2012, <http://www.mavenssemantic.com/Search.aspx?command=search&type=people&text=Food%20Safety&ref=BW&refValue=460>.

COUNTRY	NUMBER OF FOOD SAFETY RESEARCHERS ⁴⁰	FOOD SAFETY RESEARCHERS PER THOUSAND ALL RESEARCHERS ⁴¹	RELATIVE RESEARCH FOCUS: FOOD SAFETY RESEARCHERS PER \$BILLION SPENT ON R&D AT PPP ⁴²
USA	10480	No Data	26,10
UK	1186	3,71	29,44
China	1165	0,51	7,56
Italy	794	3,63	32,08
Japan	734	0,84	5,32
Canada	691	No Data	28,15
Germany	672	1,22	8,12
Netherlands	573	5,84	46,68
France	547	1,40	11,41
Spain	498	2,24	24,30
Belgium	330	5,51	42,94
Denmark	258	4,85	41,06
Ireland	183	9,04	57,83
Finland	163	2,92	21,86
Sweden	149	1,92	11,92
Austria	136	2,32	15,23
Greece	126	No Data	67,46
Portugal	79	1,51	17,91
Poland	58	0,71	11,90
Hungary	40	1,27	17,14
Lithuania	10	0,85	No Data
Romania	6	0,23	4,08
Bulgaria	5	0,30	No Data
Estonia	4	0,76	No Data
Luxembourg	3	0,61	4,23
Latvia	2	0,37	No Data
Malta	1	0,96	No Data
Cyprus	1	0,77	No Data
Czech Republic	0	0	0
Slovakia	0	0	0
Slovenia	0	0	0

TABLE 1 FOOD SAFETY RESEARCHERS RANKING

45 Ibid.

46 United Nations Educational, Scientific and Cultural Organization, 'Total R&D Personnel by Sex,' *Beyond 20/20*, 2011, <http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx?ReportId=2638>.

47 National Science Foundation, *Science and Engineering Indicators 2012* (National Science Foundation, 2012), <http://www.nsf.gov/statistics/seind12/c4/c4s8.htm>.

From Figure 4 and Table 1, a number of observations can be made about the scale and intensity of food safety research in the countries examined. On scale, the initial picture shows the overwhelming lead of the US over all of the other countries in terms of the raw number of food safety researchers. The gap narrows when considered relative to the EU as a whole, as can be seen in Figure 4. Also important is the intensity of food safety research within a country. For this we look at the figures relative to the total expenditure of each country on research and development. The statistics show a much higher emphasis on food safety in Greece, Ireland, the Netherlands, Belgium, and Denmark, who lead the pack in that order, with the US trailing. The emphasis on food safety within a country's overall research community is shown by the number of food safety researchers per thousand researchers of any kind. Though recent comparable data were unavailable for the USA, Canada and Greece, we can see that countries around the middle of the table tend to have the greatest proportion of researchers involved in food safety, with Ireland, the Netherlands, Belgium, Denmark and the UK in the lead.

Now we connect the scale of a country's food safety research to its food safety performance as identified in the GeoRisQ monitor in paragraph 1.1. There is a degree of correlation (0.51) between the number of researchers in a country and the level of food safety performance. This suggests that more food safety researchers could lead to better food safety performance. Alternatively, a third factor, such as a strong national culture of food safety, could lead to both more researchers and safer food. This relationship is demonstrated on the chart in Figure 5.

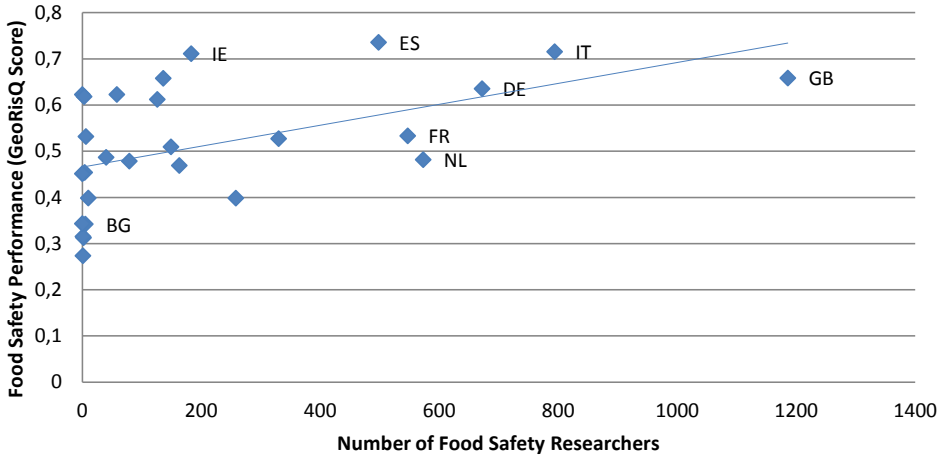


FIGURE 5 RELATIONSHIP BETWEEN FOOD SAFETY RESEARCHERS AND FOOD SAFETY RISK IN MEMBER STATES

2.2 LEADING INSTITUTIONS

Also based on numbers of researchers, forty leading institutions in the world have been identified.⁴⁸ We added to these a further five organizations, selected for their strong reputation in the industry, involvement in EU research projects or particularly relevant focus on the challenges highlighted in this report. These five are TNO in the Netherlands, Fraunhofer in Germany, Campden BRI, the Food Standards Agency in the UK and the French National Institute for Agricultural Research. The 45 institutions are highlighted on the map in Figure 6. It shows a clear and striking preeminence of the US.

48 Business Wire, 'Maven Semantic: Food Safety Research Database,' *Business Wire*, April 12, 2011, <http://www.businesswire.com/news/home/20110412005970/en/Maven-Semantic-Food-Safety-Research-Database>.

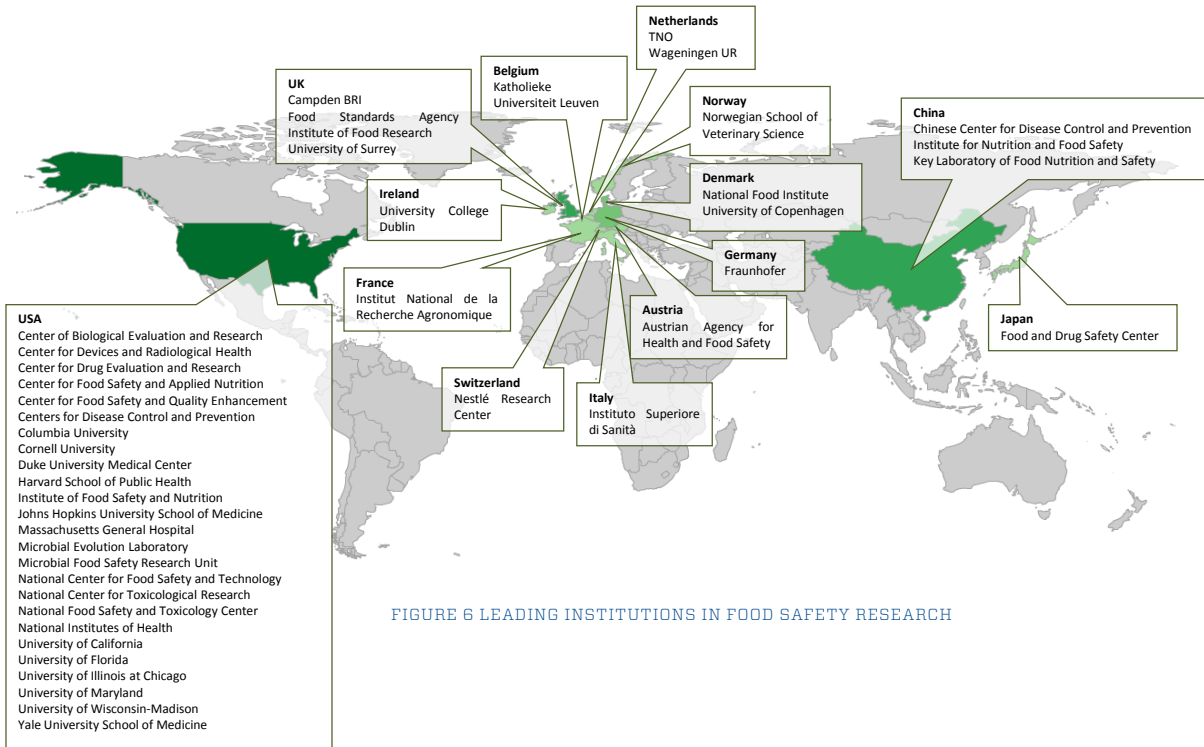


FIGURE 6 LEADING INSTITUTIONS IN FOOD SAFETY RESEARCH

2.3 RESEARCH PROJECTS IN THE EU

This section looks at research under the auspices of the EU. Virtually all of this takes place within the Framework Programmes, so we compare the profile of food safety within each iteration (FP4, FP5, FP6 and FP7). We go on to look at the funds allocated and the research focus of current FP7 food safety projects.

SEVENTH FRAMEWORK PROGRAM FOR RESEARCH (FP7)

FP7 is the key area of focus when considering EU-funded research projects on food safety. The total number of food safety-related projects under each Framework Programme increased over FP4, FP5 and FP6, with 25, 66 and 90 projects respectively. For FP7 the number (65) may be incomplete as a further (and the largest yet) round of calls for proposals under the

Programme was announced in July 2012.⁴⁹ The relative numbers are graphically represented below. The figure below also shows two specific programs related to food safety; one under FP6 and one under FP7. Under FP6, the FP6-FOOD program included 187 projects relating to various aspects of food; 54 of these specifically used the term ‘food safety’ and are represented by the circle below FP6 on Figure 7. Similarly FP7 features a research theme ‘Food, agriculture and fisheries, and biotechnology’, named FP7-KBBE. However most food safety projects within FP7 fall outside it, for example those relating to small and medium enterprises.

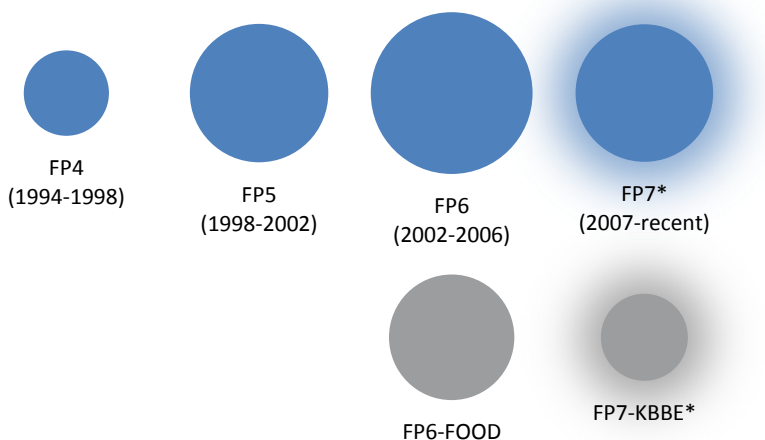


FIGURE 7 NUMBER OF FOOD SAFETY RESEARCH PROJECTS.⁵⁰

49 Community Research and Development Information Service, ‘Largest Number of Calls Ever for Next Round of FP7,’ *CORDIS*, 10 2012, http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&RCN=34831.

50 FP7 and FP7-KBBE are shown with a glow to indicate that they are likely to expand.

BUDGETS

Taking a closer look at the funds allocated to food safety under FP7, a search for the term 'food safety' yields 114 results of projects either underway or recently completed. The term 'food risk' returned virtually no relevant results. Of the 114 projects found, we selected 34 for their clear and direct link to the development and use of technology to address and mitigate the food safety risks presented in Part I. A full table of them is presented in Appendix 2.

The budgets of these projects are composed as follows:

- Total combined budget: € 72,938,194
 - EU contribution: € 57,079,731 (78% of the total)
- Average budget per project: € 2,279,319
 - EU average contribution: € 1,678,816 (86% of any given project)

All of them are funded overwhelmingly by the EU (at least 69%). A third (11/34) are funded entirely by the EU. The rest have additional sources of funding such as national governments and private firms. Half of them (17/34) include the participation of at least one private-sector organization. There is a lot of cross-border cooperation, with most studies (21/34) involving organizations based in more than one Member State. The average project lasts 3 years.

RESEARCH FOCUS

Out of our risk categories (biological, chemical, allergenic and physical), the focus of each project usually falls into one more of the four. For example, some projects look at enhancing detection of harmful agents, developing new methods of destroying pathogens, and improving traceability when problems do arise. Biological risks are the focus of the vast majority of projects (65% of studies and 60% of total spending) and constitute 83% of the EU's contributions. This is understandable considering that 90% of known food-borne illnesses are bacterial and therefore constitute biological risks.⁵¹ However, as noted in section 1.4, the extent and impact of chemical contamination is not fully understood and may be underestimated, so it is unclear whether the overwhelming focus on microorganisms is

51 Asociación de Investigación de la Industria Agroalimentaria, 'BIOLISME.'

proportionate. Similarly, the high prevalence of food allergies, their virulent reactions and impact on sufferers' quality of life raises the question whether they are given sufficient attention.

Research underway in the 34 projects identified center around three main areas: detection and traceability, intelligent packaging and modeling. These are all important topics based on current and past food safety challenges.

In **detection and traceability**, new technologies are necessary to detect bacterial and chemical risks. The development of cheap, portable testing kits is emerging as an important field for innovation to make detection more widely available.⁵²

Intelligent packaging also occurs frequently among ongoing studies. Recent years have seen breakthroughs in nanotechnology and biotechnology that have helped to measure and reduce the presence of hazards or the conditions which allow them to develop.⁵³ One way in which this already happens is through modified atmosphere packaging, where the air within a packet (of nuts, for example) is replaced with a gas known to inhibit the growth of pathogenic bacteria. Recent innovations include moisture management systems, antimicrobial packaging, and nanosensors that can detect pathogens, spoilage organisms, toxins, and allergens.⁵⁴

A third area of current innovation in the identification and development of technologies is systematic **modeling** of food products and the processes behind them. By developing models, we can gain new insights into how risks enter and develop within food and its production. The systematic cataloguing of hazards and threats can help the management of food safety crises and the identification of effective preventive measures. It can also contribute toward new ways of identifying weaknesses in and improving the design of processing equipment.

52 Fiona Lickorish, 'Horizon Scanning in the Detection of Emerging Food Safety Risks,' March 13, 2012, <http://www.food.gov.uk/multimedia/pdfs/fionalickorishpres.pdf>.

53 Marchant, 'The Identification of Future Global Food Risks,' 6.

54 Innovaro, 'Keeping Ketchup Innovative,' *Innovaro - Trend and Foresight Blog*, September 6, 2011, <http://innovaro.wordpress.com/tag/sensory-packaging/>.

2.4 PRIVATE SECTOR RESEARCH

In addition to countries, institutions and the EU, we also look specifically at the private sector. Food safety for private firms generally plays second fiddle to more lucrative areas of innovation. Most firms are more likely to invest in technologies which either increase revenues or reduce costs, for example by making their food more appealing or last longer (albeit sometimes with increased safety as an added bonus). Once food is safe, the target has been achieved; making it any safer pays few dividends. Nonetheless, a number of factors do encourage the private sector to meet the requirement to supply safe food and, consequently, invest in food safety research and technology.⁵⁵ First, market forces are compelling firms to avoid supplying unsafe food, since the outbreak of a food-borne disease for example may scare consumers and damage the firm's reputation and result in reduced market share and revenues. Second, firms risk penalties and fines if they supply unsafe food or fail to implement safe food practices. And third, they risk legal claims and product liability lawsuits, which can be costly due to court costs, legal fees and potential financial compensation for the consumers that fell ill.

When we look at the FP7 projects, there is a high level of private-sector participation. Of the 34 selected studies, half involve at least one private sector organization. In most cases, these are either suppliers of food safety technology who stand to benefit from research as sellers (technology and research firms); or users of food technology who stand to benefit from research as buyers (food producers and manufacturers). The figures of the USDA, on the other hand, appear to show very low private sector involvement in food safety research (see Figure 3). This impression of low private-sector activity is possibly misleading for two reasons. First, private companies often do not openly publicize information about food safety research. For example, Campden BRI, a British firm specialized in food and drink research services reserves access to around £2m (€2.4m) of research for its members only.⁵⁶ Second, many of the publicly funded projects listed

55 Spencer Henson and Neal Hooker, 'Private Sector Management of Food Safety: Public Regulation and the Role of Private Controls.,' *International Food and Agribusiness Management Review* no. 4 (2001): 9-10.

56 Campden BRI, 'Overview,' *Campden BRI*, n.d., <http://www.campden.co.uk/campdenbri/overview.htm>.

are partnerships involving the private sector. Since projects are not counted twice, they only feature in the chart hidden under the public institution funding the study.

2.5 THE CURRENT PICTURE

Our analysis reveals a clear lead for the US in terms of scale. However in terms of intensity, when looking at the total number of researchers or the amount spent on research in each country, a number of EU Member States also invest strongly. In addition to the countries spearheading food safety research, we also pinpointed 45 of the world institutional 'centers of excellence' for food safety. Again, the majority of these are in the US, though many are in Europe. Countries with high investment in research tend to also benefit from safer food. Some of the latest results of this research will translate into solutions capable of making demonstrable improvements.

In research funded by the EU, the attention given to the field appears to have been increasing over time. For the private sector, food safety generally plays a subordinate role to investment in innovations intended to make food more appealing or last longer. However there is extensive involvement of private companies in the food safety projects of FP7, usually firms supplying or buying food safety technology. Of the areas of research covered, three come to the fore: detection and tracing methods to better identify contaminations; modeling to provide better understanding of the contents and structure of food; and 'intelligent' packaging, which uses new systems to indicate the safety of food.

As we saw in this chapter, the EU is home to some of the most preeminent centers for food safety research in the world, dealing in some areas at the forefront of innovation. However important decisions must be made on the focus and direction of research.

3 RESEARCH OPPORTUNITIES

By focusing on a certain number of research tracks, researchers can visibly contribute to food safety in Europe. Detection, packaging, and modeling—the three main topics around which the FP7 projects largely center—are all essential to the ongoing issues of food safety surrounding biological, chemical, and allergenic risks. They address problems past and present such as the presence of pathogens, improving hygiene and monitoring processes. However they only partially deal with the pressing issues emerging in the future of the EU's food safety.

This section returns to the major risk categories from chapter 1 in turn. For each, we compare these to strengths and limitations of ongoing research in the EU which we identified in the previous chapter. We then draw attention to the areas of concern for future research as listed at the end of chapter 1: antimicrobial resistance, undetected chemicals and assessing allergenicity. Building on this, we go into greater detail about specific aims for future research that can have a considerable impact on food safety in years to come.

3.1 BIOLOGICAL RISKS

CURRENT RESEARCH

Beginning with biological risks, we look at some areas of current research in the EU and explore their advantages and limitations. For example:

- *Detection* offers the possibility of developing methods and devices to improve our ability to spot pathogens and the traces they leave. We can then use this information, most obviously to arrest contaminated food before it reaches consumers, but also plan better production techniques to avoid the risk in the first place.
- *Intelligent packaging* offers a way to signal the presence of conditions favorable to bacteria, retard their growth or even eliminate them altogether.

- *Modeling* can be used to identify with greater precision the points within production that risks occur and improve the process accordingly. It also allows us to look within the food itself to determine how pathogens are able to survive and multiply within different products.

What is underdeveloped here is a grasp of how to predict or influence the behavior and evolution of pathogens *before* they become a hazard. This is essential in relation to changing production processes. There is mounting concern that the list of effective antibiotics available to thwart various pathogens is becoming shorter. As highlighted in section 1.3, people infected with resistant bacteria often suffer worse and for longer than those who fall ill from non-resistant strains of the same pathogen. The issue can be partially addressed by legislative and regulatory measures aimed at cutting the use of antimicrobials. For example, in 2006 the EU withdrew all antibiotic growth promoters for farm animals. However the limitation of such measures is that they only apply within the EU, while farmers abroad gain a competitive advantage and perpetuate the development of resistant bacteria through the continued use and abuse of antibiotics.

FUTURE AIMS

Based on these limitations, future research should pay particular attention to **antibiotic resistance**. Research can supplement legislative and regulatory measures and help compensate their shortcomings. It can play a major role in the fight against antimicrobial resistance in a number of ways:⁵⁷

- Developing new methods, tools and products to improve animal husbandry (new and better vaccines, for example) to mitigate the spread of disease and reduce the need for antibiotics.
- Establishing criteria for determining the rational and socially responsible use of antibiotics, thus ensuring that regulatory measures tackle the challenge in the most effective way.
- Setting up surveillance programs to track and forecast emerging resistance and plan effective measures for prevention. There is a lack of epidemiological data detailing the specific nature, progress, and origin of different types of resistance—something badly needed if better strategies are to be developed.⁵⁸

57 World Health Organization, *Tackling Antibiotic Resistance from a Food Safety Perspective in Europe*.

58 *Ibid.*

- Finding alternatives in the form of new antibiotics and other drugs which achieve similar results (such as livestock growth promotion) to add to the tools at our disposal and promote more restrained use of antibiotics beyond the EU.

3.2 CHEMICAL RISKS

CURRENT RESEARCH

As with biological risks, current research on chemical risks in the EU is making important inroads.

- Detection is becoming easier thanks to the development of cheap, practical devices which allow us to spot certain chemical contaminants within food and remove or prevent them.
- Modeling allows greater insight into the processes which leave food vulnerable to contamination.

Although this research is making it cheaper to detect chemical contaminants, methods and devices under current development generally have at least one of two crucial limitations. The first is that only predetermined contaminants can be sought and found—we lack the means to expect the unexpected. The trend toward increasing complexity in the food chain makes solving this problem even more critical. The second is that there is usually a much higher cost associated with methods which try to overcome the first limitation by casting a wider net and looking for a greater number of contaminants. This involves extensive and often unnecessarily detailed analysis of the multitude of substances within a food product—an undertaking so demanding on time, animals and resources as to be unfeasible in most cases.⁵⁹

FUTURE AIMS

Given the two limitations of current research outlined above, **identifying and evaluating unspecified chemical hazards** is another area of importance, especially since the risks are often unclear and may be underestimated (see part 1.4). Research is essential if we are to address such risks as acrylamide systematically, rather than fortuitously. The research needed in this area is less like looking for a needle in a haystack and more like looking for *anything*

59 Rennen et al., *Toxicological Assessment of Complex Chemical Mixture*.

in a haystack. Nevertheless, scientific methods are being developed and deployed to do this. These involve:

- More and better in vitro tests which are important for replacing expensive, potentially misleading and ethically contested animal testing.
- New approaches to toxicological assessment of food. One such approach is the 'threshold of toxicological concern' principle, which aims to establish a value for all chemicals, below which there is a very low probability of an appreciable risk to human health.⁶⁰

3.3 ALLERGENIC RISKS

CURRENT RESEARCH

Current research in the EU addresses some aspects of allergenic risks within the three main areas of focus identified in this report. For example:

- Detection can be directed towards spotting potential allergens and developing ways to avoid them contaminating food.
- Modeling allows production systems and individual products to be scrutinized to provide greater control over their allergenic content.

However this research does not directly address the risks and consumer uncertainty highlighted in part 1.5 as it does not establish means of quantifying the risks posed by the actual final product. Allergies are becoming an ever more important issue as the food chain becomes more complex and novel foods are introduced and developed, each carrying a risk of containing allergens. We have already seen in this report the potential dangers associated with this.

FUTURE AIMS

Because of the uncertainties involved, **assessing allergenicity** is an important priority for future research. Some possible aims include:

- Rational criteria based on scientific research to develop standard methods and requirements to (1) assess the presence and risk of contamination with allergens, and (2) signal the hazards and risks in a consistent way on products. Only one such set of criteria has been proposed to date.⁶¹

⁶⁰ Ibid.

⁶¹ TNO, *Detection of Allergens in Food Products* (Zeist, Netherlands: TNO, n.d.).

- New approaches to detection and tracing of allergens. Current research into better assessing the presence of allergens is ongoing and involves technologies such as highly sensitive protein and DNA detection.⁶²

BOX 6 POTENTIAL STRATEGIC PARTNERS

To respond to the risks of antimicrobial resistance, chemical assessment and allergenicity, researchers should work closely with public and private stakeholders and other research institutes, including the centers of excellence identified in this report. Within the Netherlands, the most prominent public stakeholders are the Ministry of Economic Affairs, Agriculture and Innovation (Ministerie van Economische Zaken—EZ), Ministry of Public Health, Welfare and Sport (Ministerie van Volksgezondheid, Welzijn en Sport—VWS), the Ministry of Education, Culture and Science (Ministerie van Onderwijs, Cultuur en Wetenschap—OCW), and the Netherlands Food and Consumer Product Safety Authority (Nederlandse Voedsel- en Warenautoriteit—NVWA). Many stakeholders from the private sector, such as Unilever, Friesland Campina, Mars, Ajinomoto, Sara Lee, Nestlé, Kraft, Danisco, Danone, DSM and CSM, also have an interest in developing food safety technologies and in entering into an alliance with other researchers. Cooperation between the public and the private sector and research institutes is paramount in times of economic crisis, budget cuts and other public austerity measures.

62 Ibid.

CONCLUSION

This report has dealt with food safety in three distinct parts. First, it presented the challenge of food safety facing the EU. It identified four categories of food safety risks that repeatedly materialize as incidents or even crises in which Europeans' health was damaged. The risks are biological, chemical, allergenic, and physical. The most common risk is considered to be bacterial contamination, which is at the origin of 90% of all known food-borne outbreaks. However in the future we may see this relative importance diminish as our response to such risks becomes more effective and new chemical and allergenic challenges arise. Furthermore, since the health impact of chemicals may be underestimated, an increased focus on them may be entirely fitting.

Foresight literature points to certain trends that mean that ensuring food safety will remain a major challenge for the EU. **Globalization** will further internationalize the food chain and make the food paths from farm to fork longer, increasing the chances of contamination somewhere along the way. Higher imports from countries with less stringent standards and regulations for food safety affect all four risk categories. **Changing production** and consumption patterns will play a role too: the trend of increased meat demand and production augments the odds of new outbreaks of zoonotic diseases and antimicrobial resistance. Allergenic and chemical risks become more serious as the number of potential allergens is increasing due to **innovation**.

From the second chapter, analysis of research underway shows that at the global level, the EU has a prominent position when it comes to food safety. Other advanced economies like the US, Japan, Australia and New Zealand also stand out in the number of organizations and projects that are dealing with food safety research, though it can be concluded that the lead of the US in this respect is considerable. Based on the number of researchers too,

Europe is still far behind the US when looking at the raw number. Europe's relative focus on food safety research appears greater when the number of researchers relative to R&D expenditures and GDP is considered. At the European level, most research that focuses on developing technologies to mitigate food safety risks takes place under FP7. The projects deal with the four categories of risks. The report identified 45 centers of excellence based on the numbers they employ. Public funding is paramount for food safety research but the private sector also makes a contribution.

In chapter 3, the report looked into research areas and innovations that can help tackle some of the risks that negatively affect food safety in Europe. Food safety research in Europe is tackling many of the risks we are currently experiencing. However some key trends on the horizon highlighted in the first part of this report are only partially addressed by this current research. Table 2 summarizes the four key areas of food safety from part 1 of the report, and how present and future research can address them.

RISK	RESEARCH IN THE PRESENT	RESEARCH FOR THE FUTURE
BIOLOGICAL	Detection, intelligent packaging, modeling.	Addressing antimicrobial resistance, predicting pathogen behavior and changes.
CHEMICAL	Detection, modeling.	Identifying unspecified hazards, developing new means of assessing chemical safety.
ALLERGENIC	Detection, modeling.	Detection, developing new means of assessing hazards and risks of existing and novel allergens.
PHYSICAL	<i>Physical risks are not considered an area of pressing concern for research.</i>	

TABLE 2 SUMMARY OF RESEARCH TOPICS TACKLING PRESENT AND FUTURE FOOD SAFETY RISKS

This report identifies the following three areas of research among the most promising for the future: (1) the development of technologies for tackling antimicrobial resistance, (2) identifying and quantifying unspecified chemical risks, and (3) assessing allergenicity. These research areas can have visible impact on food safety in Europe in years to come by potentially reducing the number of food-borne illnesses due to improved consumer and supplier capabilities in the prevention, management and identification of contaminated or dangerous foods. By identifying the challenges of the future and addressing them in the present, research can help ensure the safety of our food from farm to fork and further.

APPENDIX 1: GEORISQ MONITOR METHODOLOGY

BACKGROUND

We collected data for the following four indicators: (i) outbreaks of food-borne disease, (ii) certifications of good practices within the food industry, (iii) pro-active approach to notifying food safety issues to the European Rapid Alert System for Food and Feed (RASFF), and (iv) food imported from outside the European Union (EU). We then combined the four to produce a composite score, 'Food Safety Performance'. At the end of this appendix, a table summarizes the selected indicators. A brief analysis of the results, complemented by higher-level reflections and conclusions, is available in the main report.⁶³

COMPOSITE PERFORMANCE SCORE

The overall performance score is calculated by placing all the scores on a scale from 0 (lowest performance) 1 (highest performance) and taking an average score of the four (in essence, the sum total of the component performance scores, divided by 4).⁶⁴ Our indicators are chosen and balanced to reflect overall performance in terms of **outcomes, measures taken, and vulnerability**. Figure 8 outlines the indicators and what they measure.

63 Our GeoRisQ Monitor is subject to change over time with the benefit of new data and expert contributions as they become available.

64 In rare cases, data for some countries was missing for certain indicators. In this event, we averaged the score for the remaining indicators to produce the composite score.

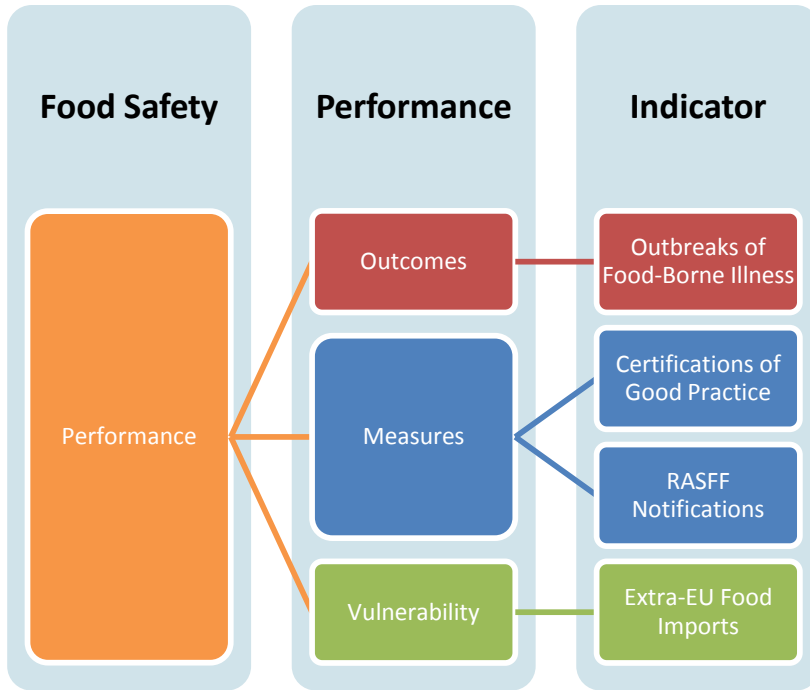


FIGURE 8 SUMMARY OF INDICATORS

The composite index ‘Farm to Fork and Further’ allows for a synthetic measure of the selected drivers of food safety challenges, an intentional aggregation of separable facts, and a form of analysis that is more conveniently presented. A number of choices have to be made when building a composite index, in particular with regard to the selection of indicators, normalization of scores, weighting schemes, and dealing with missing data. These choices could be subject to debate. It may also present methodological issues in terms of robustness of the results. In spite of this word of caution, we do consider it useful to provide an aggregate view of different aspects of food safety performance.

Our monitor and its indicators have certain broad features in common with an existing World Ranking of Food Safety Performance from the Johnson-Shoyama Graduate School of Public Policy. While our monitor looks at the

27 Member States of the EU, the Johnson-Shoyama report focuses on 16 OECD countries.⁶⁵ Whereas our monitor looks at a selection of 4 indicators covering 3 aspects of food safety performance (outcomes, measures taken and vulnerability), the Johnson-Shoyama report uses 11 indicators across 4 categories (consumer affairs, biosecurity, governance and traceability). There is a good deal of similarity in the indicators used; all four of ours feature in a similar spirit in the Johnson-Shoyama report. Reasons for excluding others from our report varied. In some cases, data simply were not available for us to adapt the Johnson-Shoyama indicators to rate EU Member States. In other cases, our view differed on the significance of an indicator. For example, on the use of agricultural chemicals, we chose not to include an indicator as this could show two conflicting things, making for a potentially misleading picture: On the one hand, the use of chemicals indicates the prevention of biological hazards such as pests, but on the other hand it also suggest a chemical hazard.

Another difference is our use of a numerical scale to rank countries, compared to the more straightforward trinomial scale (regressive, moderate progressive) employed by the Johnson-Shoyama report, which was more suited to a ranking based on qualitative indicators. Our focus on quantitative measures allows for a more detailed scale in the ranking.

OUTBREAKS OF FOOD-BORNE DISEASE

For outbreaks⁶⁶ we used the 'reporting rate' published by the European Food Safety Authority (EFSA), which measures the number of outbreaks of food-borne illness per 100,000 population.⁶⁷ This indicator looks at outcomes only, leaving outside of the scope of consideration possible variances in states' detection and reporting systems. We compensate for this in the indicator on notifications to the RASFF.

65 Sylvain Charlebois, *World Ranking: 2010 Food Safety Performance* (Canada: Johnson-Shoyama Graduate School of Public Policy, May 2010).

66 'Incidences of two or more human cases of the same disease or infection in which the cases are linked or are probably linked to the same food source.' European Food Safety Authority and European Centre for Disease Prevention and Control, 'The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2010.'

67 We excluded the figure for Latvia, which was highly anomalous due to a different definition of outbreak used in the country.

Our GeoRisQ Monitor measures performance. The relationship between performance and the rate of outbreaks is inverse: fewer outbreaks indicates better performance. Therefore for this indicator we ranked countries on a scale and inverted it so that the country with the lowest rate of outbreaks scored 1 and the country with the highest rate scored 0.

CERTIFICATIONS

Certifications of good practices within the food industry are an indicator of measures taken. For this indicator we look at the number of food establishments certified for their exemplary safety practices. Of particular interest to us were certification schemes which make use of what is referred to as a 'comprehensive approach'.⁶⁸ This involves two aspects. The first is correct implementation of the 'hazard analysis and critical control points' (HACCP) method, which is the globally recognized standard for identifying and eliminating risks at each stage of production; the second involves requirements for good manufacturing practices, such as the quality of personnel. Only two schemes in the EU make use of this approach: the British Retail Consortium (BRC) and the International Featured Standards (IFS). Only the BRC lists publicly the companies which successfully meet its auditing requirements. This information is constantly kept up to date on the BRC's website.⁶⁹ We analyze this relative to the size of the food industry in each country in terms of the number of people employed. This is available from FoodDrinkEurope.⁷⁰ We then ranked countries on a scale from 0 to 1, with the highest scores going to countries with the most certifications per number of people employed in the food industry.

A disadvantage of measuring performance in terms of BRC certifications is that the currency of schemes varies among countries. The BRC is far more

68 Nicolas Canivet, *Food Safety Certification* (Food and Agriculture Organization of the United Nations, 2006), <ftp://ftp.fao.org/docrep/fao/008/ag067e/ag067e00.pdf>.

69 British Retail Consortium, 'BRC Directory,' *British Retail Consortium*, 2012, <http://www.brcdirectory.com>. Data collected September 2012. The directory is constantly updated; figures may therefore have changed.

70 Food Drink Europe, *Data & Trends of the European Food and Drink Industry*, 04 2012, http://www.fooddrinkeurope.eu/uploads/publications_documents/Final_DT_2012_04.06.pdf.

widely used than the IFS, with offices in 23 countries compared to 10.⁷¹ However the IFS scheme is especially commonplace in France and Germany (and possibly some other countries) and the BRC certification, though still widely used, is less current there. Ideally to compensate for variances among countries in the currency of certification schemes, we would want to triangulate by using data from all comparable schemes. However the lack of publicly available data made this impossible. As a result, France and Germany particularly underperform in our ranking. We compensate for this by looking at a second indicator on measures taken: RASFF notifications.

RASFF NOTIFICATIONS

The indicator on RASFF notifications is another indicator of measures taken. The RASFF registers notifications from Member States when they take action to mitigate a food safety risk.⁷² A number of other things are also cause for a notification to the RASFF, for example outbreaks traced to a particular product; we included only data on measures taken. More notifications from a country means more measures taken and therefore better performance. We therefore ranked countries on a scale from 0 to 1, with the highest scores going to the countries reporting the highest numbers of measures taken.

FOOD IMPORTS

This indicator measures performance in terms of vulnerability to food which may be less safe as a result of it originating in countries which may have less stringent food safety standards than the EU. For food imported from outside the EU, we took figures from Eurostat,⁷³ given in the value of extra-EU-27 trade in millions of euros. We scored this relative to the population of each country to give a number of euros per capita spent on food from countries outside the EU. A higher spend on extra-EU food indicates increased vulnerability and therefore lower performance. To reflect this inverse relationship, we used an inverted ranking scale from 0 to 1, such that the countries with the lowest expenditure on extra-EU food scored highest.

71 Canivet, *Food Safety Certification*.

72 Rapid Alert System for Food and Feed, *2011 Annual Report*.

73 Gilberto Gambini, *EU-27 Consistent World Leader in Trade of Food and Drink*, Statistics in Focus (Luxembourg: Eurostat, 2009), http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-09-078/EN/KS-SF-09-078-EN.PDF.

SUMMARY OF INDICATORS

CATEGORY	INDICATOR	DEFINITION	SOURCE	YEAR
From Farm to Fork and Further: Composite Index		Sum aggregate of normalized values for outbreaks, BRC certifications, RASFF notifications, and extra-EU food imports.		
Outcomes	Outbreaks Reporting Rate	Number of outbreaks of food-borne illness per 100,000 population	European Food Safety Authority ¹⁸	2010
Measures Taken	BRC Certifications	Number of BRC-certified food establishments per 10,000 food-sector employees	Certifications: British Retail Consortium (BRC) ¹⁹	2012
			Employees: FoodDrinkEurope ²⁰	2010
	RASFF Notifications	Number of measures taken as reported to the Rapid Alert System for Food and Feed	Rapid Alert System for Food and Feed ²¹	2011
Vulnerability	External Trade in Food and Drink Relative to Population	Value of extra-EU-27 imports per country in euro expenditure per capita	Trade figures: Eurostat ²²	2008

TABLE 3 INDICATORS OF THE GEORISQ MONITOR 'FROM FARM TO FORK AND FURTHER'

APPENDIX 2: OVERVIEW OF FP7 PROJECTS RELATED TO FOOD SAFETY

DESCRIPTION	PRIVATE SECTOR PARTNER(S)?	DATES	TOTAL BUDGET (EU CONTRIBUTION)
AUTHENTIMEAT Authentication of meat products using ambient surface mass spectrometry	NO	6/11/2012 - 6/10/2014	€200 371 (€200 371)
BIOLISME Speedy system for sampling and detecting <i>Listeria monocytogenes</i> in agro-food and related European industries	YES	6/1/2009 - 2/31/2011	€1 318 067 (€1 014 308)
BIOMIMIC Biomimetic sensors as new generation of biotechnological devices for food safety and quality monitoring	NO	10/1/2009 - 9/30/2012	(€129 600)
BIOSURF Development and implementation of a contact biocide polymer for its application as antimicrobial and anti-deposit surfaces in the food industry	YES	6/1/2009 - 8/31/2011	€1 446 410 (€1 119 712)
CEFSER Reinforcing research potential in the laboratory for chemical contaminants at the faculty of technology towards the establishment of the center of excellence in food safety and emerging risks	NO	2/1/2009 - 7/31/2012	€1 007 652 (€897 650)
DIET DERIVED AGES The influence of processing method on the pro-inflammatory properties of food and pathogenesis of food-related diseases.	NO	10/1/2012 - 9/30/2014	€191 675 (€191 675)
DREAM Design and development of realistic food models with well-characterised micro- and macro-structure and composition	YES	5/1/2009 - 4/30/2013	€8 639 415 (€5 995 786)
FATAUTHENTICATION Authentication of fats and fat products used in food and feed	NO	10/15/2010 - 10/14/2012	€169 035 (€169 035)
FCUB-ERA Reinforcement of the Faculty of Chemistry, University of Belgrade, towards becoming a Center of Excellence in the region of WB for Molecular Biotechnology and Food research	NO	7/1/2010 - 6/30/2013	€1 528 412 (€1 363 000)
FLAVOURE Food and feed laboratory of varied and outstanding research in Estonia	NO	1/1/2009 - 1/31/2012	€944 501 (€843 270)

APPENDIX 2: OVERVIEW OF FP7 PROJECTS RELATED TO FOOD SAFETY

DESCRIPTION	PRIVATE SECTOR PARTNER(S)?	DATES	TOTAL BUDGET (EU CONTRIBUTION)
FOODPATH Evaluation of microbial food hazards and study of the effect of novel food processes on the virulence of foodborne pathogens	NO	9/1/2007 - 8/31/2010	€45 000 (€45 000)
FOODSAF The application of modern proteomic and metabolomic methodologies to the assessment of food safety	NO	9/1/2011 - 8/31/2013	€200 549 (€200 549)
FRISBEE New solutions for improving refrigeration technologies along the food chain	YES	9/1/2010 - 8/31/2014	€8 165 746 (€5 992 082)
HORTIBIOPACK Development of innovative biodegradable packaging system to improve shelf life, quality and safety of high-value sensitive horticultural fresh produce	YES	11/01/2009 - 4/30/2012	€1 519 156 (€1 131 807)
IMPRESS Improved food safety monitoring through enhanced imaging nanoplasmonics	NO	10/1/2011 - 9/30/2015	€589 911 (€589 911)
IQ-FRSHLABEL Developing novel intelligent labels for chilled and frozen food products, promoting the influence of smart labels application on waste reduction, food quality and safety in the European supply chains	YES	8/1/2010 - 7/31/2013	€2 476 395 (€1 857 470)
MEATCOAT Development of a new functional antimicrobial edible film for fresh meat products.	YES	12/1/2011 - 5/31/2014	€2 045 348 (€1 604 600)
MIMYCS A framework for simulating maize kernels mycotoxin contamination in Europe	NO	7/16/2010 - 7/15/2012	€144 290 (€144 290)
NAFISPACK Natural antimicrobials for innovative and safe packaging	YES	11/1/2008 - 12/30/2011	€3 967 279 (€2 971 360)
NANODETECT Development of nanosensors for the detection of quality parameters along the food chain	YES	9/1/2008 - 2/29/2012	€2 732 785 (€2 108 788)
NANOSENS Electrochemical biosensors as new generation of biotechnological devices for food safety and quality monitoring	NO	4/1/2009 - 3/31/2012	(€129 600)
NOMATOS Nonlinearity management of atomic and optical systems	NO	10/26/2009 - 12/25/2011	€202 847 (€202 847)
PLA4FOOD Active multilayer Packaging based on optimized PLA formulations for minimally processed vegetables and fruits.	YES	12/1/2010 - 5/31/2013	€1 497 973 (€1 108 845)

DESCRIPTION	PRIVATE SECTOR PARTNER(S)?	DATES	TOTAL BUDGET (EU CONTRIBUTION)
PROMETHEUS Process contaminants: mitigation and elimination techniques for high food quality and their evaluation using sensors & simulation	YES	5/1/2011 - 4/30/2014	€4 014 795 (€2 999 573)
QUAFETY Comprehensive approach to enhance quality and safety of ready to eat fresh products	YES	1/1/2012 - 12/31/2014	€4 037 464 (€2 932 684)
SAFE-BAG Novel continuous in-pack decontamination system for fresh produce	YES	9/1/2011 - 8/31/2014	€2 393 800 (€1 828 313)
SAFEMTECH Safety in Use and Emerging Technologies in Food Packaging	NO	9/1/2010 - 8/31/2014	€829 068 (€829 068)
SAFETECHNOPACK Improving the scientific and technological research capacity of food institute on safety and technology of food packaging	YES	2/1/2008 - 1/30/2012	€1 065 183 (€950 000)
SOPHY Development of a software tool for prediction of ready-to-eat food product shelf life, quality and safety	YES	2/1/2012 - 1/31/2015	€3 715 252 (€2 879 156)
SUSCLEAN Sustainable cleaning and disinfection in fresh-cut food industries	YES	1/1/2012 - 12/31/2014	€3 859 573 (€2 999 992)
SYM-BIOTICS Dual exploitation of natural plant strategies in agriculture and public health: enhancing nitrogen-fixation and surmounting microbial infections	NO	7/1/2011 - 6/30/2016	€2 320 000 (€2 320 000)
SYMBIOSIS-EU Converging technologies and their potential for the food area	YES	10/1/2008 - 3/31/2012	€3 025 597 (€2 280 098)
UNIQUE-CHECK Development of a unique means of detecting and proving illegal administration of recombinant somatotropin in dairy cows	NO	6/1/2009 - 5/31/2013	€1 049 294 (€1 049 294)
VEG-I-TRADE Impact of climate change and globalization on safety of fresh produce governing a supply chain of uncompromised food sovereignty	YES	5/1/2010 - 4/30/2014	€7 595 351 (€5 999 997)

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