



SYMPOSIUM SciCom FASFC 2011

APPLICATIONS OF MICROBIOLOGICAL RISK ASSESSMENT IN THE FOOD CHAIN

BRUSSELS
FRIDAY, 25 NOVEMBER 2011

EDITED BY THE SCIENTIFIC COMMITTEE AND THE STAFF DIRECTION
FOR RISK ASSESSMENT OF THE BELGIAN FEDERAL AGENCY
FOR THE SAFETY OF THE FOOD CHAIN (FASFC)



On the cover: scanning electron microscopic picture of EHEC O104:H4 outbreak strain (source: Holland, Laue) by courtesy of the Robert Koch Institute (Germany).

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PREFACE

Prof. em. dr. ir. André Huyghebaert

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The Scientific Committee of the Federal Agency for the Safety of the Food Chain annually organizes a scientific symposium on a specific subject.

As an independent scientific advisory body of the Food Safety Agency the Scientific Committee wishes to make a "State of the Art" in regard to an important part of its activities in the area of food safety risk assessment. In this regard, results of our work are placed in a broader context, whereas the international dimension is assured by the contribution by foreign experts. Interested parties with various activities in the food chain are invited to participate at the symposium.

Although the microbial aspects of food safety play a key role in the risk assessment activities of the Scientific Committee, they were only sporadically treated in previous editions of the annual symposium. Furthermore, the recent events in this area fully justify that the microbiological food safety is a central theme this year.

As Chair of the Scientific Committee I express my gratitude to:

- the management of the Food Safety Agency for the opportunity and the support in organizing this annual symposium,
- the colleagues of the Scientific Committee, involved in developing the program of this symposium,
- the Staff direction for risk assessment for the preliminary work.

Given the importance of the topic and its actuality, this years' symposium will undoubtedly receive considerable attention.

TABLE OF CONTENTS

Preface.....	3
Table of contents.....	5
List of Abbreviations.....	6
Program of the symposium.....	7
General introduction.....	9
Session 1: Microbiological risk assessment: possibilities and limitations.....	10
Risk assessment as the scientific basis for policy interventions: possibilities and limitations.....	11
Limitations of risk assessment.....	15
Quantitative risk assessment as a basis for evaluating performance objectives and/or targets at different stages of the food chain to control <i>Campylobacter</i> in broiler meat production.....	18
Evaluation of microbiological risks in the food industry.....	21
Session 2: Applications of microbiological risk assessment.....	23
Simplified web-based risk assessment for use of water in the primary plant production.....	24
Risk of cephalosporin resistance transfer by consumption of broiler meat.....	27
Risk of listeriosis from consumption of smoked salmon.....	31
Emerging microbial risks in the food chain.....	35
Summary and Conclusions.....	45

LIST OF ABBREVIATIONS

AFSSA	French Agency for Food Safety
a_w	Water Activity
ALOP	Appropriate Level of Protection
ANSES	French Agency for Food, Environmental and Occupational Health and Safety
BFP	Between-Flock Prevalence
BIOHAZ Panel	Panel on Biological Hazards
CFU	Colony Forming Unit
CODA-CERVA	Veterinary and Agrochemical Research Centre
CREC	Cephalosporin Resistant <i>Escherichia coli</i>
DALYs	Disability-Adjusted Life Years
EAggEC	Enterotoxigenic <i>Escherichia coli</i>
ECDC	European Centre for Disease Prevention and Control
EEA	European Environment Agency
EFSA	European Food Safety Authority
EHEC	Enterohemorrhagic <i>Escherichia coli</i>
EIEC	Enteroinvasive <i>Escherichia coli</i>
EPEC	Enteropathogenic <i>Escherichia coli</i>
ESBL	Extended Spectrum Bèta-Lactamase
ETEC	Enterotoxigenic <i>Escherichia coli</i>
EMM	Europe Media Monitor
ERDSS	Emerging Risk Detection Support System
EU	European Union
FASFC	Belgian Federal Agency for the Safety of the Food Chain
FBO	Food Business Operator
FSA	Food Standards Agency
FSMS	Food Safety Management System
FSO	Food Safety Objective
GAP	Good Agricultural Practices
GHP	Good Hygienic Practices
GIEWS	Global Information and Early Warning System
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis Critical Control Point
HDC	Horticulture Development Company
ILSI	International Life Sciences Institute
INFOSAN	International Food Safety Authorities Network
MRL	Maximum Residue Level
OIE	World Organization for Animal Health
OIVO	Onderzoeks- en Informatiecentrum voor de Verbruikersorganisaties
PO	Performance Objective
QA	Quality Assurance
(Q)MRA	(Quantitative) Microbiological Risk Assessment
RASFF	Rapid Alert System for Food and Feed
RTFP	Red Tractor Fresh Produce scheme
SciCom	Scientific Committee of the Belgian Federal Agency for the Safety of the Food Chain
STEC	Shiga-Toxin producing <i>Escherichia coli</i>
VTEC	Verocytotoxin producing <i>Escherichia coli</i>
WHO	World Health Organization
WIV-ISP	Wetenschappelijk Instituut Volksgezondheid
YOPI	Young, Old, Pregnant, Immunocompromised

Symposium
of the Scientific Committee of
the Belgian Food Safety Agency

**APPLICATIONS OF MICROBIOLOGICAL RISK ASSESSMENT IN THE
FOOD CHAIN**

Friday, 25 November 2011
Pachéco auditorium
(Finance Tower Complex)
Pachécolaan 13
1000 Brussels

9:00	RECEPTION
9:30	Introduction André HUYGHEBAERT (Prof. Em. Ghent University - Chair Scientific Committee FASFC)
	Session 1. Microbiological risk assessment: possibilities and limitations Chair: Mieke UYTENDAELE, Claude SAEGERMAN
9:40	Risk assessment as the scientific basis for policy decisions: possibilities and limitations Olivier CERF (Prof. Em. National Veterinary School of Alfort, Paris - Vice-chair of the specialized Committee of experts « Microbiology », ANSES)
10:15	Limitations of risk assessment Dirk BERKVENS (Prof. ITG, Antwerp - SciCom FASFC)
10:50	COFFEE BREAK
11:20	Quantitative risk assessment as a basis for evaluating performance objectives and/or targets at different stages of the food chain to control <i>Campylobacter</i> in broiler meat production Arie HAVELAAR (Prof. Utrecht University - Reporter of the opinion on quantitative risk assessment of <i>Campylobacter</i> from broilers - BIOHAZ panel, EFSA)

11:55	Evaluation of microbiological risks in the food industry
	FRANÇOISE DELMAS-JULIEN (Ph.D. Nestlé Research Center)
12:20	RECEPTION
13:00	LUNCH
	Session 2. Applications of microbiological risk assessment Chair: Katelijne DIERICK, Etienne THIRY
14:20	Simplified web-based risk assessment for use of water in the primary plant production
	Jim MONAGHAN (Harper Adams University College, UK)
14:45	Risk of cephalosporin resistance transfer by consumption of broiler meat
	Jeroen DEWULF (Prof. Ghent University - SciCom FASFC)
15:10	COFFEE BREAK
15:40	Risk of listeriosis from consumption of smoked salmon
	Lieve HERMAN (Head of division ILVO-T&V - SciCom FASFC)
16:05	Emerging microbial risks in the food chain
	Mieke UYTENDAELE (Prof. Ghent University - SciCom FASFC)
16:30	Summary and conclusions
	Xavier VAN HUFFEL (Director Staff direction for risk assessment, FASFC)

GENERAL INTRODUCTION

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The EHEC O104:H4 epidemic outbreak in Northern Germany in the spring of 2011 has shown the great vulnerability of the consumer to emerging pathogens having acquired a deadly combination of virulence factors and being introduced into the food chain through unexpected gateways. The observation that infected sprouted seeds were on the origin of the German outbreak and the French cluster of hemolytic uremic syndrome was crucial to implement the necessary control measures. Although EHEC O104:H4 has never been isolated in Belgium, its absence on vegetables had to be proven in order to help to restore export of Belgian fresh produce to the international markets.

Other pathogens have also threatened recently the safety of our food chain: *Listeria monocytogenes* in cheeses, *Salmonella* spp. in pork sausages and in grinded white pepper, etc. The acquisition of multiple antibiotic resistance genes by many foodborne bacteria and commensal flora is also a food safety issue which cannot be denied any longer. These examples show that the risk for microbial contamination of food stuffs needs continuous attention during primary production, food processing and food handling and preparation during food service and at home.

The Scientific Committee of the Belgian Food Safety Agency has therefore decided to focus this years' annual symposium on the subject of '**Applications of microbiological risk assessment in the food chain**'. Microbiological risk assessment is a corner stone in safe food production and in the development of an adequate food safety control policy. It is a timely and interesting subject to be discussed with scientists, policy makers and stakeholders in the food chain.

In this symposium general viewpoints on the possibilities and limitations of risk assessment will be dealt with as well as more concrete examples will be explained of the application of microbiological risk assessment. National and international experts will give their opinion on the challenges and bottlenecks of microbiological risk assessment related to specific topics and on the emergence of microbiological risks in the food chain.

SESSION 1: MICROBIOLOGICAL RISK ASSESSMENT: POSSIBILITIES AND LIMITATIONS



RISK ASSESSMENT AS THE SCIENTIFIC BASIS FOR POLICY INTERVENTIONS: POSSIBILITIES AND LIMITATIONS

Prof. em. dr. Olivier Cerf

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FOOD SAFETY, THE PRESENT SITUATION

Let be an adverse health condition with a specific nature and severity, caused by the consumption of a food. The causative agent in the food is named a *hazard*, and the probability or frequency of that health condition is named a *risk*. This is a terminology common to the Commission of the Codex Alimentarius and the World Organisation for Animal Health (OIE). In order to protect the consumer against hazards, food business operators (FBO) must implement good hygienic practices (GHP) and apply the principles of the Hazard Analysis Critical Control Point system (HACCP). The result is the actual situation regarding the morbidity and mortality of foodborne diseases. According to countries, this situation is called Appropriate Level of Protection (ALOP) or Acceptable Risk.

FBOs are provided with a number of helpful Guides to GHP. Most links in the food chain (primary production, processing industry, retail) have their own Guides, and these are published independently from each other. Therefore, even if the preceding link has done its best, this is not always what the next link in the chain would have wished and the FBO has to do its best with what is provided to him. It must be mentioned that some misconceptions are still present in many guides as regards the application of HACCP principles. A weakness of the Hygiene Package is the absence of reference to the Directive 2006/42 on Machinery and its Annex A, Section 2.1. Hygienic design is not inspected by the competent authority, and is lacking in the Guides to GHP. As a consequence, many premises and equipment are uncleanable and allow the persistence of unwanted bacteria. The Hygiene Package establishes microbiological criteria for foods (Regulation 2073/2005). Yet, the Regulation does not



include the case of indicators that produce toxins when their concentration becomes high. Another problem is the labeling of the “best before” or “use by” dates (Directive 2000/13). Their validity is questionable and the competent authorities have no harmonized EU verification framework.

When the level of consumer protection degrades or the risk is perceived to be or to become unacceptable, the present remedy lies in the regulatory implementation of more, or more severe, hazard control measures. It can be said, therefore, that the present system is empirical and “*hazard focused*”. As each link in the chain acts independently, it is difficult in general, and even impossible in most cases, to estimate the effect of a hazard control measure on the risk to the consumer. While the system works globally, one may ask if it could be possible to adopt a better one.

DOING BETTER?

Since the 1st January 1995, the Member States of the World Trade Organization must justify their decisions as regards their sanitary protection by means of a scientific risk assessment, with reference to their ALOP or Acceptable Risk. *Risk Assessment* is the first component of the *Risk Analysis* process. It consists in a *scientific evaluation* of the risk, done by independent scientists. The second component is *Risk Management*, a *political evaluation* of the risk and the taking of decisions on law, regulation, etc. by the Risk Managers, which are the “competent authorities” of the States. The third component, *Risk Communication*, implies interactive exchange between all interested parties about the risks, risk factors, as well as about opinions and perceptions. Hence, the political decision has to account not only on the risk itself, but also on societal considerations.

QUALITATIVE RISK ASSESSMENT

According to the definition of risk, the public health outcome of consuming a dangerous food is expressed in terms of disease severity and probability. These two components must be combined to arrive at a qualitative estimation of the risk. The usual combination is the multiplication of the probability by the severity. You can multiply numbers, but not words: this is why numbers are usually attributed to words, and why the misnomer name of semi-quantitative risk assessment is given to this technique. For example, on a 1 to 3 scale, the severity of listeriosis can be qualified as severe, score 3, that of campylobacteriosis as mild in general, score 1; the probability of listeriosis can be qualified as low, score 1, that of campylobacteriosis as high, score 3. According to these scores, the risks of listeriosis and campylobacteriosis are the same: 3. Is such a scoring useful to the Risk Manager?

Systems that are more elaborate are therefore developed. One example was the scheme established in 2008 for animal health risk assessment by the French Agency for Food Safety (AFSSA), with scoring on 0 to 9 scales for the probability of illness and the severity of consequences. That scheme should be further elaborated before being applicable to foodborne hazards.

When assessing new technological processes, the experts answer questions such as: “Does the process reduce the exposure to the hazard(s)?”. The Expert Committee on Microbiology of ANSES (French Agency for Food, Environmental and Occupational Health and Safety), for example, was asked recently to give advices on the UV treatment of beef carcasses, the chemical decontamination of poultry carcasses, the decontamination of wheat flour by peracetic acid, the ultra-high pressure treatment of prepared dishes, etc. Simple answer leading to simple decisions by the Risk Manager can be given to this simple question.



QUANTITATIVE RISK ASSESSMENT

To overcome the limitation of qualitative risk assessment, a three component quantitative process is recommended. The first component is the *Exposure Assessment* which estimates the dose, which is the amount of hazard ingested. This component can be limited to the study of the end-product, but a model encompassing the whole food chain allows optimizing the hazard

control measures. The second component is the *Dose-Response Assessment* where a relation is established between the dose ingested and the probability for one consumer to suffer from the studied adverse health condition. It is assumed (i) that the minimum infectious dose is one colony forming unit, which causes the illness with probability r , and (ii) that the probability of illness P is equal to the product of r by the dose. Each vulnerable sub-population for a given hazard has a specific value for r . The establishment of dose-response relations is the most difficult part of risk assessment. The third component is *Risk Estimation*, which combines the outcome of the two other components. The whole process can be done with a single value for each element of a so-called *deterministic model*. It can also be done with distributions of values, accounting for variability and/or uncertainty in a so-called *probabilistic model* [1]. In the latter case, the models can be intricate, when sophisticated mathematical techniques such as Monte Carlo simulation and Bayesian inference are used. The question posed, the complexity of the studied process, the availability of data, the allowed time frame dictate the kind of model deemed appropriate. Overly simplistic models and super-complex ones should be avoided. Yet, some degree of complexity is needed for the model to be reasonably realistic and to enable process optimization.

The information on the ALOP is of no practical use to FBO. Therefore, two operational concepts were developed: the maximum frequency and/or concentration of a hazard in the servings at the time of consumption (Food Safety Objective-FSO) or at earlier steps in the food chain (Performance Objective-PO) that provide or contribute to the ALOP. The link between the ALOP and the FSO is the dose-response relation. According to the Commission of the Codex Alimentarius, FSO must be established by the competent authority, while POs can be established by the industry and in some cases also by the competent authority. The definitions of FSO and PO are not satisfactory: they relate to concentration instead to dose, and assume that a limit must “never” be exceeded.

Examples of quantitative risk assessments will be given to illustrate that apparently simple questions may lead to complex answers causing embarrassment to the Risk Managers: *Cronobacter* in powdered infant formulas, *Listeria monocytogenes* in ready-to-eat foods, STEC (Shiga-Toxin producing *Escherichia coli*) in minced beef meat.

DISCUSSION

Qualitative risk assessment is simple, it can be done in emergency situations, and is easy to understand and implement. However, it can be too simplistic, and when it uses numbers to score hazard exposure and consequences, it may give the illusion of objectivity. *Quantitative* risk assessments is more objective, and it forces to look closely to every steps of the event chain leading to a risk; it allows optimizing the interventions; it is the only solution when experiments cannot be done or when the risk is low. However, deterministic models can be simplistic, while probabilistic ones can be costly, time consuming and seldom practicable in emergency situations; they can be difficult to understand and their conclusions can be difficult to implement.

Management focusing on *hazards* is easy to do, and is the basis of traditional inspection procedures. However, it is empirical; each link of the food chain is considered independently from the other links, and no quantitative relation is established between hazard control measures and their effect on public health. Management focusing on *risks* is more scientific and systematic; it is focused on what is acceptable for public health; it enables to consider the food chain in its entirety from the last link (the table) back to the first one (the farm); and it enables

optimization of processes. However, it can be complex to achieve and difficult to understand. In addition, it should lead to revise inspection procedures.

In the future, according to circumstances and availability of data, the coexistence of qualitative and quantitative risk assessment is expected as well as the one of hazard and risk focused approaches to risk management. Yet, quantitative risk assessment and management focused on risk are already gaining importance.

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LIMITATIONS OF RISK ASSESSMENT

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ABSTRACT

The risk analysis paradigm is a powerful tool for the assessment and management of risks in numerous domains of public concern. It produces useful, unambiguous information as long as the necessary care is taken to ensure proper communication of the uncertainty inherent to its inputs and outputs. Alternative methods, such as scenario analysis or fuzzy logic analysis, offer equally useful approaches, but all partners must be aware that recourse was taken to these alternatives because the risk could not be quantified correctly.

CONTENT

The first recorded reference to risk analysis is attributed to Pericles in his famous funeral speech before the assembled Athenians (Thucydides, 431 BCE), although it does take some imagination to interpret the paragraph in question as an example of rational risk assessment and risk management. Trying to understand the etymology of the word 'risk' is in itself an interesting pursuit: generally accepted appears the Greek root *peirao* (danger), coming to us via the Latin *periculum*, although one must admit encountering the Latin *resecare* (to cut back) quite regularly as well.

An unambiguous definition of the concept 'risk' is even more of a problem, as Kaplan (1997) reminds us: *Many of you here remember that when our Society for Risk Analysis was brand new, one of the first things it did was to establish a committee to define the word 'risk'. This committee labored for 4 years and then gave up, saying in its final report, that maybe it's better not to define risk. Let each author define it in his own way, only please each should explain clearly what that way is.* The real problem would seem to be people tending to forget the second part of the last sentence.



Irrespective of the definition, the risk assessor must be able to communicate two important quantities to the risk manager: first, the probability that something will or will not happen and, second, how certain one is about one's assessment. Ensuring correct transmission of the level of uncertainty in the estimate, the lack of knowledge, the lack of reliable information is just as important as reporting an average, median or modal probability. But this aspect is all too often overlooked when people attempt to develop a novel approach to measure risk.

The central issue always has been (and still is and will remain to be so) finding a common language in which to communicate lack of knowledge. An obvious (and ideal) vehicle consists of the framework offered by the probability theory, in which it is possible to precisely quantify the level of uncertainty in an unambiguous way. Unfortunately, many people refuse to accept a situation where uncertainty is so overwhelming that the only correct way to inform the risk

manager is to state 'I know nothing'. Fear for the application of the precautionary principle is usually the motive to insist on performing a risk analysis anyhow.

A common way to overcome the absence of reliable and usable information is to resort to a so-called qualitative approach. A discussion on quantitative versus semi-quantitative versus qualitative is in the end an aimless and counterproductive undertaking. What is important is on the one hand to ensure that both sides (risk assessors and risk managers) understand the methodology used (i.e. ensure there is a common language) and on the other hand to guarantee that the uncertainty about the parameter estimates is clearly communicated. As stated before, ideally probability distributions are used (Aven, 2003, 2010; Stirling, 2007), but other systems, respecting the basic properties of probabilities (i.e. comprehensiveness and mutual exclusiveness) can also be employed (Maudoux *et al.*, 2006).

Potential problems arise when systems to measure and communicate risks are developed that do not adhere to the basic principles of probability theory (see above) but that make use of scales typical of fuzzy logic (e.g. Anon, 2008). Computation rules and final defuzzification are specific to this domain and are not always amply understood by both risk assessors and managers, who may both underestimate the uncertainty of the inputs and outputs during this process. The assessors should make it absolutely clear that this approach is strictly speaking not a risk analysis and managers should understand the implications. Essentially the same remark goes for the application of scenario analyses, but it should nevertheless be clear that, given transparent communication, both approaches are perfectly valid, as was shown in the case of the risk evaluation of *Trichinella* in Belgium (Advice 23-2009, Sci Com FASFC).



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QUANTITATIVE RISK ASSESSMENT AS A BASIS FOR EVALUATING PERFORMANCE OBJECTIVES AND/OR TARGETS AT DIFFERENT STAGES OF THE FOOD CHAIN TO CONTROL CAMPYLOBACTER IN BROILER MEAT PRODUCTION

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Following a request from the European Commission, the Panel on Biological Hazards of the European Food Safety Authority was asked to deliver a scientific opinion on *Campylobacter* in broiler meat production: control options and performance objectives and/or targets at different stages of the food chain. EFSA commissioned the development of a quantitative microbiological risk assessment (QMRA) model which has been used to estimate the impact on human campylobacteriosis due to the presence of *Campylobacter* spp. in broiler meat. This QMRA was also used to rank/categorize selected intervention strategies in the farm to fork continuum, for which quantitative data, of sufficient quality on efficacy for *Campylobacter* reduction at the point of application, were available. The evaluation of microbiological criteria required the development of a specific model by the BIOHAZ Panel, using data from the EU baseline survey, as an input.

It is estimated that there are approximately nine million cases of human campylobacteriosis per year in the EU. The disease burden of campylobacteriosis and its sequelae is 0.35 million disability-adjusted life years (DALYs) per year and total annual costs are 2.4 billion €.

Campylobacter jejuni and *C. coli* are considered equivalent for the purpose of risk assessment in this opinion because there is no information on variability between these two species with respect to their behavior in the food chain, impact of interventions or virulence for humans. There are no indications that *Campylobacter* strains with antimicrobial resistance behave differently in the food chain than their sensitive counterparts.

As previously estimated by the BIOHAZ Panel, handling, preparation and consumption of broiler meat may account for 20% to 30% of human cases of campylobacteriosis, while 50% to 80% may be attributed to the chicken reservoir as a whole (broilers as well as laying hens). The transmission routes from chickens to humans, other than handling, preparation and consumption of broiler meat, are not well understood, and related public health benefits cannot currently be quantified.

The public health benefits of controlling *Campylobacter* in primary broiler production are expected to be greater than control later in the chain as the bacteria may also spread from farms to humans by other pathways than broiler meat. There is, however, very little information about these pathways and quantifying the impact of interventions at farm level was only done for broiler meat-related cases.

Strict implementation of biosecurity in primary production and of GMP/HACCP during slaughtering is expected to reduce the level of colonization of broilers with *Campylobacter*, and the contamination level of carcasses and meat from colonized flocks. The effects of such



implementation cannot be quantified because they depend on many interrelated local factors. Nevertheless, their impact on public health risk reduction may be considerable.

Quantitative risk assessment based on data from four countries has concluded that there is a linear relationship between prevalence of *Campylobacter* in broiler flocks and public health risk. The risk reduction associated with interventions in primary production is expected to vary considerably between MSs. Reducing the numbers of *Campylobacter* in the intestines at slaughter by 3 \log_{10} -units, would reduce the public health risk by at least 90%. Reducing the numbers of *Campylobacter* on the carcasses by 1 \log_{10} -unit, would reduce the public health risk by between 50 and 90%. Reducing counts by more than 2 \log_{10} units would reduce the public health risk by more than 90%. The risk reduction associated with reducing concentrations on carcasses is expected to be similar in all MSs (although the baseline level of risk differs considerably).

Vertical transmission does not appear to be an important risk factor for colonization of broiler chickens with *Campylobacter*. Logistic slaughter, the separate slaughter, dressing and processing of negative and positive flocks, has negligible effect on human health risk.

Based on the results of the quantitative risk assessment, the specific control options discussed in this opinion would reduce public health risk is as follows:

In primary production, based on the results of one MS, 50-90% risk reduction can be achieved by the use of fly screens in the presence of strict biosecurity measures. Based on the results of four countries, up to 50% risk reduction can be achieved by restriction of slaughter age of indoor flocks to a maximum of 28 days, and up to 25% risk reduction by discontinued thinning.

After slaughter, a 100% risk reduction can be reached by irradiation or cooking on an industrial scale, if re-contamination is prevented. More than 90% risk reduction can be obtained by freezing carcasses for 2-3 weeks. A 50-90% risk reduction can be achieved by freezing for 2-3 days, hot water carcass decontamination or chemical carcass decontamination with lactic acid, acidified sodium chlorite or trisodium phosphate.



Scheduled slaughter aims to identify colonized flocks before slaughter so that they can be subjected to decontamination treatment. In low prevalence situations, the number of batches that need treatment is strongly reduced. Risk assessment, based on data from two countries, indicated that, when testing four days before slaughter, 75% of the colonized flocks are detected.

Control options in primary production, such as restriction of slaughter age and discontinuing thinning are directly available from a technical point of view but interfere strongly with current industrial practices. Control options for reducing carcass concentration, such as freezing, hot water and chemical decontamination are also directly available. Chemical decontamination is subject to approval in the EU and no chemicals are currently approved for use.

The BIOHAZ Panel has evaluated the public health risk reduction of applying instruments that are currently available in EU legislation, i.e. targets at primary production and microbiological criteria for foodstuffs.

Assuming all countries with a between-flock prevalence (BFP) of less than 25% or 5% in 2008 maintain that status, then achieving a target of 25% or 5% BFP in all other MSs is estimated to

result in 50% and 90% reduction of public health risk at the EU level, respectively. The realistic time period needed to obtain reductions due to targets in primary production will differ between countries depending on the present status and possibilities for practical implementation of different interventions and is a risk management issue. It is not realistic to consider targets for flocks with outdoor access. The share of such flocks in the total production is expected to increase in future.

The public health benefits of setting microbiological criteria were evaluated using data from the 2008 EU baseline survey. These estimates are average values for the whole EU; the impact could be very different between MSs. Theoretically, a public health risk reduction > 50% or > 90% at the EU level could be achieved if all batches that are sold as fresh meat would comply with microbiological criteria with a critical limit of 1000 or 500 CFU/gram of neck and breast skin, respectively. Correspondingly, a total of 15% and 45%, of all batches tested in the EU baseline survey of 2008, would not comply with these criteria.

Microbiological criteria could theoretically be implemented immediately but the ability to comply will also differ between MSs. They stimulate improved control of *Campylobacter* during slaughter.

The BIOHAZ Panel recommended that effective control options should be selected and verified under conditions where the application is intended to be used by industry to reduce *Campylobacter* and comply with potential targets and/or microbiological criteria when established. Several data gaps were identified and generation of data in several areas was recommended.

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TOOLS TO SUPPORT SAFETY ASSESSMENTS IN NESTLÉ

Microbiological Risk Assessment (MRA) is a structured and scientific process for evaluating the risk posed by microorganisms in food and is recognized as an essential approach in food safety management, together with risk management and risk communication.

While governments perform MRA to evaluate the public health risks that are associated with food products on the national markets, the food industry is approaching MRA differently. Indeed the food industry does not conduct risk assessments as governments do, but they need to ensure safe and stable product and process design. In order to achieve this goal they can apply the principles of MRA to any single food/process of interest. Most of the time the endpoint of such analyses/safety assessments is not in terms of public health statistics but in terms of survival or growth of pathogens or spoilage microorganisms in a given food/process. At Nestlé such studies are conducted to support safe and stable product innovation and renovation and this is a real challenge based on the huge range of products we are manufacturing.

Microbiological food safety in general is a complex issue which is continuously changing: evolving microorganisms, globalization of the supply chain, new consumption trends and changes in human population. Aware of the food safety challenges, Nestlé management has clearly demonstrated its commitment to food safety microbiology. One of the actions resulting from this commitment is the enforcement of food safety microbiology in Nestlé R&D worldwide. The food safety microbiologists have, supported by others R&D specialists, developed instructions and tools to contribute to or to conduct safety assessments. For example there are systems to identify emerging/re-emerging hazards, prevalence of microorganisms in raw materials and to do shelf life determination and challenge tests.



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SESSION 2: APPLICATIONS OF MICROBIOLOGICAL RISK ASSESSMENT



SIMPLIFIED WEB-BASED RISK ASSESSMENT FOR USE OF WATER IN THE PRIMARY PLANT PRODUCTION

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INTRODUCTION

UK growers produce safe food to some of the highest standards in the world. Every now and then we see news stories about outbreaks of foodborne illness associated with fresh produce. The effect of these outbreaks is to lower consumers' confidence in fresh produce and reduce product sales. As a consequence, there is particular focus within the UK retail sector on the microbiological risks associated with the consumption of produce that is not cooked before being eaten, such as fruit and salad vegetables.

THE ROLE OF QA STANDARDS IN MAINTAINING MICROBIAL FOOD SAFETY.

The UK industry has a number of guidelines specifically managing microbiological contamination of fresh produce along the supply chain. Many UK retailers look to industry-wide schemes such as the Red Tractor Fresh Produce scheme (RTFP) in the UK, and GLOBAL G.A.P. overseas, to provide the standards. Producers can also gain guidance from trade-funded bodies such as the Chilled Foods Association. Some retailers such as Tesco and Marks and Spencer have developed mandatory global codes of practice which are enforced as a condition of trade. These apply to suppliers irrespective of the country of production.

WHEN IS SAFE, SAFE ENOUGH?

These codes of practice were developed following the principles of Hazard Analysis and Critical Control Points (HACCP). However, the reality of crop production means that, in contrast to a ready meals factory, in many instances it is not possible to eliminate risk by the use of a 'true' critical control point such as cooking in a product that is to be eaten raw. The philosophy applied when growing crops that are likely to be eaten uncooked is one of imposing 'hurdles' to minimize the risk of contamination as far as possible.

A key component of developing food safety systems on farm is through risk assessing crop inputs. But when is the level of risk acceptable? Put another way, when is safe, safe enough? To complicate matters all of the QA schemes and codes of practice rely on independent audits of growers to establish whether crops are being produced in compliance with the standards. This means that there will be times when a grower and auditor disagree about a risk assessment – because they rely on opinion about acceptable levels of risk.

Whereas growers get clear guidance as to when a pesticide residue is acceptable, through maximum residue levels (MRL) for active ingredients, there is limited guidance for growers on whether inputs are acceptable from a food safety perspective. All the schemes require growers to test water sources for microbial quality but there are no statutory criteria for indicator bacteria in UK irrigation waters. One



retailer, Tesco, has put in place a web-based system that enables growers to complete a risk assessment on-line for water use in leafy salad crops along with limits for acceptable micro testing of water for irrigation. Marks and Spencer have also given clear guidance on acceptable micro testing for both water and manure inputs. Growers stated that they found this approach helpful for developing their own food safety systems.



There were two key recommendations from a recent UK Food Standards Agency (FSA) report undertaken by Monaghan *et al.*, (2009) relating to micro testing and risk assessments: a) growers wanted guidance on micro testing, particularly of water, and what indicator bacteria should be monitored; b) growers also wished for guidance in interpreting the relative risks in the areas of water, manure and worker hygiene to help develop robust risk assessments that were comparable across the UK production base.

HDC/FSA FUNDED PACKAGE TO HELP GROWERS

In response to this feedback, the grower funded levy-board, the Horticulture Development Company (HDC) and FSA jointly funded a package of work for 2010 that included a factsheet, web-based risk assessment tools and a series of roadshows around the UK.

- The factsheet '**Monitoring microbial food safety of fresh produce**' was available Summer 2010. This gave a grower-friendly overview of the main bacteria and viruses that should be considered; summarized the possible indicator species that could be tested for; and gave recommendations on how growers could best interpret laboratory reports and respond to them.
- Three **web-based tools to support risk assessments** were developed and launched in October 2010 (www.safeproduce.eu). The three risk assessments covered were: water use; manure/composted manure inputs; and worker hygiene. Decisions on relative risk were based on scientific evidence and current FSA recommendations. Where the scientific evidence was limited, industry best practice was taken as the basis for relative risk and the RTFP standards were taken as the base standard. Each stage of the risk assessment is linked to help pages summarizing the evidence behind each statement, giving growers robust, evidence-based risk assessments that are applicable to both QA schemes and codes of practice.
- **Keeping it Clean seminars** were held in the main fresh produce production areas in England, Scotland, Wales and Northern Ireland. The seminars covered the best practice approach to risk assessment, micro testing of crop inputs and gave hands-on training for using the web-based tools to support risk assessments for all the attendees.

The process of development and uptake of the web-based tools will be summarized in this presentation along with a discussion of the challenges to getting growers to use the available tools to ensure their crop production systems are as safe as possible, minimizing risks to the consumer.

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RISK OF CEPHALOSPORIN RESISTANCE TRANSFER BY CONSUMPTION OF BROILER MEAT

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ABSTRACT

From a public health perspective, the risk of exposure to cephalosporin resistant *E. coli* through consumption of broiler meat was assessed. A quantitative risk model was built based on existing validated models, expert opinions and scientific data to quantify the risk of exposure to different doses of cephalosporin resistant *E. coli* present in a meal containing broiler meat. The risk of exposure to 1000 cfu cephalosporin resistant *E. coli* in a meal was estimated to be 1.5%. The major part of the exposure is due to cross-contamination in the kitchen, pointing out the importance of good hygiene measures during preparation of broiler meat. Furthermore the proportion of cephalosporin resistant *E. coli* (within the total number of *E. coli*) in primary production and the overall contamination of broiler carcasses or broiler parts with *E. coli* are of significant influence on the risk of consumer exposure to cephalosporin resistant *E. coli*. The risk of this exposure for human health however, cannot be estimated at this stage given a lack of understanding and quantitative data on the minimal infective dose needed to enable transmission of antimicrobial resistance genes and the impact of a variety of influential factors in the human gut.

INTRODUCTION



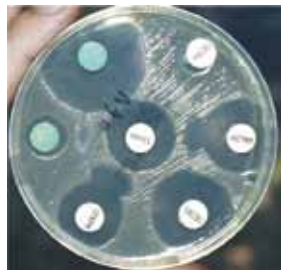
The acquired resistance of *E. coli* against cephalosporin antimicrobial drugs is becoming a major issue in intensive broiler farming. In Belgium, about 36% of the *E. coli* strains isolated from broilers are resistant to cephalosporin antimicrobial drugs while 60% of the broilers are found being carrier of these cephalosporin resistant *E. coli* (CREC) after selective isolation.

The risk for the consumer of broiler meat that is contaminated with CREC consist mainly of the possible transfer of resistance genes to other, possibly pathogenic, bacteria. Indeed, CREC strains of broilers cause only exceptionally infections in humans. On the other hand it is possible that they transfer their resistance genes to possibly pathogenic bacteria in the human digestive tract during transfer or colonization of that digestive tract.

Therefore, from a food safety point of view, the Scientific Committee wanted to gain insight into the possible exposure of consumers to CREC through consumption of broiler meat. For that purpose a quantitative risk analysis model that aims at estimating the possible uptake of CREC by the Belgian consumer of broiler meat that was produced in Belgium was designated.

MATERIAL AND METHODS

The model consists of different modules that closely simulate the farm to fork chain starting from primary production, over slaughter, processing and distribution to storage, preparation and consumption of broiler meat. The model was built using @risk software (Pallissade inc. USA) and was composed based on existing validated models, next to additional expert information and scientific data. The model consists of three major modules. Module 1 starts at primary production, where the proportion of CREC present in broilers was estimated, next to the number of *E. coli* present on broiler carcasses and parts to come to the load of CREC present on broiler carcasses or parts. Also possible changes to this proportion during the slaughter process are simulated based on prior knowledge (Persoons et al., 2010). Module 2 covers the processing and transformation of broiler meat, where possible freezing, mincing, transport circumstances and ways of cross contamination are taken into account. In module 3 the actual preparation of broiler meat at home is simulated.



RESULTS AND DISCUSSION

The results indicate that about 1,5% of the meals with broiler meat contain more than 1000 colony forming units (cfu) of CREC. Table 1 provides the exposure rates for different doses of CREC.

TABLE 1. EXPOSURE RATE TO DIFFERENT DOSES OF CEPHALOSPORIN RESISTANT *E. COLI*

Exposure dose (cfu/portion)	Risk of exposure
10	0,39%
100	1,53%
1000	3,26%
10000	7%

The Table shows that the exposure rate is largely dependent of the dose that is considered to be relevant. However, the true impact of the exposure dose on human health cannot be estimated at this stage given a lack of understanding and quantitative data on the minimal infection dose needed to allow resistance transmission and the effect of all influential factors in the human gut. Furthermore the model points out that the majority of exposures is caused by cross contamination in the kitchen (Table 2), which is again an argument to respect good hygiene measures during preparation of broiler meat.

TABLE 2. EFFECT OF DIFFERENT TYPES OF EXPOSURE

	10000 cfu	1000 cfu	100 cfu	10 cfu
exposure from minced broiler meat	0%	0%	0%	0,03%
exposure from broiler parts	0%	0%	0%	0%
exposure from whole carcass	0%	0%	0%	0%
exposure from ready cooked	0%	0%	0%	0%
exposure from broiler meat in general	0%	0%	0%	0,03%
exposure from cross contamination	0,39%	1,53%	3,26%	6,97%
total exposure	0,39%	1,53%	3,26%	7%

Furthermore the proportion of CREC (within the total number of *E. coli*) in primary production and the overall contamination of broiler carcasses or broiler parts with *E. coli* are of significant influence on the risk of consumer exposure to CREC. This means that a sound antibiotic drug policy in primary production and respect of good hygiene practices in the slaughterhouse and cutting plant could reduce significantly the risk of exposure to CREC during consumption of broiler meat.



CONCLUSION

The model shows that exposure to cephalosporin resistant *E. coli* through consumption of broiler meat is possible. The question remains, however, what the relevant dose is to which a consumer needs to be exposed that may lead to transfer of resistance genes and colonization of the intestinal tract. Regardless of the magnitude of impact of this route of transfer from broilers to men, efforts must be done in primary production to stop the emergence of cephalosporin resistance and antimicrobial resistance as a whole to prevent jeopardizing human health. Also in human health, continuous efforts – like good cooking practices - are needed to limit the possibility of transfer from animals or animal products to men.

ACKNOWLEDGEMENTS

The authors thank the Scientific Committee of the FASFC for critical reading.

The text is based on the Advice 08-2010 of the FASFC Sci Com on exposure assessment to cephalosporin resistant *E. coli* through consumption of broiler meat.

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RISK OF LISTERIOSIS FROM CONSUMPTION OF SMOKED SALMON

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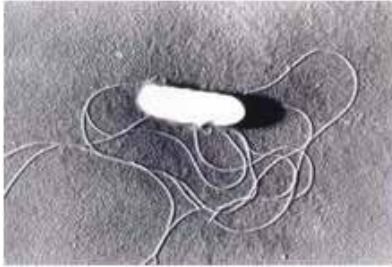
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ABSTRACT

Listeria monocytogenes is a Gram-positive foodborne pathogenic bacterium, causing listeriosis. It is able to grow at refrigeration temperatures in different food products, including smoked salmon. The risk of listeriosis by consumption of smoked salmon is quantitatively assessed, using several sets of data: 1) the prevalence and enumeration data of *L. monocytogenes* on smoked salmon obtained by the FASFC control program; 2) the Belgian consumption data for smoked salmon as obtained by the Belgian consumption survey (WIV, 2006); 3) the demographic data of the Belgian population (FOD Economie, KMO, Middenstand en Energie, 2010); 4) the storage temperatures in distribution (4°C or data from FASFC inspections) and at the consumer level (7°C or data from the Belgian consumption survey, WIV, 2006). The FASFC data of the monitoring program indicate a high prevalence of *L. monocytogenes* in smoked salmon on the Belgian market (18.7% and 15.4% samples positive in 25 g for data of 2002-2005 and 2006-2009, respectively). The microbiological results obtained from the FASFC monitoring program were complemented by expert opinion, pathogen growth modeling and the use of literature data on the relation between *L. monocytogenes* uptake and infection. Using realistic conditions of storage temperature and time, the number of listeriosis cases in Belgium due to the consumption of smoked salmon was estimated 3-4 per year. With a total reported listeriosis cases in Belgium (10.5 million inhabitants) ranging from 32-68 per year in the period 1998-2008, the data suggest that smoked salmon is one of the food products, contributing to human listeriosis. Growth modeling enables the evaluation of different scenarios of temperature and time during the shelf life of the products. Risk management can be based on this scenario analysis. The overall reduction of the shelf life with 25% decreases the number of listeriosis cases with 57.7%; temperature control at retail (max 4°C) with 30.6% whereas temperature control at consumer level (max. 7°C) is estimated to accomplish a 70.7% reduction of listeriosis cases attributed to consumption of smoked salmon. The combination of both temperature control at retail and at consumer level) is estimated to reduce the number of listeriosis cases with 95.2%. This study shows that the microbiological results obtained from the FASFC monitoring program in Belgium may support the elaboration of a quantitative risk assessment if they are complemented with expert opinion, pathogen growth modeling, and some supplementary research data.

CONTENT

Listeria monocytogenes is the causative agent of listeriosis. It is one of the most virulent foodborne pathogens, with 20 to 30 % of clinical infections resulting in death. Clinical features range from mild influenza-like symptoms to meningitis and/or meningo-encephalitis. Illness is most likely to occur in pregnant women, neonates, the elderly and immunocompromised individuals, but apparently healthy individuals may also be affected. In pregnant women,



infection of the fetus can occur and can lead to abortion, stillbirth, or delivery of an acutely ill infant. In Belgium, about 6 listeriosis cases per 10^6 inhabitants are yearly registered (WIV).

L. monocytogenes is a Gram-positive, non-spore-forming, motile, facultative anaerobic, rod-shaped bacterium, which is widespread in nature. It is able to grow at temperatures as low as 1°C , pH 4.3 and a water activity of 0.92. *L. monocytogenes* is a foodborne pathogen and at risk products have

been identified as processed foods with an extended shelf life under refrigeration such as soft cheeses, smoked fish products, cooked or raw cured smoked meat products and deli-salads. *L. monocytogenes* has been frequently found in smoked salmon and smoked salmon salad on the Belgian market (Van Coillie et al., 2004; Uyttendaele et al. 2009).

In this study, the risk of listeriosis by consumption of smoked salmon is quantitatively assessed, using several sets of data: 1) the prevalence and enumeration data of *L. monocytogenes* on smoked salmon obtained by the FASFC control program; 2) the Belgian consumption data for smoked salmon as obtained by the Belgian consumption survey (WIV, 2006); 3) the demographic data of the Belgian population (FOD Economie, KMO, Middenstand en Energie, 2010); 4) the storage temperatures in distribution (4°C or data from FASFC inspections) and at the consumer level (7°C or data from the Belgian consumption survey, WIV, 2006).

The FASFC data of the control program confirms the high prevalence of *L. monocytogenes* in smoked salmon on the Belgian market (18.7% and 15.4% samples positive in 25 g for data of 2002-2005 and 2006-2009, respectively). Samples, kept in the lab at refrigeration temperature till the end of the shelf life, indicate that 27% of the positive samples and 5% of all samples did not comply to the threshold value of < 100 cfu/g at the end of the shelf life.

The FASFC monitoring data of *L. monocytogenes* in smoked salmon and the FASFC experimental data of the growth of *L. monocytogenes* in the positive samples kept until the end of the shelf life, were complemented by expert opinion, defining the maximal contamination at the end of shelf life at $\leq 100,000$ cfu/g. Based on this, different probabilistic distributions were fitted to the contamination levels of *L. monocytogenes* in smoked salmon. On the other hand the FASFC data were also complemented by modeling the growth of *L. monocytogenes* after production till consumption using a mathematical model available in literature. Therefore, the growth boundary model was used, taking into account the typical physico-chemical characteristics of smoked salmon such as pH and lactic acid, salt and phenol content (Mejholm & Dalgaard, 2007). The model was applied using different probabilistic distributions of the contamination of smoked salmon after production. This approach enabled to evaluate the risk for the consumer at different moments of consumption (not limited to the end of shelf life) and to evaluate the effect of the storage temperature and the storage time on the growth of *L. monocytogenes* and hence the risk for the consumer.



The Belgian consumption data indicate that the Belgian population between 15-99 years old consumes $6.6 \cdot 10^6$ portions/ 10^6 individuals/year with 95% of them consuming ≤ 100 g salmon/portion. A distribution of the portion size of smoked salmon in

Belgium was elaborated. A distribution of the exposure level of the Belgian population to *L. monocytogenes* due to the consumption of smoked salmon was calculated by combining the data of the contamination levels of smoked salmon with those of the portion consumed. In the next step a dose/response model from literature was used to relate the uptake of *L. monocytogenes* cells with listeriosis (WHO/FAO, 2004). The combination of the exposure data with the dose/response model results in the determination of the risk of the Belgian consumer to get listeriosis from the consumption of smoked salmon. In this analysis the number of vulnerable persons for listeriosis (YOPI) was estimated to be 2.5×10^6 (statistical data FOD Economie, KMO, Middenstand en Energie, 2010).

Depending upon which probabilistic distribution of *L. monocytogenes* contamination in smoked salmon was selected, the mean number of listeriosis cases in Belgium due to consumption of smoked salmon was estimated between 0.2 and 1 per year (using the actual *L. monocytogenes* data obtained by FASFC after storage of positive samples until the end of shelf life) and between 1 and 1.6 cases (after simulation of the growth of *L. monocytogenes* during shelf life by modeling under the same conditions as in the first risk assessment). The model was also used with conditions that are more consistent with reality: use of a temperature distribution for the chilled distribution and the refrigerator of the consumer, assumption of consumption at 75% of shelf life and the assumption that half of the total storage time (shelf life) of smoked salmon occurred in retail and the other half in the household refrigerator of the consumer. After simulation, the number of listeriosis cases in Belgium (10,5 million population) by consumption of smoked salmon was estimated to be 3.14 per year. In 2008, 53 listeriosis cases were reported in Belgium. These data suggest that smoked salmon is one of the food products, contributing to human listeriosis.

By using scenario analysis the impact of storage temperature of smoked salmon both in the retail and in the household refrigerator on the number of listeriosis cases was evaluated. The study shows that temperature control at the distribution (max. 4°C) decreases the risk for listeriosis with 30.6 % and at the consumer level (max. 7°C) with 70.7%, indicating the importance of temperature control in the Belgian household kitchens. The combination of temperature control both at retail and at consumer level reduces the amount of listeriosis cases with 95.2%. Also the impact of shortening the shelf life was evaluated: e.g. the number of listeriosis cases decreases with 57.7% when the consumption was assumed on 75% of the shelf life instead of 100%.

CONCLUSION

This study shows that the microbiological results obtained from the FASFC monitoring program in Belgium may support the elaboration of a quantitative risk assessment if they are complemented with expert opinion, pathogen growth modeling, and some supplementary research data. The inclusion of predictive modeling in the quantitative risk assessment has the advantage that it allows the evaluation of different scenarios of temperature and time during the shelf life of the products on the risk for listeriosis. Risk management can be based on this scenario analysis.

Concerning listeriosis, this study confirms the high prevalence of *L. monocytogenes* on smoked salmon and its contribution to human illness with an estimated cases of 3.14 per year. The reduction of the shelf life with 25% reduces the amount of listeriosis cases with 57.7%; temperature control during distribution (max. 4°C) with 30.6% and at consumer level (max. 7°C) with 70.7%, and the combination (temperature control during distribution and at consumer level) reduces the amount of listeriosis cases with 95.2%.

ACKNOWLEDGEMENTS

The authors thank the Scientific Committee of the FASFC for critical reading.

The text is based on the Advice 35-2010 of the FASFC Sci Com on risk assessment of *Listeria monocytogenes* in smoked salmon.

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EMERGING MICROBIAL RISKS IN THE FOOD CHAIN

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INTRODUCTION

The global dimensions and increased complexity of food and feed supply chains nowadays make them more vulnerable to the occurrence of food and feed safety hazards in products meant for human consumption. The increased awareness and knowledge of food and feed safety hazards also leads to an increased concern towards our supply chain and explain the increased efforts to control related emerging risks. Marvin et al. (2009) have recently evaluated a number of worldwide early warning systems for existing and new risks and classified them in three categories, namely Reactive systems which are endpoint- or hazard-focused and which are designed to monitor the food and feed safety hazard or human, animal and plant diseases (e.g. Enter-Net, INFOSAN, OIE, PulseNet International, ProMED, RASFF); Proactive predictive systems for known hazards, such as those systems developed for prediction of mycotoxin contamination of wheat and maize (e.g. DONcast) or broadly orientated information collecting systems such as GIEWS and EMM, and Holistic systems, which also take into account developments outside the food and feed supply chain that may eventually lead to the emergence of risks within this chain (e.g. EPICA, “Futures” studies, ERDSS) (EFSA 2011a). Best known by stakeholders and widely used to be informed on emerging risks are the weekly summaries and annual reports from RASFF published on the European Commission’s website (http://ec.europa.eu/food/food/rapidalert/index_en.htm). Furthermore, EFSA has set up a dedicated Emerging Risks unit, EMRISK, supporting the development of an operational capacity to identify emerging risks in food and feed at an earlier stage, ideally before they have developed (<http://www.efsa.europa.eu/en/panels/emrisk.htm>).

The definition of emerging risk currently in use in EFSA is as follows: “an emerging risk to human, animal and/or plant health is understood as a risk resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard”. Main data and information sources that are of use to identify emerging risks may be clustered into four types, namely “soft” including media and grey literature; “regulatory” including data from rapid alert systems and compulsory reporting/monitoring of foodborne illness; “scientific” including published papers, proceedings, research findings and documented reports and “expert judgment”. The data sources may vary considerably in quality and their usefulness for the identification of emerging risks and are further extensively discussed in a recent EFSA colloquium (EFSA, 2011b) and a recently issued EFSA Technical Report on Data collection for the identification of emerging risks related to food and feed (EFSA 2011a). In a Discussion Forum on safety of fresh produce organized within the framework of the EU FP7 Veg-i-Trade project in January 2011, various stakeholders were asked to rank their dominant data sources for being up to date on emerging risks and as expected the EC RASFF was considered to be the most important information source for opinion forming concerning the safety of fresh produce. Other data sources within the overall Top 5 were in decreasing order official reports issued by various national and

international organizations or agencies, legislative documents, informal face-to-face contacts and scientific literature (<http://www.veg-i-trade.org/visibility/cm/cm2/cm2.php>).

To extract and collect information from the available data sources, sophisticated computer added data mining systems may be developed and applied. In some countries or organizations experience is being built with the set-up and use of intelligence management systems for identification of emerging risks or at least to contribute in a systematic way to an early warning system. For animal diseases the MOSS system was recently developed by CODA-CERVA. In the mean time in most countries or organizations, at various stakeholders committees or within the competent authorities and academic and research institutes there is continuous reflection on emerging risks based upon input experts receive ad hoc or on an annual basis from the above mentioned data sources. Following, some reflections are presented in relationship to emerging microbiological risks in the food chain and the challenges this puts to risk assessment strategies.

MICROBIAL BIODIVERSITY

The wide biodiversity of microbial strains and the pool of pathogenic genes in the microbial community is a continuous potential source of emerging pathogens. This can well be illustrated by the German EHEC outbreak strain, a multiresistant Shiga-toxin producing *Escherichia coli* (STEC) that belongs to serotype O104:H4. The outbreak strain possessed an unusual combination of virulence factors of STEC/VTEC usually associated with ruminant strains and enteroaggregative *E. coli* (EAggEC), which is a typical human pathogen. The concept of *E. coli* pathotypes, such as EHEC, EIEC, EPEC, ETEC, EAggEC, etc., has long been used as a convenient way to describe *E. coli* strains carrying specific virulence-associated genes, production of distinct toxins and the clinical characteristics associated with infection. Owing to the genetic mobility of some virulence-associated genes (i.e. genes can move between bacteria via mobile genetic elements such as plasmids or bacteriophages), *E. coli* strains can no longer simply be classified as belonging to one pathotype. The complexity of *E. coli* (including EAggEC VTEC) belonging to various serotypes and possessing a wide variety of virulence factors also reflects on the subsequent difficulties in defining and characterizing the *E. coli* pathogens to be targeted for food monitoring and surveillance for public health purposes. The *E. coli* O104 outbreak investigations revealed the complexity to detect and differentiate the pathogenic *E. coli* strains from the commensal *E. coli* strains. It exemplified the need to identify emerging pathogens at the strain level and no longer at the species level. Consequently, there is a need for a tool box of molecular techniques to identify the pathogenic culprit strains. This outbreak also showed that despite all the science and research being elaborated, we still need to be modest about our knowledge and understanding of the microbial world and that we should be aware about the limitations of our current methods and classification systems. It does show as well that close monitoring of human diseases and timely aggregation and analysis of clinical data within a region or a country, may be a particular important early warning system on potential emerging risks. It should be pointed out however referring again back to the EHEC outbreak in Germany, that although this combination of VTEC and EAggEC as manifested in the *E. coli* O104:H4 outbreak strain is very rare it has been previously described in strains of serotype O111:H2 involved in a small outbreak of HUS in children in France (Beutin et al., 2004). Furthermore, EAggEC VTEC have also been reported to be involved in an European outbreak (Morabito et al., 1998) and in patients with HIV in Bangui, Central African Republic (Mossoro et al., 2002), but it is impossible to predict which new, chimeric pathogenic *E. coli* strain is the next to be linked to foodborne outbreaks.

In a similar way, the same biodiversity exists for the other well-known pathogens that belong to the Enterobacteriaceae family e.g. *Salmonella* sp., *Yersinia enterocolitica*, *Shigella* sp. Also within these species a large number of bio-/serotypes exists of which variation in pathogenic character occurs and some of these bio-/serotypes are frequently associated with a specific host and incidence being dependent upon region. For example for *Yersinia enterocolitica*, strains belonging to biogroup 1A are not commonly associated with human infections unlike serotypes within biogroup 1B (O:8, O:4, O13a, 13b, O:18, O20 and O:21), biogroup 2 (O:9, O:5, 27), biogroup 3 (O:1,2,3, O:5, 27), biogroup 4 (O:3) and biogroup 5 (O:2,3). In Europe, *Yersinia enterocolitica* biotype/serotypes 4(O:3) and 2(O:9) are commonly associated with human disease. In the USA where sporadic infections are less commonly reported, bio-/serotype 1B(O:3) is commonly associated with outbreaks (EFSA, 2007a). Also for *Salmonella* sp. a wide variety of serotypes is reported. For *Salmonella* sp., majority of reported cases are still associated with *S. Enteritidis* and *S. Typhimurium*, and (still) linked to consumption of (insufficiently heated) eggs, pork or poultry meat. The main focus is put on the following five serotypes to reduce the amount of infected poultry breeders: *S. Enteritidis*, *S. Infantis*, *S. Hadar*, *S. Typhimurium*, *S. Virchow* and *S. Typhimurium*-like strains (EU regulation 2160/2003). However all non-Typhi *Salmonella* serovars are of a comparable pathogenicity for humans, and apart from eggs, poultry and pork also other food types have been involved in recent years in *Salmonella* outbreaks (e.g. melons in US in 2011 due to *S. panama*, fresh produce in US in 2010 due to *S. Hvittingfoss*, jalapeño and serrano peppers in US in 2008 due to *S. Saintpaul*, etc.). Thus continuous attention to other *Salmonella* serotypes potentially on the rise, or other foods that may serve as vehicle of infection is needed. In particular, certain serotypes which might adapt and find an ecological niche in animals or plant production may lead to emergence of new microbial risks.

Another expression of biodiversity of foodborne pathogens leading to emergence of pathogens, could be due to a new or increasing exposure route e.g. a previously unexpected ability to adapt to adverse conditions applied in food processing and food preservation. For example also within the group of Enterobacteriaceae, *Salmonella* and *Cronobacter sakazakii* (formerly known as *Enterobacter sakazakii*) have been demonstrated to survive for prolonged periods (several months) in low a_w foods. Examples include foods containing high levels of sucrose e.g. chocolate, cake, biscuits and confectionery such as pepperoni and salami and dried foods such as milk powder, flour and powdered infant formula. Similarly, the increased acid tolerance of *E. coli* O157 strains and thus its improved ability for survival in for example dry and semi-dry fermented meat products or fruit juices has contributed to its rise as a foodborne pathogen (ILSI 2011a).

Furthermore there is increasing concern that feeds and foods act as vehicles for the dissemination of antibiotic resistant bacteria to humans of which in particular ESBL bacteria have drawn much attention lately (Van Boxstael et al., 2011; Sci Com FAVV, 2011). This increased biodiversity and versatility of microorganisms leads to the fact that new pathogens emerge, but also “old” established pathogens such as *Salmonella* still pose threats to public health and may re-emerge and get renewed attention. It is a challenge for microbial risk assessment to take into account the variability in pathogenicity and growth characteristics. Further research in hazard identification and data on the prevalence and behavior of these various bio-/serotypes of (re-)emerging pathogens is recommended.

NON ZOOONOTIC AGENTS AS FOODBORNE PATHOGENS

The large *E. coli* O104 outbreak in Germany and France in May/June 2011 that has been widely discussed (EFSA 2011c,d,e) also emphasizes the fact that bacterial strains with a predominantly human reservoir, are more and more getting recognized as possible foodborne pathogens (human to human transmission via food). Coagulase positive staphylococcus intoxications are a well known established example. EAaggEC have a predominantly human reservoir and infections are usually associated with prolonged watery diarrhea, particularly among children and travelers to developing countries (ECDC, 2011). The same holds for Norovirus and Hepatitis A virus (HAV) as emerging pathogens. Again these enteric virus types causing human infections are at the present time not considered to be zoonotic pathogens (i.e. any disease and/or infection which is naturally transmissible directly or indirectly between animals and humans) but have a predominant human reservoir. Recent studies suggest the presence of noroviruses in pigs and cattle, but there is no evidence for direct zoonotic transmission. In the EU, the major mode of transmission for enteric viruses remains person-to-person (directly from the human reservoir) but indirect transmission from the human reservoir, mainly as a consequence of travelling to endemic regions, or consuming contaminated water or food has been increasingly acknowledged. Numerous foodborne outbreaks caused by viruses have been seen in the EU. In 2008, 19 MSs reported a total of 697 outbreaks, and for the second year in a row, the total number of outbreaks caused by viruses increased. For those outbreaks that were verified, noroviruses were the most frequent cause, followed by HAV. Apart from tickborne encephalitis virus, which can be shed by infected dairy animals and subsequently infect humans via milk; and hepatitis E virus which can be transmitted through consumption of undercooked meat, viral foodborne infections are limited to the recycling of human viruses back to humans (EFSA 2011c).

Thus, these pathogens with predominant human reservoir (whether bacteria or viruses) although not recognized as zoonotic agents, are nowadays often detected as contaminants in the food supply chain and are therefore classified as foodborne pathogens. Viruses do not multiply in food, but may persist for extended periods of time as infectious particles in the environment, or in food. They are characterized by a low infection dose. Also some non-zoonotic bacteria (such as pathogenic *E. coli* with human reservoir), if recognized as foodborne pathogens are generally characterized by a low infectious dose and ability to persist in the environment and in food. These non-zoonotic (viral or bacterial) pathogens may in particular emerge in foods in institutional catering or in food services in restaurants or home parties. Most of the time in these outbreaks ready-to-eat foods are involved which are prone to extensive manipulation by food handlers (prior diseased or potentially asymptomatic carriers) during preparation, or during harvest and processing. Also foods that are imported from third countries or regions in which these pathogens are endemic in the population and/or where hygienic implementation is prone to improvement have been involved in such outbreaks of non-zoonotic pathogens e.g. the HAV outbreak linked to sun-dried tomatoes imported from Turkey in spring 2011.

Other pathogens that may emerge, and for which, just as for viruses, until recently their role as foodborne pathogens is not yet elucidated because of lack of expertise with methods of detection among food microbiologists, are protozoa. Infection with *Cryptosporidium parvum*, *Cyclospora cayetanensis*, *Giardia lamblia* occurs mainly through contaminated water (through swimming in contaminated water or through consumption of fruit and vegetables irrigated with contaminated water containing protozoa). In the case of *Cyclospora*, humans are the only host and as such human fecal contamination is a prerequisite for infection (contamination can occur through contaminated irrigation water with untreated wastewater or due to contact during harvesting (manually picking) of for example soft red fruit). *Giardia* and *Cryptosporidium* have a

wide range of mammalian hosts besides humans, thus making it very difficult to eradicate. Giardiasis is also known as “beaver fever” as beavers and muskrats are important reservoirs (Devlieghere et al., 2011).

Non-zoonotic foodborne pathogens put challenges to microbial risk assessments as contamination is often a random localized effect (when unhygienic handling by infected food handler occurs) and very few data are currently available on the prevalence and distribution of these pathogens in the food chain (rare events makes appropriate sampling plans difficult to elaborate and in addition detection methods are still cumbersome and difficult to interpret). Thus the elaboration of risk assessment studies may need a different methodological approach and close collaboration as well with experts in water microbiology and/or clinical microbiologists. Furthermore as growth of these pathogens is not or less applicable but the (international) trade and/or organization of the food services operation may have a large impact, it would be recommended to include logistic models in risk assessment studies.

WATER QUALITY IS A CRITICAL CONTROL POINT IN THE FOOD CHAIN

The use of wastewater, excreta and greywater in agriculture and aquaculture can help communities to grow more food and make use of precious water and nutrient resources. However, it should be done safely to maximize public health gains and environmental benefits. In 1973, the World Health Organization (WHO) published *Reuse of effluents: Methods of wastewater treatment and public health safeguards*. This normative document provided guidance on how to protect public health and how to facilitate the rational use of wastewater and excreta in agriculture and aquaculture. In 2006 these guidelines were updated to take into account scientific evidence concerning pathogens, changes in sanitation practices, social/equity issues and socio-cultural practices.

Water plays an important role in the food supply chain, not only in primary production as irrigation water or to apply pesticides, in aquaculture or livestock watering but also in postharvest and food processing and preparation. Water may be used as an ingredient, for reconstitution of powders, as transport medium, for washing, rinsing, scalding, chilling, blanching, pasteurizing, steam production, in brines, etc. and of course also in cleaning, sanitation, disinfection. Water may enable to reduce the microbial contamination, in particular by rinsing and removing dirt and soil which are sources of bacteria, by washing and reducing bacterial contamination on the condition that microbial cells are able to detach from the surface of the food item, or by dilution of microbial contamination (if water used as an ingredient). However, water, if insufficient in quality, may also act as a vehicle for transfer of enteric pathogens. This in particular if no sanitizer or other inactivation treatment is used to control microbial quality of water, or if water basins are not refreshed on a regular basis and thus built up of organic material and associated microbial load is possible during storage or processing time. In addition water and moist environment or areas with condensed or standing water (including drains, floors, coolers, conveyors and case washing) may also promote the survival of for example *L. monocytogenes*, promote persistence, enhance the more homogeneous spreading and prolonged survival of pathogens throughout the product and production environment, and enable for biofilm formation (Uyttendaele, 2009).

As there is a scarcity of (potable) water, food business operators are forced for first development of unit operations that use less water and optimization of water circuit, second recycling or reuse (following reconditioning) of water or third to look for alternative sources as potable or “clean” water. Recycling/reuse of water is possible (according to EC N°852/2004) if the residual water quality is of the same standard as potable water, and the quality of the “clean”

water cannot affect the wholesomeness of the foodstuff in its finished form. Reuse of water should neither affect the quality nor the safety of the food product and thus is a complex and demanding process to document. As such water has become a critical control point in many food processes and recycling/reuse of water requires appropriate procedures and monitoring in place once implemented. Risk assessment studies are warranted on a case by case basis to provide input to the potential water sources and water quality applicable for a defined application or process and the prerequisites set for the use of “clean” water e.g. reconditioning techniques need to be validated; time/temperature conditions during stockage to be established, frequency of refreshment of water, microbiological criteria to be set which are fit for purpose, etc.

GOOD HYGIENIC PRACTICES REVISITED

Concerning control measures to guarantee food safety, it is established that the application of good agricultural practices (GAP), good manufacturing practices (GMP), good hygienic practices (GHP), the introduction of HACCP (hazard analysis critical control points), and the certification of food safety management systems (FSMS) are considered to be important for assuring the safety of food (Baert et al., 2011a). Although in the last 10 years many efforts have been put in HACCP and HACCP based preventive systems for assuring food safety, it should be noted that still GAP, GMP, GMP are the prerequisite programs that are the basis for elaboration of HACCP and advanced FSMS and as such still these basic prerequisites also need a fair deal of attention. Often in foodborne outbreaks, the origin of the outbreak might be traced back to rupture in respect of these “good practices” in place i.e. cleaning and disinfection, infrastructure and maintenance of equipment, respect of the cold chain, personnel hygiene, operator health conditions, etc. This continuous attention to cleaning and disinfection of the production environment (floors, walls), equipment (e.g. cutting machines, centrifuges, refrigeration, transport carts), to separation of – if applicable – heated (processed) products and unheated (unprocessed) components and products, respect of the cold chain (including at the consumer’s stage) has been noticed to be in particular important to prevent contamination or limit the growth of *L. monocytogenes* and the food intoxicating microorganisms such as *Staphylococcus aureus* and *Bacillus cereus*. In particular for the production of bacterial toxins (either preformed in the food or in the gastro-intestinal tract upon ingestion of high levels of the toxin producing organism with the food) usual scenario involves unacceptable (post)contamination and/or inadequate cool-down and storage conditions (at distribution or preparation and food service operations or the consumer’s home).

As such in risk assessment in order to include this noncompliance to “good practices” it is important to have sufficient data on the variability in adherence to “good practices” in agricultural production and processing in order to assess the potential for unacceptable high levels of contamination (the tails of the input distribution in a risk assessment study) and post-contamination events. In addition for accurate risk assessment it is important to have access to “reasonable foreseen” time and temperature profiles during storage and distribution, and to have reliable information on consumer behavior on home storage and preparation (probability of undercooking and cross-contamination). The importance of these type of data sets is illustrated in the risk estimate for listeriosis due to *L. monocytogenes* in the smoked salmon as elaborated recently by the FASFC Scientific Committee (Sci Com FAVV, 2010).

In connection to assessing “good practices” in food businesses, again as these are random rare events, screening for the pathogens itself is preferred but might not always provide sufficient information as incidence is expected to be low (< 1%) and thus sampling and analysis may provide false negative results and distributions fit to the obtained contamination levels may still

be prone to high uncertainty. Nevertheless, sampling and testing might be useful for detection of systematic failures in “best practices” in the supply chain and major routes of transmission/introduction of pathogens in the supply chain. In addition as a proxy to looking for the pathogens itself, hygiene indicators may be monitored which to some extent might serve as an index or marker organisms for the “pathogen contamination” e.g. *E. coli* as fecal hygiene indicator, *S. aureus* as indicator of personnel hygiene, aerobic sporeforming organisms or sulfite reducing clostridia as hygiene and quality indicators or *Listeria* spp. as indicator for *L. monocytogenes*. It is however, a challenge to include these data sets based on hygiene indicators in risk assessment studies as there is a need for correlation of these proxy indicators to actual foodborne pathogens contamination which is not always a straightforward one to one relationship but rather an increased probability of finding also pathogens in the food (Habib et al., 2011a).

With regard to obtaining information on consumer behavior, very few studies are available and collection of data is time consuming and outcome should be carefully interpreted dependent upon the methodology applied. For example questionnaire and interview data are largely reliant upon self-reported practices and consumer knowledge. Discrepancies between self-reported practices and actual food-handling behaviors have been reported (Redmond et al., 2003). Also regional differences or variation depending upon age and education or social status in consumer behavior may occur thus needing representative sampling.

It has been noticed that in particular with regard to adherence to “good practices” and daily operation of food production, significant variability may occur in time and between food businesses. Awareness and knowledge of guidelines and procedures, but also persistence of existing habits and attitudes may influence compliance and actual implementation of procedures in place! However, compliance to good practices may be significant to the pathogen prevalence and levels in the final food product. For example in pigs, *Salmonella* carriage is high, but it is obvious that slaughterhouse hygiene is a determinative factor for managing carcass contamination (Botteldoorn et al., 2003). It was also noted in the EFSA *Campylobacter* baseline study that the risks for contamination of broiler carcasses with *Campylobacter* and for higher *Campylobacter* counts on carcasses varied between slaughterhouses within countries, even when other associated factors, such as the prevalence *Campylobacter*-colonised batches and the age of the broilers, were accounted for. These findings indicate that certain slaughterhouses are more capable than others in preventing *Campylobacter* contamination and in controlling the contamination and/or the *Campylobacter* counts on the carcasses, implying that the slaughterhouse and the processing steps offer both an opportunity for *Campylobacter* risk mitigation in broilers and can contribute to increasing the risk, notably in the case of poor hygienic performances (EFSA opinion 2010; Habib et al., 2011b). The challenge for risk assessment studies is to built in these variability on good hygienic practices or other risk factors in the outcome of the overall risk estimate which is again data intensive but may be relevant.

EMERGING EATING HABITS AND THE NOTION OF ACCEPTABLE RISK

Individuals tend to eat more out-of-home, often at cafeterias, canteens, fast food outlets, bars and restaurants. A national food consumption survey in Belgium demonstrated that in 2004 more than 35% of the population consumed more than 25% of their daily energy intake out-of-home (WIV, 2006). New foods e.g. sushi, pasta salads and new cooking trends including e.g. wokking, microwave heating are popular as is the tendency for consumption of raw foods e.g. carpaccio's, raw milk and raw milk products.

There is an increased demand of consumers for convenience foods and or mildly processed food. Increased sales of cooked chilled food or ready-to-eat meals as well as prepacked bagged fresh produce mixes or sliced meat products have been reported over the last decennium. Mild processing techniques and hurdle technology are available to reply to consumer demands of a better quality product with enhanced convenience, freshness, texture, flavor and color attributes. However also safety of these products needs to be guaranteed. This drives the need for a risk assessment approach. Microbiological risk assessment can be used to evaluate the safety impact of alternative processes. The severity of the established preservation method or heat treatment can be balanced against the level of control in the other parts of the process in the food processing chain e.g. by ensuring low initial contamination levels or by alternative product formulation and appropriate packaging to inhibit growth (ILSI, 2011b). Determination of initial levels, reductions to be achieved, potential growth that can occur, etc. must be based on solid information. Such data can be obtained from literature, databases, predictive models, surveys and experiments. It is clear that in a probabilistic approach the outcome of a microbial risk assessment is also a probability distribution and as such that a zero risk is not achievable but can be minimized and controlled. The same holds for many of our traditional processed food and in particular in case of raw consumption of meat and produce.

An example of new trends in demands of the consumer for 'healthy' food is the increasing demand for products with less salt. The demand for products with less salt (NaCl) has been increasing, which is attributed to an increasing awareness of the society considering nutrition and health. However, salt (NaCl) is an important factor in food preservation (reduction of a_w value) and also causes growth inhibition of *L. monocytogenes*. The risk for listeriosis, also for these food products can be guaranteed but needs appropriate food product formulation (alternatives to salt (NaCl) to decrease a_w value) and may need more advanced quality assurance and control systems in place (Devlieghere et al., 2011).

In respect of the current financial-economic crisis, consumers' choice of food products gets more driven by price. In a recent survey of OIVO in Belgium (<http://www.oivo-crioc.org/files/nl/6014nl.pdf>), it was determined that consumers' intention to buy a particular food item is mainly driven by its cost price (43%), followed by its attributed quality aspects (20%), freshness (15%), taste (6%), brand (4%) and organic character (lack of pesticides use) (3%). Also in the inquiry of the stakeholders in Belgium on the pressures that may affect the status of the safety of the food chain, financial and economic aspects were considered by all actors to be a dominant factor with potential impact on the actual status of food safety (Baert et al., 2011b). With increasing impact of what could be called aspects of "food security" versus "food safety" and the awareness and social debate on food waste (exemplified by the phenomenon of dumpster diving and questioning the usefulness of the expiry date), there might be pressures on the resources and preparedness to pay for and invest in a high level of food safety. Within this context there is an increasing need for appropriate risk communication and debate on the notion of acceptable risk.

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SUMMARY AND CONCLUSIONS

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The Scientific Committee of the Belgian Food Safety Agency has the tradition to organize an annual symposium or workshop addressed to a broad public of food policy makers, food safety control inspectors, scientists, representatives of food industry associations, food business operators and consumer organizations. Different topics have already been treated in the previous editions such as the precautionary principle, risk assessment in the food supply chain, the use of databases in food safety risk assessment, emerging animal diseases, measurement of food safety via indicators and nanotechnology. The annual symposium provides the opportunity to the Scientific Committee to communicate with a broad public on specific subjects and on its proper work (scientific opinions) done in the field of food safety and risk assessment.

This year the focus lies on applications of microbiological risk assessment to support food safety and risk management – a subject which turned out to be very up-to-date given the recent EHEC O104:H4 outbreak in Northern Germany. With 2.987 cases of acute gastro-enteritis, 855 patients suffering from HUS and 53 mortalities (state on 16/8/2011) this outbreak is considered as one of the most serious food safety crisis's of the last decade in Western-Europe. It has taught us that virulent pathogens may emerge in the food chain at any time and under given circumstances may affect both public health and trade and markets dramatically within a short period of time. Rapid availability of appropriate diagnostic methods to detect the presence as to prove the absence of the incriminated pathogen on suspected food items and sampling by food safety authorities has been shown to be very important to restore consumers' confidence and international market access.

This symposium however was not specifically dedicated to discuss on the EHEC O104:H4 outbreak. The objective of the symposium was to reflect on various aspects of microbiological risk assessment and to present a number of specific case studies.

Nowadays, it has been widely accepted that risk assessment is the scientific basis for food policy interventions. However, risk assessment has its possibilities and limitations. Thanks to international organizations such as the Codex Alimentarius, the World Organization for Animal Health, the EFSA and other competent advisory bodies and research institutions, food safety risk assessment has become a structured process with a standardized terminology and approach. Qualitative and quantitative methodologies in evaluating a risk can be used depending upon the availability of data and resources, the nature of the questions, etc. A major bottleneck however still remains the issue on how to deal with uncertainty and how to communicate transparently on knowledge and on lack of knowledge to risk managers. These aspects have been discussed in the presentations by O. Cerf and D. Berkvens.

Different speakers have presented results on specific applications of the quantitative microbiological risk assessment methodology.

With regard to *Campylobacter* in the broiler meat production chain (A. Havelaar) it was shown that the quantitative risk assessment methodology allows the evaluation of the public health benefits of setting microbiological criteria and the application of selected intervention and

control strategies along the production and processing chain. The scientific opinion elaborated by EFSA in that regard provides very useful information and recommendations for risk managers and for the sector to make further steps in the control of *Campylobacter* in broilers and broiler meat.

Microbiological hazards are of increasing concern in ready to eat fresh produce (fruit, salad vegetables, etc.). Pre-harvest preventive measures (e.g. sanitary quality of irrigation water, worker's hygiene) are recognized as being important to prevent or reduce microbial contamination of fresh produce. In that respect a web-based risk assessment tool (J. Monaghan), recently launched in the UK, was presented. This tool was developed to support at the farm level the growers to assess the risks of water, manure and workers and to implement the information in their codes of practice.

The risk of antibiotic resistance transfer through the food chain is becoming more and more an important preoccupation which has to be taken very seriously. By use of a quantitative risk assessment model the exposure to cephalosporin resistant *Escherichia coli* per meal containing broiler meat could be estimated under Belgian consumption circumstances (J. Dewulf). These type of studies are a first step to better understand the role of food (and practices in the food chain) in the antibiotic resistance transfer issue. The actual effect of transfer of resistant genes to the human intestinal flora and the related health effects cannot be determined up till now due to lack of basic information on the dose-response effect and on the complexity of microbial ecology and host-microbe interactions within the human gastrointestinal system.

By a combination of Belgian monitoring program data on *Listeria monocytogenes* on smoked salmon, consumption data, predictive modeling and expert opinion a quantitative risk assessment model was worked out. The study enabled to estimate the risk of listeriosis by consumption of smoked salmon and showed the effect of different shelf life condition scenarios (L. Herman).

Finally, the issue of emerging microbial risks in the food chain was discussed (M. Uyttendaele). It remains a very challenging and complex topic as it is related to global change in food production systems, consumption patterns, microbial biodiversity, human-animal-ecosystem interaction etc. Surveillance of the emergence of new combinations of virulence factors in foodborne pathogens originating from the animal as well as from the human reservoir seems to be important. Future microbiological risk assessments should take advantage of a close collaboration between food and clinical microbiologists and between specialists in (fresh produce) hygienic production systems and water quality. Intelligent and efficient early warning systems with the capacity to continuously and automatically scan national and international information sources and extract alert messages will have to be developed. New diagnostic toolboxes for the early diagnosis of (still unknown) emerging pathogens even by routine laboratories are required in order to be prepared for upcoming food safety crisis.

In the food industry risk assessment is used differently (F. Delmas-Julien). Safety assessments are conducted to identify (re)emerging hazards and to do shelf life determination and challenge tests.

In conclusion the following statements can be made:

- (Microbiological) risk assessment is the scientific basis for food safety policy development and the identification of efficient control measures,

- Risk assessment has many possibilities but has also still to deal with important limitations such as assumptions to be made, data gaps, major uncertainties and efficient risk communication,
- Examples of quantitative microbiological risk assessments have shown that this methodology is very useful to propose performance objectives in the food chain or to evaluate the contribution of specific foodstuffs or consumption patterns in the risk of developing foodborne diseases,
- Simplified tools for risk assessment can help primary plant producers to evaluate the risks of their production methods,
- Microbiological risks assessment is an important tool in the food industry to assess the safety of production methods, shelf life determination, etc.,
- Recent incidents in the food chain have shown that continuous alertness for emerging microbial risks in the food chain is necessary,
- Special attention should be paid to the risks of particular production methods in particular to those producing ready-to-eat foodstuffs,
- As some of the most effective interventions (e.g. irradiation, sanitizers, heat treatment) are neither acceptable to consumer (or national legislation) nor applicable to 'ready-to-eat foods' to eliminate pathogens currently in particular for ready-to-eat foods, in line with the concept of risk assessment a zero risk cannot be guaranteed. However, adherence to "best practices" from farm to fork to control microbial contamination is recommended in order to reduce the risk to as low as reasonable achievable and risk assessment may support the elaboration of most appropriate interventions

