



## Quantitative microbiological risk assessment (QMRA) of food-borne zoonoses at the European level

P. Romero-Barrios, M. Hempen, W. Messens, P. Stella, M. Hugas\*

Unit on Biological Hazards (BIOHAZ), European Food Safety Authority (EFSA), Via Carlo Magno 1A, 43126 Parma, Italy

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### ABSTRACT

At EU level, the European Food Safety Authority (EFSA) is the body responsible for risk assessment in the field of food and feed safety. Following a request from European Union (EU) risk managers, the EFSA Panel on Biological Hazards (BIOHAZ) provided, for the first time, two EU-wide farm-to-fork quantitative microbiological risk assessments (QMRA), with regard to *Salmonella* in slaughter and breeder pigs and *Campylobacter* in broilers. The Scientific Opinion on a QMRA of *Salmonella* in pigs represented a major step forward in terms of modelling from farm to consumption as it took into account the variability between and within EU Member States. This QMRA model was developed to estimate the prevalence of infection/contamination and the microbial load from the farm to the point of consumption (exposure) and then estimating the probability of infection. It was used to investigate the effect of interventions to control *Salmonella* in pigs at different points of the food chain and resulted in a hierarchy of suggested on farm and slaughterhouse control measures, with estimates of the reduction of human cases. To model the effect of interventions from farm to fork on the incidence of human campylobacteriosis, a QMRA model was developed and used in the framework of the Scientific Opinion on a QMRA of *Campylobacter* in broiler meat. Reductions to the public health risk of campylobacteriosis could be achieved through a variety of interventions, both in primary production or at the slaughterhouse, with different impacts. Reductions of public health risk using targets at primary production or microbiological criteria were also estimated through modelling using additional models. QMRA of food-borne pathogens at European level has proven a useful/good tool to enable risk managers to evaluate the feasibility and the cost-benefit ratio of introducing control measures and targets to further protect public health of European consumers.

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### 1. Introduction

In the European Union (EU) food legislation has to be based on “risk analysis” following Regulation (EC) No 178/2002 (General Food Law), which establishes the general principles governing food and feed safety. The risk analysis framework, as initially defined by FAO, WHO and the Codex Alimentarius Commission (CAC (Codex Alimentarius Commission), 1999), consists of three components: risk assessment, risk management and risk communication. At EU level, the European Food Safety Authority (EFSA), also established by the General Food Law and operating since 2002, is the body responsible for risk assessment and, more in general, for providing independent scientific advice to the EU risk managers in relation to legislation and policies in all fields which have a direct or indirect

impact on food and feed safety in the EU. EFSA's main attributes for this task are represented by the Scientific Committee and the Scientific Panels. The EFSA Scientific Panel on Biological Hazards (BIOHAZ Panel) provides independent scientific advice on biological hazards in relation to food safety and food-borne diseases, covering food-borne zoonoses, transmissible spongiform encephalopathies, food microbiology, food hygiene and animal by-products.

Risk assessments carried out by the BIOHAZ Panel are usually provided to the risk manager in the form of Scientific Opinions and can be either quantitative or qualitative, depending on the scope and on the extent of data, resources and time available, or may also take the simpler form of risk profiles depending on the terms of reference provided.

A study commissioned by EFSA in 2005 (Havelaar, 2005) identified many expected benefits from quantitative microbiological risk assessment (QMRA) at European level, such as:

- a more solid basis for common and more objective, science-based criteria for food safety across Europe;

\* Corresponding author. Tel.: +39 0521 036 216; fax: +39 0521 036 0216.

E-mail addresses: [pablo.romerobarrios@efsa.europa.eu](mailto:pablo.romerobarrios@efsa.europa.eu) (P. Romero-Barrios), [michaela.hempen@efsa.europa.eu](mailto:michaela.hempen@efsa.europa.eu) (M. Hempen), [winy.messens@efsa.europa.eu](mailto:winy.messens@efsa.europa.eu) (W. Messens), [pietro.stella@efsa.europa.eu](mailto:pietro.stella@efsa.europa.eu) (P. Stella), [marta.hugas@efsa.europa.eu](mailto:marta.hugas@efsa.europa.eu) (M. Hugas).

- support in evaluating possible risk mitigation options to be used at national level to reach common EU targets;
- increased transparency, enhancing risk communication between professionals and trust among stakeholders;
- increased sharing and optimal use of available data and resources, avoiding duplication of work between EU Member States (MSs), and a help to focus data collection efforts;
- a useful tool to rank the relative contribution of different exposure pathways.

Since the appointment of the first mandate in 2003, the BIOHAZ Panel has evolved in its scientific advice to the risk managers. At the request of EU risk managers, the BIOHAZ Panel provided, for the first time, two full farm-to-fork QMRA for the whole EU, with regard to *Salmonella* in slaughter and breeder pigs, and *Campylobacter* in broiler meat (EFSA Panel on Biological Hazards (BIOHAZ), 2010a, 2011). These risk assessments were briefly described previously (Hugas, 2011), and with this article the authors aim at providing additional details about these models and other related activities undertaken in the field of food-borne zoonoses in the EU.

According to Regulation (EC) No 2160/2003, targets should be established for the reduction of the prevalence of zoonoses and zoonotic agents at various levels of the food chain. In 2006, the European Commission requested EFSA to carry out a QMRA on *Salmonella* in slaughter and breeder pigs. In particular, EFSA's BIOHAZ Panel was requested to quantitatively assess the public health risk of the presence of *Salmonella* in slaughter pigs, including a quantitative estimation of risk factors and the effect of mitigation options. In addition, the BIOHAZ Panel was requested to provide a similar assessment in relation to the risk posed by the presence of *Salmonella* in breeder pigs as a source of infection for slaughter pigs. A working group (BIOHAZ *ad hoc* Working Group on "a Quantitative Microbiological Risk Assessment of *Salmonella* in slaughter and breeder pigs") was established to draft the Scientific Opinion for consideration by the BIOHAZ Panel. In order to support the *ad hoc* working group in assessing the impact of *Salmonella* targets and the public health risk measured as incidence of human salmonellosis, EFSA commissioned modelling of the pig meat food chain, from farm to fork, to an external consortium (see Acknowledgements for details).

With the view to considering similar targets for the reduction of the prevalence of *Campylobacter* along the broiler meat chain and/or setting microbiological criteria in broiler meat, the European Commission asked EFSA in 2009 to perform a QMRA on *Campylobacter* in broiler meat. In particular, EFSA's BIOHAZ Panel was requested to identify and rank possible control options within the broiler meat production chain, taking into account the expected efficiency in reducing human campylobacteriosis, and to propose potential performance objectives and targets along the broiler meat chain that would allow a 50–90% reduction of human campylobacteriosis cases in the EU. A working group (BIOHAZ *ad hoc* Working Group on "*Campylobacter* on broiler meat: control options and performance objectives and/or targets") was also established in this case to draft the Scientific Opinion for consideration by the BIOHAZ Panel. In addition, in order to support the *ad hoc* working group in estimating the impact on human campylobacteriosis due to the presence of *Campylobacter* in broiler meat, EFSA commissioned the development of a full farm-to-consumption QMRA model (CAMO model) to an external contractor (see Acknowledgements for details). This model was also used to rank/categorize selected intervention strategies in the farm-to-fork continuum. The evaluation of microbiological criteria required the development of an additional specific model by the BIOHAZ Panel and its *ad hoc* working group (CAMC model), and a further model was also developed in order to estimate risk reduction according to different

targets for prevalence of *Campylobacter* in broiler flocks (CamPrev model).

## 2. Material and methods

### 2.1. Quantitative microbiological risk assessment on *Salmonella* in slaughter and breeder pigs

In order to facilitate the investigation of interventions at different points of the food chain, a farm-to-consumption framework was adopted to model the prevalence of infection/contamination and the microbial load from the farm to the point of consumption (exposure). The probability of infection, or illness, could then be estimated by applying a dose–response model using the estimated amount of *Salmonella* bacteria ingested at consumption.

The QMRA model characterises the variability between EU Member States and, in particular, the inclusion of variability between MSs in their pig farms, slaughterhouses and consumption patterns.

To demonstrate the parameterisation and use of the model, four MSs were selected as cases. These MSs were selected by performing a cluster analysis (Lattin, Green, & Carroll, 2006) for the EU using criteria relating to pig production and consumption patterns to group the MSs into clusters (e.g. ratio of small versus big farm holdings, amount of pork consumed per capita). Using the *k*-means clustering method, (MacQueen, 1967) four regions or clusters of MSs were identified within the EU. Based on which MSs had the most available data, one MS was selected from each cluster.

In the exposure assessment, a probabilistic modular risk model (Modular Process Risk Model) as proposed by Nauta, van der Fels-Klerx, and Havelaar (2005) was developed, in which the food production pathway for pig meat was split into four modules: Farm; Transport & Lairage; Slaughter & Processing and Preparation & Consumption. Fig. 1 shows a schematic representation of these modules in the model. The output from one module is the input to the next and so collectively they model the entire farm-to-consumption chain.

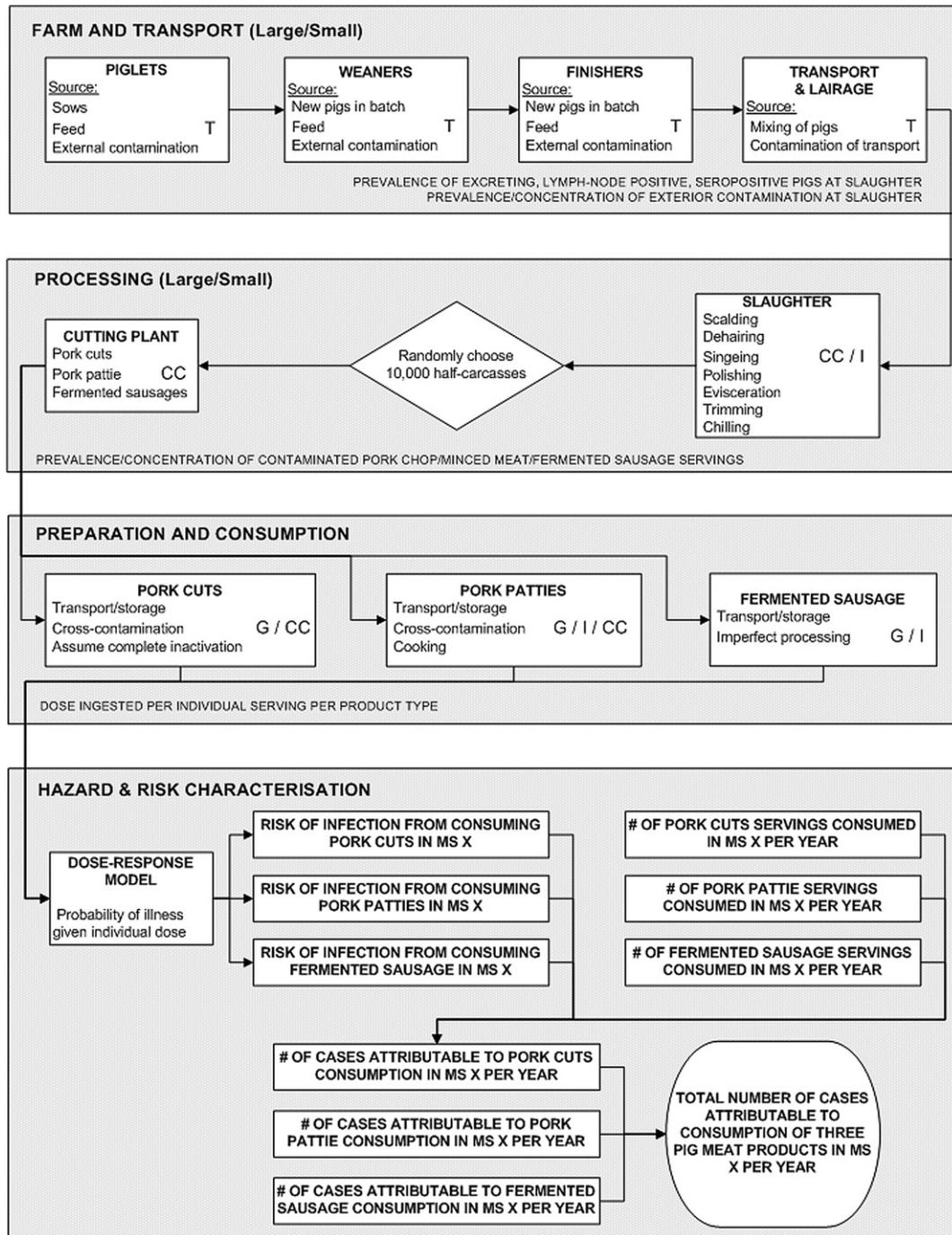
In 2006/2007, an EU-wide baseline survey on the prevalence of *Salmonella* in slaughter pigs was carried out to determine, at the point of slaughter, the prevalence of pigs infected with *Salmonella* (EFSA, 2008). The prevalence data from this EU baseline survey were used for the validation of the QMRA model together with data from other sources.

Following discussions at the BIOHAZ Panel, three product types were included in the QMRA model: pork cuts, minced meat and fermented sausage. These products were chosen to represent a range of different production/preparation practices and consumption patterns, which will affect the *Salmonella* levels within these products at consumption, and hence the probability of human illness.

For more detail on the risk assessment methodology, readers are advised to consult the full modelling report (VLA, DTU & RIVM, 2011).

### 2.2. Quantitative microbiological risk assessment on *Campylobacter* in broilers

The CAMO model (to estimate the effect of interventions on *Campylobacter* in broilers) was built to reflect the situation in the broiler meat production chain of individual MSs, based on data of the EU baseline survey on prevalence of *Campylobacter*-positive broiler batches and counts on broiler carcasses (EFSA, 2010). The model was populated with the available and currently



**Fig. 1.** An overview of the modules within the farm-to-consumption QMRA. Icons represent the relevant microbiological processes: T – transmission; CC – cross-contamination; I – inactivation; G – growth. Adapted from VLA, DTU & RVM (2011).

implemented interventions in each MS. This model characterises the variability of the level of contamination by the normalized central moments (mean, variance, skewness and kurtosis) of the log<sub>10</sub> numbers and evaluates the effects of processing, interventions, etc. by combining the raw moments of variables in the model using analytical mathematical equations. The purpose of using the moments to describe log contamination levels and the log effect of interventions is to be free from having to make assumptions about the distributional form at each stage. This was an innovative mathematical approach, different than in previously built QMRA models, which have mainly used random sampling of each

probability distribution through Monte Carlo simulation (see for example Vose, 2008). The effect of interventions on microbial load and/or between-flock prevalence and/or within-flock prevalence was implemented in the model and the relative change in the predicted human health burden was evaluated. Based on the prevalence of *Campylobacter*-positive batches, level of carcass contamination as reported in the EU baseline survey and on the availability of data, four MSs were selected for modelling.

For evaluation of interventions aimed at reducing *Campylobacter* concentrations, three different dose–response (DR) models were used: the simple exponential and modified Beta-Poisson DR

functions proposed by the contractor, and, in addition, the generally accepted approach to dose–response modelling, *i.e.* to estimate the risk of infection and/or illness as a function of the ingested dose at the point of consumption, as discussed by Nauta and Christensen (2011). The addition of this latter DR model to CAMO was labelled the “classic + DR model”. Sensitivity analyses on the choice of the DR model were performed. A visual representation of this model can be found in Fig. 2. For more detail on the risk assessment methodology, readers are advised to consult the full modelling report (Vose Consulting, 2011).

The CamPrev model was developed by working group experts and aimed to estimate the risk reduction according to different targets for prevalence of *Campylobacter* in broiler flocks. It was based on a risk reduction for human health that was proportional to the reduction of between-flock-prevalence of broilers at the farm. The initial value for this was based on the prevalence of *Campylobacter*-positive broiler batches as derived from the baseline survey (EFSA, 2010).

The CAMC model was also built by working group experts to evaluate microbiological criteria and was based on the prevalence of *Campylobacter*-positive broiler batches and counts on broiler carcasses data from the EU baseline survey (EFSA, 2010). It assumed that these data represent the prevalence and level of contamination of all batches produced in one country. A lognormal distribution was fitted to the observed counts, and in the default model the fraction of the total variance that is assigned to within-batch variance was set at 30%. One-stage sampling plans were applied, with different values for  $m$  (the limit to microbiological counts in colony forming units (CFU)/gram of skin sample),  $n$  (the number of units comprising the sample) and  $c$  (the number of sample units on which the country may exceed  $m$ ). The percentage of batches not complying with the criterion was calculated. The public health risk associated with each batch was then calculated using the classic+ DR-model (Nauta and Christensen, 2011) and the minimum relative residual risk calculated by comparing the average risk for all batches (*i.e.* current risk) with the risk associated with only those batches that meet the microbiological criteria, in the theoretical scenario that all batches were tested with perfect test sensitivity and specificity, and that batches not complying with the microbiological criteria would not be accepted for distribution into the fresh meat chain. These assumptions meant that the calculated estimates were the (theoretical) maximum achievable risk reduction, providing a minimum residual risk.

**Table 1**

Estimated effect of interventions in primary production on the prevalence of *Salmonella* in slaughter pigs (adapted from EFSA Panel on Biological Hazards (BIOHAZ), 2010a).

Interventions in primary production	Estimated reduction in pig prevalence <sup>a</sup>	
	High prevalence <sup>b</sup> MSs	Low prevalence <sup>b</sup> MSs
Ensuring that breeder pigs are <i>Salmonella</i> -free	70–80%	10–20%
Feeding only <i>Salmonella</i> -free feedstuffs	10–20%	60–70%
Preventing infection from external sources of <i>Salmonella</i> ( <i>i.e.</i> rodents and birds)	10–20%	10–20%

<sup>a</sup> Estimated reduction of *Salmonella* prevalence in pig lymph nodes at slaughter.

<sup>b</sup> Existing prevalence of *Salmonella* in breeding herds.

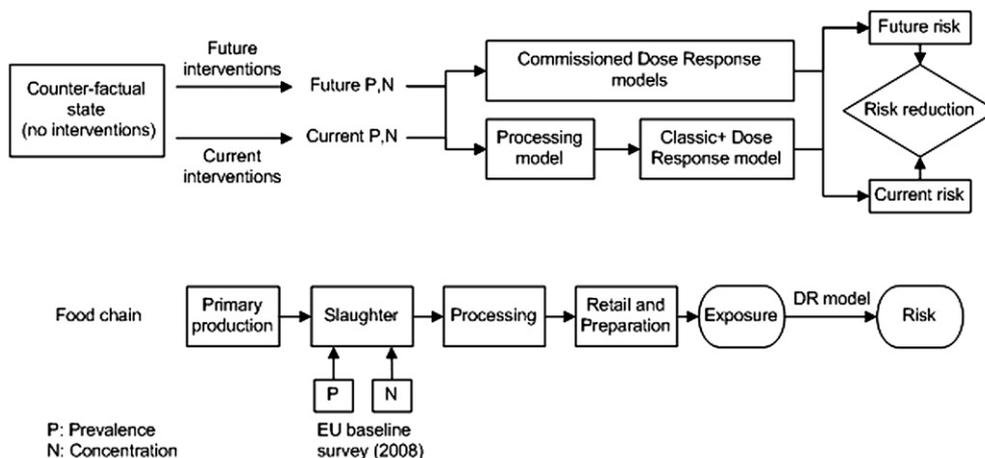
### 3. Results and discussion

#### 3.1. Quantitative microbiological risk assessment on *Salmonella* in slaughter and breeder pigs

The Scientific Opinion on a QMRA on *Salmonella* in slaughter and breeder pigs (EFSA Panel on Biological Hazards (BIOHAZ), 2010a) represented a major step forward in terms of modelling *Salmonella* in pigs from farm to consumption as it took into account the variability between and within EU MSs. It was estimated that around 10–20% of human *Salmonella* infections in EU may be attributable to the pig reservoir as a whole. From the QMRA analysis it was concluded that an 80% or 90% reduction of *Salmonella* prevalence in lymph nodes should result in a comparable reduction in the number of human cases attributable to pig meat products.

Regarding the reduction of *Salmonella* prevalence in fattening pigs through on-farm measures, this reduction differed depending on the existing prevalence of *Salmonella* in breeding herds. According to the Scientific Opinion several scenarios appeared possible, and are summarised in Table 1. A hierarchy of control measures was therefore suggested – a high prevalence in breeder pigs needs to be addressed first, followed by control of feed and then control of environmental contamination.

The impact of transport, lairage and the slaughter processes on contamination of carcasses, and the expected reduction of *Salmonella* cases in humans that could be achieved at these stages in the



**Fig. 2.** Commissioned QMRA model (CAMO model): Modelling approach used to estimate reductions of risk of campylobacteriosis due to interventions during primary production and slaughtering (adapted from EFSA Panel on Biological Hazards (BIOHAZ), 2011).

production chain were also assessed by the QMRA. At the slaughterhouse, a reduction of two logs (*i.e.* 99%) of *Salmonella* numbers on contaminated carcasses would result in a more than 90% reduction of the number of human salmonellosis cases attributable to pig meat consumption in all MSs. On the other hand, transport and lairage interventions were estimated to have an insignificant effect in reducing human infection, even if implemented fully and with 100% effectiveness.

The BIOHAZ Panel concluded that the control of *Salmonella* in pig meat as a public health problem should be based on the individual MS situations and include combinations of following interventions: *Salmonella*-free breeder pigs, *Salmonella*-free feed, cleaning-disinfection between batches both on-farm and during lairage, avoidance of faecal contamination during slaughter, and decontamination of the carcasses. Efficient vaccination would also be useful to control *Salmonella* on farm, but might interfere with the interpretation of serological test results in monitoring/surveillance programmes. From the estimates provided by the model, it would appear that specific slaughterhouse interventions are, at present, more likely to produce greater and more reliable reductions in human illness, at least in a shorter timeframe than can be achieved at the farm in high prevalence MSs. However, the hypothetical reductions and multiple interventions investigated with the risk assessment model suggested that MSs can achieve more effective reductions in human cases by targeting *Salmonella* at both farm and the slaughterhouse. The slaughterhouse remains a critical step of the pig meat chain in respect to pig and carcass contamination and numerous aspects (*e.g.* airborne transmission of *Salmonella* in the abattoir) still remain unknown. For this reason, the BIOHAZ Panel recommended that studies need to be performed to properly assess the ways carcasses become contaminated.

In summary, from the scientific standpoint, the control of *Salmonella* in the pig reservoir in the EU was considered a reasonable objective. The EU *Salmonella* control strategy in pigs should be continuously evaluated to identify possible improvements.

The development of this QMRA model for the specific purpose of addressing several questions regarding the control of *Salmonella* in pigs posed by risk managers presented an additional opportunity, as MSs should have the possibility to assess their national pig meat food chains and evaluate potential interventions using this QMRA model. For this reason, and to foster the scientific cooperation between the EFSA and MSs, EFSA decided to award a contract for the provision of a more user friendly version of the QMRA model, which can then be made available to scientists and policy makers at MS level.

As outlined above, the results of this Scientific Opinion were meant to be used by the European Commission as input for a cost-benefit analysis, which would be the basis for the risk manager to set relevant targets for the reduction of *Salmonella* in the EU pig population. A first exercise was commissioned by the European Commission and resulted, in 2011, in the development of cost-benefit analyses for targets set at primary level, in both slaughter and breeding pigs (FCC Consortium, 2010, 2011). These assessments failed to demonstrate a positive economic benefit from setting such targets to reduce *Salmonella* in pigs.

A further exercise is being currently carried out with the aim of investigating costs and benefits of control measures at pigs' slaughterhouse level. Based on the outcome of the risk assessment and these cost-benefit analyses, the EU risk manager will consider possible measures to be implemented in EU legislation.

### 3.2. Quantitative microbiological risk assessment on *Campylobacter* in broilers

The BIOHAZ Panel concluded that there are approximately nine million cases of human campylobacteriosis per year in the EU,

based on data describing differential risks to Swedish travellers as published originally by Ekdahl and Giesecke (2004). The disease burden of campylobacteriosis and its sequelae was estimated at 0.35 million disability-adjusted life years (DALYs) per year and the total annual costs 2.4 billion € (EFSA Panel on Biological Hazards (BIOHAZ), 2010b). Broiler meat may account for 20%–30% of these, while 50%–80% may be attributed to the chicken reservoir as a whole (broilers as well as laying hens). The public health benefits of controlling *Campylobacter* in primary broiler production were expected to be greater than control later in the chain as the bacteria may also spread from farms to humans by pathways other than broiler meat (EFSA Panel on Biological Hazards (BIOHAZ), 2011). As described previously, the CAMO model was used to model the effect of interventions in the farm to fork continuum in four selected countries. The only intervention strategies that were modelled were those for which quantitative data were available on their efficacy for *Campylobacter* reduction, and were of sufficient quality.

In primary production, a 60% reduction of human campylobacteriosis cases attributable to the consumption of broiler meat from flocks coming from different production systems (further referred to as risk reduction) was estimated to be achieved in one MS by the use of fly screens in the presence of strict biosecurity measures. Up to 43% risk reduction could be achieved by restricting slaughter age of indoor flocks to a maximum of 28 days, and up to 25% risk reduction by discontinued thinning of indoor flocks. The impact of improving hygiene barriers in indoor flocks was also assessed but the estimate, modelled in one country, was very uncertain.

Assuming certain experimental interventions that aim at reducing *Campylobacter* numbers in the intestines were available, the potential risk reduction would range from 48% to 100% for reductions of one to six log units of *Campylobacter* in the intestines.

At the slaughterhouse, an estimated risk reduction of 100% can be achieved by irradiation or cooking of broiler meat on an industrial scale. An 87–98% risk reduction could be obtained by freezing carcasses for three weeks. A 37–96% risk reduction could be achieved by short time freezing (2–3 days), hot water or chemical carcass decontamination with lactic acid, acidified sodium chlorite or trisodium phosphate (all reducing carcass concentrations by at least 1 to 2 log units). For these interventions, the classic + DR model generally predicted a greater risk reduction than the original DR models in CAMO. Results are presented in more detail in Table 2.

The effect of scheduled slaughter was evaluated for two different potential detection protocols with markedly different sensitivities. The benefits of scheduled slaughter would be maximised when using a rapid test with high sensitivity, as this would allow a comparable risk reduction to public health risk (to that achieved without scheduled slaughter), but by treating only positive flocks. This would have obvious benefits in countries with a low prevalence of *Campylobacter*.

From the model output it can be concluded that strict implementation of biosecurity in primary production and Good Manufacturing Practices and Hazard Analysis and Critical Control Points during slaughter may reduce colonization of broilers with *Campylobacter*, and therefore contamination of carcasses. The effects could not be fully quantified because they depend on many inter-related local factors. In addition, the use of fly screens, restriction of slaughter age, or discontinued thinning may further reduce consumer risks but have not yet been tested widely. Nevertheless, their impact on public health risk reduction may be considerable.

Using the CamPrev model it was estimated that achieving a target of 25% or 5% between-flock prevalence in all MSs with a prevalence above this target, would result in 50% and 90% reduction of public health risk, respectively.

**Table 2**

Effect of interventions in primary production and at the slaughterhouse on the relative reduction in human campylobacteriosis cases attributable to broiler meat for consumers of broiler meat from flocks coming from different production systems (adapted from EFSA Panel on Biological Hazards (BIOHAZ), 2011).

Interventions	Estimated risk reduction
<b>In primary production</b>	
Improved hygiene/biosecurity in indoor flocks	16% <sup>a</sup>
Application of fly screens in indoor flocks	60% <sup>a</sup>
Discontinued thinning of indoor flocks	1.8–25% <sup>b</sup>
Reduction of slaughter age of indoor flocks	
- to 42 days	0–5% <sup>b</sup>
- to 35 days	0.6–18% <sup>b</sup>
- to 28 days	21–43% <sup>b</sup>
Reduced colonization in caecal contents of indoor and outdoor flocks by	
- 1 log <sub>10</sub> units	48–83% <sup>b,c</sup>
- 2 log <sub>10</sub> units	76–98% <sup>b,c</sup>
- 3 log <sub>10</sub> units	90–100% <sup>b,c</sup>
- 6 log <sub>10</sub> units	100% <sup>b,c</sup>
<b>At the slaughterhouse</b>	
Treatment of broiler carcasses with lactic acid (2%)	37–56% <sup>b,c</sup>
Treatment of broiler carcasses with acidified sodium chlorite (1200 mg/l)	75–96% <sup>b,c</sup>
Treatment of broiler carcasses with trisodium phosphate (10–12%, pH 12)	67–84% <sup>b,c</sup>
Short time freezing (2–3 days) of broiler carcasses	62–93% <sup>b,c</sup>
Long time freezing (3 weeks) of broiler carcasses	87–98% <sup>b,c</sup>
Hot water immersion of broiler carcasses	75–89% <sup>b,c</sup>
Irradiation/cooking of broiler meat on industrial scale	100% <sup>b,c</sup>

<sup>a</sup> Based on one study country.

<sup>b</sup> Range of expected reduction in public health risk based on four study countries.

<sup>c</sup> Calculated using the Classic + DR model.

The CAMC model was used to evaluate microbiological criteria. Results suggest that a public health risk reduction of more than 50% or more than 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 *m* of 1000 or 500 CFU/g of neck and breast skin respectively, while 15% and 45% of all tested batches would not comply with these criteria. Microbiological criteria could theoretically be implemented immediately but the ability to comply would also differ between MSs.

Compliance with microbiological criteria was estimated to be effective to reduce risks for *Campylobacter* on broiler meat because of high within-batch prevalences and low within-batch variability enabling the detection of highly contaminated batches even when taking a limited number of samples, which could 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.

Similarly to what was done following the first QMRA described, a cost-benefit analysis is presently being carried out on the initiative of the European Commission in relation to measures for the control of *Campylobacter* in the broiler meat chain. Results from this exercise are expected to guide the risk manager in considering appropriate legislative measures for the control of this pathogen in broilers and broiler meat at EU level.

#### 4. Conclusions

QMRA of food borne pathogens at European level has proven to be a feasible and good tool to enable risk managers to undertake impact and cost-benefit assessment studies of introducing control

measures and targets to further protect public health of European consumers. The Scientific Opinions of the BIOHAZ Panel outlined in this paper are the result of the interaction of several actors. First of all, the external consortium and contractor, who developed the mathematical models to support the respective BIOHAZ *ad hoc* working groups. Then, the two *ad hoc* working groups, consisting of experts from the BIOHAZ Panel and of additional external experts, who drafted the two Scientific Opinions for consideration by the BIOHAZ Panel. Finally, the Panel itself, who revised, finalised and adopted the Scientific Opinions. In the context of the EU food safety risk analysis framework, the Scientific Opinions were then published and delivered by EFSA to the European Commission, who will then consider possible risk management measures.

After undertaking some major exercises in identifying quantitatively some microbiological risks in some animal populations and/or foodstuffs, the BIOHAZ Panel is now reflecting on what were the lessons learnt and how improvements could be introduced in future exercises. As outlined in the recommendations for addressing QMRA at the European level (Havelaar, 2005), quantitative assessment should be used whenever feasible and practical to get more precise answers on microbial risks for food safety. The mandates given to EFSA's BIOHAZ Panel by the European Commission increasingly ask for a quantitative evaluation of public health benefits and risks, and the results should be the basis for cost-benefit analyses. Therefore, mathematical models are often necessary for answering the mandates and questions in sufficient depth. Moreover, models identify important data gaps or lacks of knowledge thereby indicating future research priorities. As a further step, EFSA has requested the BIOHAZ Panel to describe successful QMRA approaches and challenges, to suggest practical improvements, e.g. development of technical guidelines or a standard checklist for the technical specifications for outsourced modelling work, and to develop guidelines for transparent and consistent description of the models.

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