Opportunities and limitations of Quantitative Risk Assessment: *Campylobacter* and *Salmonella* in poultry based meat preparations / eggs

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Microbiological Risk Assessment as a tool for food safety/ FSO /PO

Ex. QRA for *Campylobacter* in poultry based meat preparations

Ex. QRA for *Salmonella* in eggs

Opportunities/limitations of QRA
Microbiological Risk Assessment as a tool for food safety

On the demand of the competent national authorities/ initiative (inter)national organisations:

**Quantitative risk assessments:**

For specific microbiological hazard in the food supply to estimate the impact of a particular hazard on public health

With the intention outputs will be used in the development of food safety measures at the (inter)national level
Microbiological Risk Assessments (FAO/WHO JEMRA)

Risk assessments
- *Salmonella* spp. in broilers/eggs
- *Vibrio parahaemolyticus* in oysters and fish, *Vibrio vulnificus* in oysters, *Vibrio cholerae* in shrimp
- *Campylobacter jejuni* in poultry.
- *Enterobacter sakazakii* in powdered food formulae

**MRA** can be developed on many levels of detail, depending upon the complexity of the issue, the urgency for obtaining the risk estimate and the data available.
Food safety
issue identification

Consider issue

Managed by existing regulations

Immediate action

Monitoring and review

Risk profile

Define scientific needs

Collect more information, do research

Interim action

Urgent

Interim food safety assessment

No food safety justification

Consider information

Need more information

Limited assessment

Sufficient information to act

Risk management decision

Implement food control measure

Monitoring and review

Do nothing

Food Safety objective (FSO)
Performance objective (PO)

FSO - The maximum frequency and/or concentration of a hazard in a food at the time of consumption that provides or contributes to the ALOP (CAC 2004)
e.g. *L. monocytogenes* in RTE food shall not exceed 3.5 log CFU/serving size of food when eaten

PO – the maximum frequency and/or concentration of a hazard in a food at a specified step in the food chain before the time of consumption that provides/contributes to an FSO or ALOP (CAC 2004)
e.g. Salmonellae and EHEC shall not exceed 1 CFU/10 l when fruit juice is packaged for distribution
Microbiological Risk Assessment vs Food Safety Management systems

Country level

Risk Analysis

ALOP

Food Safety Control:
- high level, generic
- providing guidance/targets
- link between operation and policy

FSO → Food Safety Objective

Operation level

HACCP

GHPs/ GMPs/ GAPs

Food Safety Management:
Local and specific management at supply chain level

Goris, Food control 2005
QRA for *Campylobacter* in poultry based meat preparations
to support the development of risk-based microbiological criteria in Belgium

Taking into account data of *Campylobacter* spp. in poultry based meat preparations from the FAVV Surveillance testing program

Quantitative risk assessment of *Campylobacter* spp. in poultry based meat preparations as one of the factors to support the development of risk-based microbiological criteria in Belgium (Uyttendaele et al. 2006 Int. J. Food Microbiology 111,149-163)
QRA for *Campylobacter* in poultry based meat preparations

**Limited food safety assessments:**
= readily accessible information, realistic scenarios, modules from previously constructed MRA

![Retail to table approach](image)

To analyse, in a relative manner, the **reduction of the risk** of campylobacteriosis associated with a decrease in the *Campylobacter* contamination level by definition of various “**maximum acceptable level**” for these types of food products (poultry based meat preparations) relating to the current situation
Retail
Natural logarithm of concentration of Campylobacter in raw chicken meat products (Crcmp)

Consumer handling
Undercooking
Prevalence of undercooking (Pu)
Proportion of cells in protected area (Proprot)

Cross contamination
Prevalence of cross contamination (Pcross)
Log10 of the proportion of transferred cells from meat to surface and from surface to meat (Ptms & Ptsm)
Number of cells in outside layer (No)

Prevalence of Campylobacter in raw chicken meat products (Prcmp)
Number of Campylobacter in a raw chicken meat product of 100g (Nrcmp)

Prevalence (% contaminated)

Number of Campylobacter

Transport and preservation at retail & home
(time/temperature)

Preparation (cross contamination)
Heat treatment (undercooking)

Consumption
Dose – Response

Consumption

Probability of exposure to Campylobacter (Pcsm)
Probability of infection (Pc) or ratio of ingested dose and infective dose (Rc)
Probability of illness (Pl) or ratio of ingested dose and infective dose, when illness can occur (Rl)

Infection and illness
Dose response or infective dose (Ninf)
Probability of illness given infection (Pill i)

Number of Campylobacter in a cooked chicken meat product due to undercooking (Ncu)
Number of Campylobacter in a cooked chicken meat product due to cross contamination (Ncc)
Probability of Campylobacter in a cooked chicken meat product due to undercooking (Pu)
Probability of Campylobacter in a cooked chicken meat product due to cross contamination (Pcross)

Number of Campylobacter in a raw chicken meat product of 100g (Nrcmp)

Prevalence of Campylobacter in raw chicken meat products (Prcmp)

Prevalence (% contaminated)

Number of Campylobacter

Transport and preservation at retail & home
(time/temperature)

Preparation (cross contamination)
Heat treatment (undercooking)

Consumption
Dose – Response

Consumption

Probability of exposure to Campylobacter (Pcsm)
Probability of infection (Pc) or ratio of ingested dose and infective dose (Rc)
Probability of illness (Pl) or ratio of ingested dose and infective dose, when illness can occur (Rl)
QRA for *Campylobacter* in poultry based meat preparations: input distribution

Lack of quantitative data (enumeration)!

Scenario analysis based on the current situation but limiting (<1%) *Campylobacter* positive samples at > 1000/g
- at > 100/g
- at > 10/g ......
### QRA for *Campylobacter* in poultry based meat preparations: dose response

#### Table: Dose Response

<table>
<thead>
<tr>
<th>Situation</th>
<th>Exposure (cfu per 100g serving)</th>
<th>Approach 2 (Probability of infection)</th>
<th>Approach 3 (% infected)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>1*</td>
<td>2.02E+07</td>
<td>2.38E-03</td>
<td>0.0353</td>
</tr>
<tr>
<td>1* (raw)</td>
<td>1.45E+10 (sit 1x718)**</td>
<td>4.98E-02 (sit 1x21)</td>
<td>1.0155 (sit 1 x 29)</td>
</tr>
<tr>
<td>2 (&lt;1% with &gt; 10000/g)</td>
<td>1.83E+05 (sit 1:110)</td>
<td>1.38E-03 (sit 1:2)</td>
<td>0.0089 (sit 1:4)</td>
</tr>
<tr>
<td>3 (&lt;1% with &gt; 1000/g)</td>
<td>1.77E+03 (sit 1:11390)</td>
<td>6.72E-04 (sit 1:4)</td>
<td>0.0016 (sit 1:22)</td>
</tr>
<tr>
<td>4 (&lt;1% with &gt; 100/g)</td>
<td>1.98E+01 (sit 1:1.0x10^6)</td>
<td>2.42E-04 (sit 1:10)</td>
<td>0.0003 (sit 1 : 118)</td>
</tr>
<tr>
<td>5 (&lt;1% with &gt; 10/g)</td>
<td>3.26E-01 (sit 1:6.2x10^7)</td>
<td>5.50E-05 (sit 1:43)</td>
<td>0</td>
</tr>
<tr>
<td>6 (&lt;1% with &gt; 1/g)</td>
<td>1.23E-02 (sit 1:1.6x10^9)</td>
<td>6.33E-06 (sit 1:376)</td>
<td>0</td>
</tr>
<tr>
<td>7 (&lt;1% with &gt; 1/10g)</td>
<td>1.63E-03 (sit 1:1.2x10^10)</td>
<td>6.75E-07 (sit 1:3525)</td>
<td>0</td>
</tr>
</tbody>
</table>

*Approach 3 (% infected)*
QRA for *Campylobacter* in poultry based meat preparations: output

Reduction of the *Campylobacter* contamination level
- Eliminate samples with >100/g (<1%)
- Restrict samples >10/g (max. 2%)

**Decrease probability of infection: 10x**

Raw consumption

**Increase probability of infection: 20x**

Verification risk estimate of current situation: need epidemiological data!

Lack of extended supporting data: the uncertainty of the outcome may be high!
QRA for *Campylobacter* in poultry based meat preparations: scientific needs

- (semi-)quantitative data for pathogen in food under consideration
- data related to consumer habits, concerning food handling procedures/consumption patterns
- prevalence of undercooking, prevalence of cross-contamination
- effect of packaging and exact survival of *Campylobacter* during storage

Limited data sets, surrogate data, assumptions, simplifications increase the uncertainty of the outcome of the QRA
QRA for *Salmonella* in eggs
To identify effective strategic interventions

- QRA of salmonellosis due to the consumption of shell eggs contaminated with *S. Enteritidis* in Belgium


- exposure assessment adapted to the Belgian situation

QRA for *Salmonella* in eggs: Model structure

**Production** → **Distribution and storage** → **Preparation and consumption**

**Egg products processing**

**Farm to table approach**: number of flocks, flock prevalence, storage in packing station, transport, consumers behaviour, etc.
QRA for *Salmonella* in eggs: Distribution and storage module

- **Initial egg temperature (°C)**
- **Initial *Salmonella* contamination**
- **Probability of yolk contamination**

- **Storage before Transportation**
  - k – Temperature
  - Time

- **Transportation**
  - k – Temperature
  - Time

- **Storage before processing**
  - k – Temperature
  - Time

- **Processing**
  - k – Temperature
  - Time

- **Storage after processing**
  - k – Temperature
  - Time

- **Transportation to retail/institutions**
  - k – Temperature
  - Time

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- **Number of *Salmonella* in egg after processing**

- **Bacterial growth is modelled with a modified Baranyi-model**
- **Lag phase is imposed by the membrane breakdown time**

- **Initial contamination in albumen, small fraction in yolk (3% on average)**

- **Inactivation only considered in preparation phase**
### QRA for *Salmonella* in eggs: Some inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flocks</td>
<td>460</td>
</tr>
<tr>
<td>Average hens/flock</td>
<td>24332</td>
</tr>
<tr>
<td>Eggs/day</td>
<td>0.72</td>
</tr>
<tr>
<td>Days in Lay</td>
<td>365</td>
</tr>
<tr>
<td>Prevalence of infected flocks</td>
<td>25%</td>
</tr>
<tr>
<td>Percent eggs to shell egg processor</td>
<td>50%</td>
</tr>
<tr>
<td>Time-temperature homes</td>
<td>Grijspeerd <em>et al.</em> (1999)</td>
</tr>
<tr>
<td>Time-temperature institutions</td>
<td>Messens <em>et al.</em> (2002)</td>
</tr>
</tbody>
</table>
QRA for *Salmonella* in eggs: Baseline results
### QRA for *Salmonella* in eggs: Baseline results

<table>
<thead>
<tr>
<th>Output</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
<th>5th percentile</th>
<th>95th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive eggs</td>
<td>29</td>
<td>70990</td>
<td>12480170</td>
<td>1156</td>
<td>275693</td>
</tr>
<tr>
<td>Servings</td>
<td>1</td>
<td>259781</td>
<td>43416730</td>
<td>4138</td>
<td>1011592</td>
</tr>
<tr>
<td>Cases</td>
<td>1</td>
<td>18926</td>
<td>3399768</td>
<td>258</td>
<td>72122</td>
</tr>
<tr>
<td>Recovery with no medical care</td>
<td>0</td>
<td>17770</td>
<td>3197186</td>
<td>242</td>
<td>67788</td>
</tr>
<tr>
<td>Physician visit</td>
<td>0</td>
<td>996</td>
<td>186807</td>
<td>13</td>
<td>3848</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>0</td>
<td>85</td>
<td>14591</td>
<td>1</td>
<td>330</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>9</td>
<td>1183</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Reactive arthritis</td>
<td>0</td>
<td>565</td>
<td>107786</td>
<td>8</td>
<td>2168</td>
</tr>
</tbody>
</table>

Considerable uncertainties with model input/structure output distributions can be very wide.
QRA for *Salmonella* in eggs: Sensitivity analysis

Systematically varying inputs (e.g. base value ± 25%) to have an indication of the most influential inputs.
QRA for *Salmonella* in eggs: Mitigation strategies

Limit temperature to 6°C

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>5th percentile</th>
<th>95th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole chain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>5810</td>
<td>52</td>
<td>21136</td>
</tr>
<tr>
<td>Cases from homes</td>
<td>3378</td>
<td>28</td>
<td>12568</td>
</tr>
<tr>
<td>Cases from institutions</td>
<td>2350</td>
<td>9</td>
<td>8452</td>
</tr>
<tr>
<td>Retail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>11693</td>
<td>145</td>
<td>50009</td>
</tr>
<tr>
<td>Cases from homes</td>
<td>9062</td>
<td>104</td>
<td>37425</td>
</tr>
<tr>
<td>Cases from institutions</td>
<td>2553</td>
<td>12</td>
<td>10818</td>
</tr>
<tr>
<td>Consumer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>11556</td>
<td>149</td>
<td>46945</td>
</tr>
<tr>
<td>Cases from homes</td>
<td>8712</td>
<td>109</td>
<td>35911</td>
</tr>
<tr>
<td>Cases from institutions</td>
<td>2728</td>
<td>12</td>
<td>9496</td>
</tr>
<tr>
<td>Institutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>18307</td>
<td>253</td>
<td>71894</td>
</tr>
<tr>
<td>Cases from homes</td>
<td>15961</td>
<td>232</td>
<td>66859</td>
</tr>
<tr>
<td>Cases from institutions</td>
<td>2234</td>
<td>9</td>
<td>7511</td>
</tr>
</tbody>
</table>
Opportunities/Limitations of risk assessment

• Risk assessment is a valuable tool to identify effective strategic interventions to reduce the number of human *Salmonella/Campylobacter* cases
  - often scenario analysis / equivalence of alternative technologies
  - verification risk estimate: difficult task!

• Define research and data collections needs
  - set priorities for data collection and format/quality of data
  - concept of QRA / impact of assumptions / uncertainty

• a tool to decide on control measures
  - “any action and activity that can be used to prevent or eliminate a food safety hazard or to reduce it to an acceptable level” e.g. microbiological criteria
# FSO versus Microbiological criteria

## Characteristics of FSOs and microbiological criteria

<table>
<thead>
<tr>
<th>Food safety objective</th>
<th>Microbiological criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A goal on which food chains can be designed so that the resulting food will be expected to be safe</td>
<td>A statement that defines the acceptability of a food product or lot of food</td>
</tr>
<tr>
<td>Aimed at consumer protection</td>
<td>Confirmation that effective GHP and HACCP plans are applied</td>
</tr>
<tr>
<td>Applies to food at the moment of consumption</td>
<td>Applies to individual lots or consignments of food</td>
</tr>
<tr>
<td>Components:</td>
<td>Components:</td>
</tr>
<tr>
<td>• Maximum frequency and/or concentration of a microbiological hazard</td>
<td>• Microorganisms of concern and/or their toxins/metabolites</td>
</tr>
<tr>
<td>• Product to which it applies</td>
<td>• Sampling plan</td>
</tr>
<tr>
<td></td>
<td>• Analytical unit</td>
</tr>
<tr>
<td></td>
<td>• Analytical method</td>
</tr>
<tr>
<td></td>
<td>• Microbiological limits</td>
</tr>
<tr>
<td></td>
<td>• Number of analytical units that must conform to the limits</td>
</tr>
</tbody>
</table>

Used only for food safety

*Source: Based on van Schothorst (2002).*

**Sampling plan ~ confidence level**

**Method ~ degree of uncertainty**
Opportunities/Limitations of risk assessment

• Need of open and objective communication between risk assessors and risk managers
  o QRA should have clear purpose and scope
  o Point out uncertainty of outcome and implications
  o Communicate the right information in the right format, including an interpretation of mathematical results
  o Communication of scientific basis to all interested parties

• Planning and resources allocation is essential:
  o Lack of good quality data for undertaking QRA
  o Create modular components, can be adapted by individual countries with different data inputs → international context!
Acknowledgements

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