CARMA: Food Safety and Expert Judgement

H.J. van der Fels-Klerx, A.H. Havelaar and M.J. Nauta
National Institute of Public Health and the Environment (RIVM)
Bilthoven, the Netherlands

L.H.J. Goossens and R.M. Cooke
Delft University of Technology
Delft, the Netherlands

Abstract

In the Netherlands, *Campylobacter* infections are estimated to cause yearly many health problems, deaths and considerable economic losses. Effective prevention of human campylobacteriosis requires a well-balanced set of control measures in the chicken meat production chain. To that aim the CARMA project is carried out in the Netherlands. Aspart of the project, RIVM and TU Delft executed an expert study to obtain estimates on input parameters of the risk assessment model for broiler chicken processing. The expert study focused on the transmission of *Campylobacter* in industrial chicken processing plants. Twelve experts have provided quantile assessments of the query variables. The aggregated expert data will be used to achieve uncertainty distributions of the model variables. With the results a generic picture will be present which will be used to assess possible risk abatement measures to prevent or reduce *Campylobacter* contamination in chicken processing lines as much as possible. The goal of this paper is to discuss the results of the expert judgement study.

1 Introduction

In the Netherlands, *Campylobacter* infections [1] are estimated to cause yearly 100,000 cases of gastro-enteritis (among which about 23,000 GP consultations and 25 deaths), 60 cases of Guillain-Barré syndrome and thousands of cases of reactive arthritis, resulting in a loss of 1400 health life years and considerable economic losses. Effective prevention of human campylobacteriosis requires a well-balanced set of control measures in the production chain of chicken meat. The Dutch Ministries of Health and Agriculture sponsor the CARMA (***Ca****mpylobacter* **R**isk **M**anagement and **A**ssessment) project to advise on the effectiveness and efficiency of intervention measures. Risk assessment models for the various stages of the chicken meat production chain (farms, processing, retail, consumption) are being developed. RIVM and TU Delft executed an expert judgement study which focused on the transmission of *Campylobacter* in chicken processing plants.

2 The broiler chicken processing model

The broiler chicken processing model [2] distinguishes five important stages of industrial chicken processing, being:

1. scalding (low or intermediate)
2. defeathering
3. evisceration
4. washing
5. cooling (by air or by spray cooling)

An identical model [2] represents each processing stage. The model describes the expected number of *Campylobacter* on the exterior of a chicken as a result of internal (intestinal) colonization, external contamination, and exchange with the environment (among others, processing plant machinery). Model predictions can be calculated under various circumstances; for instance, a flock of contaminated chickens (generally a flock contains over 10,000 chickens) enters a clean processing line, or a clean flock enters a contaminated line.

Consider a line of chicken carcasses being processed, i.e., the carcasses move through the five consecutive stages. In each stage, each carcass entering the particular stage is contaminated with *Campylobacter* on its exterior (skin and feathers) and a concentration of *Campylobacter* per gram faeces in its interior (intestines). Also at each stage *Campylobacter* leak from its interior either to its exterior or to the direct environment. Note that faecal leakage is only relevant as long as the carcass holds intestines, which is the case in stages scalding, plucking and evisceration. The broiler chicken processing model contains 7 parameters. It provides model equations with which the number of *Campylobacter* at the end of each stage can be calculated if the parameter values were known.

3 The expert judgement study

A structural expert judgement study was held in order to obtain expert assessments on the parameters of the broiler chicken-processing model. These parameters are impossible or hard to measure in practice. However, there is relevant scientific expertise available motivating the use of a formal expert judgement [3]. The parameters of the broiler chicken-processing model represent uncertain quantities taking values in some continuous ranges. Quantitatively, uncertainty must be represented mathematically, for instance, as a probability distribution in cases of quantities with values in a continuous range. Within the subjective interpretation of a probability distribution, uncertainty is a person's degree of belief on the probability the particular quantity might take different values [3]. In the current study the experts provided the median value and the 90 percent confidence values of their assessed probability distributions.

The current expert judgement study followed the procedure guide for structured expert judgement [4]. The protocol consists of 15 steps outlined in [4].

4 The expert judgement Classical model

The Classical model [5] is a performance based linear pooling or weighted averaging model based on statistical hypothesis testing. It aggregates individual experts' assessments in order to obtain one combined assessment for each variable. Experts can be weighted equally or according to their expertise, typically indicated by their performance on seed variables. The Classical model assumes that the future performance of the experts on the query variables can be judged on the basis of their past performance on the seed variables. Therefore the seed variables must resemble the query variables as much as possible [4].

The individual experts' weights are based on two quantitative performance measures: calibration and information. Calibration measures the statistical likelihood that the realizations of the seed variables[1] correspond, in a statistical manner, with an expert's assessments. Information represents the degree to which an expert's assessed distribution is concentrated, relative to some chosen background measure, and is always positive. Good performance corresponds with good calibration and high information. The virtual expert or DM (decision maker) resulting from the combination of two or more experts also has a calibration and information score attached, calculated from the individual experts' scores [5].

The individual experts' performance-based weights are proportional to the product of calibration and information. The combined score or 'unnormalized weight' has the following properties [4]:

- Calibration dominates over information.
- The combined score in the long run is a proper scoring rule. An expert achieves the maximal expected score by and only by stating his/her true beliefs (in the long run).
- Calibration is scored as 'statistical likelihood' with a cut-off. An expert is associated with a statistical hypothesis, and the seed variables enable to measure the degree to which that hypothesis is supported by the observed data (the realizations). If this likelihood score is below a certain cut-off point, the expert is unweighted.
- The cut-off value for (un)weighting experts is determined by optimizing the calibration and information performance of the DM.

[1] Seed variables are variables of which the realizations are known to the analyst but not to the expert. They are, in general, experimental data, not yet published in open literature.

5 The query and seed variables

The variables of interest (target variables) included the seven parameters of the broiler chicken-processing model, to be assessed per processing stage, if relevant. Only the model parameters related to the probability of leakage of faeces from the carcass and the amount of faeces leaked were regarded as observable quantities and could be directly assessed as query variables. The resulting five parameters, being transfer coefficients, were regarded as non-observable, and could therefore not be elicited directly. Instead query variables were formulated which were functions of these target variables. Probabilistic inversion techniques were applied later to transform the distributions of the query variables into distributions of the target variables.

Next to the query variables, twelve seed variables were defined. The seed variables came from unpublished experimental data. They were related to the percentage of broiler chicken flocks carrying *Campylobacter* prior to processing, levels of internal infection and external contamination of broiler chickens, and contamination levels of products.

6 The expert sessions

Experts were defined as persons having extensive knowledge and experience on broiler chicken processing in the Netherlands as well as behaviour of pathogens, in particular *Campylobacter,* during the various processing stages. Out of 21 potential experts identified, 12 experts eventually joined the panel: 5 from industry, 1 from government, 3 from science, and 3 from combination of science and practice.

Prior to the elicitation sessions a dry-run meeting was held with two other experts to provide comments on the case structure (with background information on the study and problem at hand) and the questionnaire (with the query and seed variables). Next, a group meeting was held to train the experts in assessing probabilities. Finally, all experts were interviewed individually on their assessments.

7 Results on expert performance

The results of the application of equal weighting and performance-based weighting without and with optimisation of the DM are presented in Tables 1, 2 and 3. The performance of the 12 experts and the DM, expressed by calibration scores, information scores, unnormalized weights and normalized weights with DM is presented. The normalized weight with DM is the weight that the expert would receive if the DM had been added to the expert panel as an additional virtual expert.

Examination of the Tables shows that although a few experts (Exp. 3, 6, 7 and 8) succeed in combining good calibration with high information, the optimized DM coincides with the results of one expert (Exp. 7, Table 3). In other words, performance is optimal when weight one is assigned to this single expert.

8 Conclusions

The paper describes in short how an expert judgement study on *Campylobacter* contamination of broiler chickens is organized. A full paper on the topic will be published soon [6].

Expert ID	Calibration	Information (realizations)	Unnorm. Weight	Norm. weight with DM
Exp. 1	0.001	1.00	0.001	0.0004
Exp. 2	0.01	1.34	0.01	0.01
Exp. 3	0.68	0.57	0.39	0.14
Exp .4	0.001	0.74	0.001	0.0003
Exp. 5	0.22	0.26	0.06	0.02
Exp. 6	0.68	0.73	0.50	0.18
Exp. 7	0.82	1.48	1.21	0.43
Exp.8	0.68	0.77	0.52	0.19
Exp. 9	0.0001	1.13	0.0001	0.00
Exp. 10	0.0001	2.12	0.0002	0.0001
Exp. 11	0.0005	1.03	0.0005	0.0002
Exp. 12	0.0001	1.90	0.0002	0.0001
DM	0.47	0.24	0.11	0.04

Table 1. Results of scoring experts relative to the decision maker (DM), based on equal weighting.

Expert ID	Calibration	Information (realizations)	Unnorm. Weight	Norm. weight with DM
Exp. 1	0.001	1.00	0.001	0.0003
Exp. 2	0.01	1.34	0.01	0.01
Exp. 3	0.68	0.57	0.39	0.13
Exp .4	0.001	0.74	0.001	0.0003
Exp. 5	0.22	0.26	0.06	0.02
Exp. 6	0.68	0.73	0.50	0.17
Exp. 7	0.82	1.48	1.21	0.41
Exp.8	0.68	0.77	0.52	0.18
Exp. 9	0.0001	1.13	0.0001	0.00
Exp. 10	0.0001	2.12	0.0002	0.0001
Exp. 11	0.0005	1.03	0.0005	0.0002
Exp. 12	0.0001	1.90	0.0002	0.0001
DM	0.47	0.53	0.251	0.085

Table 2. Results of scoring experts relative to the decision maker (DM), based on performance-based weighting without DM optimization.

Expert ID	Calibration	Information (realizations)	Unnorm. Weight	Norm. weight with DM
Exp. 1	0.001	1.00	0	0
Exp. 2	0.01	1.34	0	0
Exp. 3	0.68	0.57	0	0
Exp .4	0.001	0.74	0	0
Exp. 5	0.22	0.26	0	0
Exp. 6	0.68	0.73	0	0
Exp. 7	0.82	1.48	1.21	0.50
Exp.8	0.68	0.77	0	0
Exp. 9	0.0001	1.13	0	0
Exp. 10	0.0001	2.12	0	0
Exp. 11	0.0005	1.03	0	0
Exp. 12	0.0001	1.90	0	0
DM	0.82	1.48	1.21	0.50

Table 3. Results of scoring experts relative to the decision maker (DM), based on performance-based weighting with DM optimization.

Acknowledgments

The authors acknowledge the consulted experts for their participation to this study, B. Kraan and D. Kurowicka from Delft University of Technology and S. Mylius from the National Institute for Public Health and the Environment for their attendance in the elicitation teams, and W. Jacobs-Reitsma of the Animal Science Group of Wageningen University for her contribution in defining the seed variables.

References

1. Havelaar AH, de Wit MA, van Koningsveld R & van Kempen E. Health burden in the Netherlands due to infection with thermophilic *Campylobacter spp.* Epidemiology and Infection 2000; 125:505-522
2. Nauta MJ, van der Fels-Klerx HJ & Havelaar AH. A poultry processing model for quantitative microbial risk assessment. Risk Analysis (to be published)
3. Cooke RM & Goossens LHJ. Procedures guide for structured expert judgement in accident consequence modelling. Radiation Protection Dosimetry 2000; 90(3):303-309
4. Cooke RM & Goossens LHJ. Procedures guide for structured expert judgement. Report 18820. Office for Official Publications of the European Communities Luxembourg, 2000
5. Cooke RM. Experts in uncertainty. Oxford University Press New York, 1991
6. Van der Fels-Klerx HJ, Cooke RM, Nauta MJ, Goossens LHJ & Havelaar AH. A structured expert judgment study for a model of *Campylobacter* contamination during broiler chicken processing. Risk Analysis (to be published)