

A Quantitative Microbiological Risk Assessment for Salmonella transmission in pigs in individual EU Member States

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Abstract

A farm-to-consumption quantitative microbiological risk assessment (QMRA) for Salmonella in pigs has been developed for the European Food Safety Authority. The primary aim of the QMRA was to assess the impact of reductions of slaughter-pig prevalence and the impact of important control measures applied at the farm and during transport, lairage and slaughter on the number of human cases of salmonellosis. The QMRA estimates the risk of salmonellosis and number of human cases for three product types: pork cuts, minced meat and fermented ready-to-eat sausages.

For four case study European Union Member States (MSs) the average probability of illness was estimated to be between 1 in 100,000 and 1 in 10 million servings given consumption of one of the three product types. The total numbers of cases attributable to the three product types was also estimated. The results from the intervention analysis suggest that specific slaughterhouse interventions are currently best placed to produce consistently large reductions in the number of human cases and that for high breeding prevalence MSs reducing infection on breeder farms would seem to be an important on-farm control measure.

Introduction

Under Article 36 of the European Parliament and Council Regulation (EC) No 178/2002 (EC, 2002), the European Food Safety Authority (EFSA) published a call and funded a "Quantitative Microbiological Risk Assessment (QMRA) on Salmonella in slaughter and breeder pigs". This QMRA was developed to provide evidence to a Scientific Opinion from the EFSA Panel on Biological Hazards (EFSA, 2010a) which would assist the EC on setting targets for Salmonella in Pigs and individual European Union (EU) Member States (MSs) with the development of a MS-specific National Control Plan (NCP). The full report of this QMRA is available on the EFSA website (EFSA, 2010b).

The aims of the QMRA were to assess the impact of (hypothetical) reductions of slaughter-pig prevalence and the impact of important control measures applied at the farm and during transport, lairage and slaughter on the number of Salmonella cases in humans; the sources of infection for fattening pigs at the farm level and the impact of transport, lairage and slaughter processes on the contamination of carcasses.

Material and Methods

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

EFSA requested that the QMRA should characterise the variability between EU MSs and, in particular, the inclusion of variability between MSs in their pig farms, slaughterhouses and consumption patterns; this presented numerous challenges. These challenges were overcome by the development of a generic model with a clearly defined set of parameters that may vary between MSs, the values of which can be easily input for any specific EU MS. To demonstrate the parameterisation and use of the model, four MSs were selected as case studies (MS1, MS2, MS3 and MS4).

The exposure assessment was split into 4 modules: Farm; Transport & Lairage; Slaughter & Processing and Preparation & Consumption. The output from one module is the input to the next and so collectively they model the entire farm-to-consumption chain. Efforts were made to take into account the natural variation of Salmonella infection and/or contamination in the modelling. This was done by, wherever possible, allowing for stochastic variation of parameter values. Consequently, as much as possible, variability within and between batches of pigs, farms, transport vehicles, slaughterhouses, cutting plants, retail outlets and consumer practices, both within and between MSs, was described. Three product types are included in the QMRA: pork cuts, minced meat and fermented ready-to-eat 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. Within the mandate, EFSA were asked "to consider all serovars in pigs that are of human health significance", and hence the QMRA considered only Salmonella spp. as a group, rather than distinguishing between serotypes. The risk assessment was parameterised using data from the published and unpublished literature and, where necessary, expert opinion.

Results

The results of the QMRA are summarised in Tables 1 & 2. For all four MSs the average probability of illness is between 1 in 100,000 and 1 in 10 million servings given consumption of one of the three product types. MS2 is predicted to have a higher probability of illness. For all of the MSs, the product with the highest probability of illness per serving is fermented sausage. The lowest risk per serving is associated with pork cuts (MS1, MS2) and minced meat (MS3, MS4). The total number of cases attributable to each of the three product types was also estimated. However the QMRA appears to overestimate the number of cases, which can be attributed to a variety of factors including a lack of data regarding immunity and the dose response relationship, and the assumption that all Salmonella spp. were to be regarded as a potential public health threat.

Table 1: Baseline results from the QMRA: mean probabilities of illness by eating one serving of pork cuts, minced meat or fermented sausage in the 4 case study MSs.

Member State	<i>P</i> _{illness}		
	Pork Cuts	Minced Meat	Fermented Sausage
MS1	7.65×10^{-07}	8.84×10^{-07}	1.87×10^{-06}
MS2	1.86×10^{-05}	2.24×10^{-05}	4.25×10^{-05}
MS3	3.88×10^{-07}	2.32×10^{-07}	5.78×10^{-07}
MS4	2.55×10^{-06}	2.58×10^{-07}	4.29×10^{-06}

Table 2: Number of cases, per year, attributed to pork cuts (PC), minced meat (MM) and fermented sausage (FS), for the four case study MSs.

	MS1	MS2	MS3	MS4
No. of predicted cases by PC/year	520	9,802	1,162	1,384
No. of predicted cases by MM/year	125	11,148	182	56
No. of predicted cases by FS/year	375	4,298	165	1,246
Total no. of predicted cases (PC + MM + FS)/year	949	25,248	1,509	2,686
Predicted number of cases per 100,000 habitants	12	42	4	26

A key part of the QMRA was the investigation of interventions (for further information see Hill et al. 2011b). From the intervention analysis it was concluded that certain farm intervention mechanisms (such as reducing the susceptibility of the pig to infection, possibly by vaccination or organic acids) may produce significant changes in the slaughter pig prevalence, although evidence that specific farm interventions consistently work was sparse. In addition, considering the results from the farm model (see Hill et al 2011a), the model results lead us to suggest those MSs with a high breeding herd prevalence should focus on these herds in order to reduce the burden of infected new stock entering the weaning/growing/finishing stages (as these new stock are the main source of infection for slaughter pigs). Likewise it was concluded that MSs with low breeding herd prevalence should focus their attentions on reducing contamination of feed. From

the current evidence, it would appear that specific slaughterhouse interventions are currently best placed to produce consistently large reductions in the number of human cases. However, the multiple farm and abattoir intervention scenarios investigated here suggest that MSs can achieve larger reductions by targeting farm and slaughterhouse together. Reducing the prevalence at farm level is also considered important for preventing the transmission of Salmonella from pigs to other livestock species such as laying hens and broilers, where the prevention and control efforts are focused on the farm.

The intervention analysis described above highlighted a fairly proportional relationship between slaughter pig prevalence and risk of human illness. This was unexpected given the non-linearities included in the model, especially cross-contamination at the abattoir. However, further analysis (not shown here) has shown that arguably the most important non-linearity captured within the model, cross-contamination at the abattoir, is dominant only at lower levels of carcass contamination. These lowly-contaminated carcasses contribute only a small proportion of the overall risk (where most of the human risk comes from highly-contaminated carcasses), and hence cross-contamination is not important in terms of affecting human risk.

Discussion

Similar to other farm-to-consumption QMRAs (Havelaar et al 2008) the model probably overestimates the number of human cases. However it should be noted that there are uncertainties associated with the reported number of cases due to, for example, potentially significant under-reporting the level of which will vary between MSs. The validity of the model at earlier stages within the farm-to-consumption chain was assessed by comparing the QMRA estimated prevalence to the observed prevalence at the point of lairage (from EFSA slaughter pig baseline survey) and retail (MS surveys); the QMRA outputs were deemed to be plausible at these two points. Consequently, it is likely that factors such as the lack of data regarding immunity, the dose-response relationship and the assumption of all Salmonella spp. being equal are contributing to this potential overestimation. However the QMRA still allows for the prediction of the relative impacts of different interventions during the Farm, Transport, Lairage and Slaughterhouse stages, which was the main purpose of the QMRA.

During the development of the baseline model a number of data gaps/deficiencies were identified; some of which were assessed in an uncertainty analysis to have an important impact on the probability of illness. It is recommended that further data generation is undertaken in order to provide improved estimates for the parameters identified as uncertain and influential. The identification of such data gaps is a positive feature of any risk assessment model and many risk managers utilise such information to direct future research.

In relation to the intervention analysis, it is important to note that there was very inconsistent evidence to suggest whether any of the farm interventions can be consistently applied to produce either the required reduction in environmental contamination or the required increase in a pig's resistance to infection. Probably of extreme importance, but not investigated here, is the rate of uptake and correct application of interventions by farmers – if this is not universal across a MS the effect in reducing human illness will be reduced.

Conclusion

In conclusion, a QMRA has been developed that will assist the EC on setting targets for Salmonella in pigs and individual EU MSs with the development of a MS-specific NCP. The QMRA characterises the variability between EU MSs and in particular, the variability between pig farms, slaughterhouses and consumption patterns. This was achieved by developing a generic EU model with a clearly defined set of parameters that may vary between MSs, the values of which can be easily input for any specific MS model. Using the QMRA to perform an intervention analysis we have shown, theoretically, that large reductions in the number of pig-meat attributable cases of Salmonella within a MS can be achieved via intervention at either the farm and/or slaughterhouse level.

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