Stochastic modelling of *Salmonella* monitoring in finishing pigs

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Abstract

Results of serological monitoring for *Salmonella* in finishing pigs are used to classify herds and target control measures at herds with high prevalence. The outcome of monitoring depends on three factors: (a) the optical density percentage (OD%) used to declare a sample positive, (b) the herd classification scheme, and (c) the number of samples. The goal of this study was to analyse the impact of these three factors on the reliability and cost of *Salmonella* monitoring in finishing pigs. A stochastic simulation model was constructed to evaluate 12 monitoring scenarios based on: (a) four cut-off values for the OD% and (b) three herd classification schemes. Furthermore, eight different sampling schemes were evaluated. The main outputs of the model are (a) the percentage of herds changing classification as a reliability criterion and (b) the total number of samples taken as a cost criterion. Results indicated that monitoring scenarios based on cut-off OD% 10 are most reliable. Moreover, inclusion of a zero-prevalence class decreased the reliability of monitoring. The economically optimal sampling scheme depended on the monitoring scenario used.

Introduction

Pork and pork products are one of the major sources of salmonellosis in Western Europe. Some countries already implement surveillance and control programmes for *Salmonella* in finishing pigs that aim at reducing the prevalence of *Salmonella* bacteria in both pig herds and pork products (e.g. Alban et al., 2002; Blaha et al., 2003). Within a couple of years, surveillance and control programmes for *Salmonella* in pigs will become mandatory for all EU member states (CEC, 2003). However, as the results of these programmes largely depend on the criteria used to allocate farms to low-, medium-, or high-risk classes, a uniform and transparent classification approach is needed to allow comparison of results over countries.

The above-mentioned programmes usually consist of two parts: (i) monitoring of *Salmonella* prevalence and (ii) implementing control measures on farms with a high prevalence. This study focuses on serological monitoring of finishing pigs at the slaughterhouse aimed at classifying herds according to their *Salmonella* status (i.e. prevalence). Monitoring was based on meat juice samples. Monitoring results depend on three factors: (a) the detection level, i.e. the optical density percentage (OD%) used to declare a sample positive, (b) the herd classification scheme, and (c) the number of samples. The goal of this study was to analyse the impact of these three factors on the reliability and cost of *Salmonella* monitoring in finishing pigs.

Material and methods

Study design

Monitoring of *Salmonella* in finishing pigs was evaluated for 12 monitoring scenarios based on: (a) four cut-off values for the OD% to declare a sample positive (10, 20, 30, and 40) and (b) three herd classification schemes (Table 1). These monitoring scenarios were evaluated for eight different sampling schemes.

Table 1 *Salmonella* prevalence levels of three different herd classification schemes

	Classification I	Classification II	Classification III
Zero	n.a.[1]	0	n.a.[1]
Green	< 20	> 0 and < 20	< 10
Orange	• 20 and < 40	• 20 and < 40	• 10 and < 40
Red	• 40	• 40	• 40

[1] Herd classification schemes I and III have no zero class.

Simulation model

A stochastic simulation model was developed in Microsoft Excel with the add-in programme @Risk 4.5.4.

Input. A database containing 1 151 pig farms from Lower Saxony, Germany was used as input for the simulation model. For each farm data were available on farm size, number of samples taken in the period 2003 up to 2004, and the OD% of each sample. Model calculations are based on serological testing of meat juice samples from pig carcasses with an indirect enzyme-linked immunosorbent assay (ELISA).

Output. The main output parameters of the model used to analyse the different monitoring scenarios for their reliability and cost are (i) the percentage of herds for which monitoring resulted in allocation to a different *Salmonella* prevalence class than the herd was originally in (old class • new class) and (ii) the total number of samples taken over all iterations, respectively.

Model calculations. In each iteration a different herd is simulated. This herd is drawn from a discrete distribution taking into account the real distribution of all 1 151 herds in the German data set over the different *Salmonella* prevalence and herd size classes (see Fig. 1). Data on herd size, *Salmonella* herd prevalence, sample size, and test sensitivity and specificity were used to calculate the number of carcasses testing positive. This result was used to allocate the herd to a new *Salmonella* prevalence class.

Figure 1 Schematic representation of the calculations for finishing farms in the simulation model for *Salmonella* monitoring in finishing pigs.

N_{herd} = herd size; P_{herd} = herd prevalence; N_{sample} = annual sample size; I_{sample} = number of infected carcasses in annual sample; T^{+}_{sample} = number of carcasses testing positive; AP_{herd} = apparent herd prevalence

Results

The most important results indicated the following:

- Monitoring scenarios based on cut-off OD% 10 are most reliable.
- Decreasing the cut-off value from OD% 40 to OD% 30 does not improve reliability.
- Inclusion of a zero-prevalence class decreases reliability.
- The preferred sampling scheme depends on the monitoring scenario used:
    - for OD% 40 and classification I, a sampling scheme based on *Salmonella* prevalence class with an annual sample of 20, 20, 40, and 60 carcasses per herd for zero, green, orange, and red herds, respectively is preferred;
    - for OD% 10 and classification III, the choice for a sampling scheme is a trade-off between reliability and cost.

Discussion

Reliability was measured by the percentage of herds for which monitoring resulted in allocation to a different *Salmonella* prevalence class than the herd was originally in (old class • new class). This is actually an indicator for the robustness of the outcome of monitoring: do herds end up in the same prevalence class after ‘re-sampling’ when no changes did occur at herd level with respect to true *Salmonella* prevalence? Robustness is important when *Salmonella* control programmes are based on this classification. The reliability measured in this study does, however, not tell if herds are classified correctly, i.e. if the true herd prevalence corresponds with the Salmonella prevalence class the herd is allocated to.

Results of this modelling study show that a monitoring scenario based on cut-off OD% 10 is most reliable, i.e. relatively few herds changed classification when ‘re-sampled’. Monitoring based on cut-off OD% 10, however, results in a large fraction of herds in the orange and red classes. This might be an undesired outcome of monitoring as it gives the impression that *Salmonella* is a problem in the majority of finishing herds which possibly leads to a bad image with respect to food safety.

Conclusion

The simulation model described in this paper provides insight into the impact of cut-off OD%, herd classification scheme, and sampling scheme on reliability and cost of monitoring. It is a useful tool to evaluate *Salmonella* monitoring programmes in finishing pigs based on serology of meat juice samples and can as such be used to support decision-making on *Salmonella* monitoring.

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