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Variation in the effect of carcass decontamination impacts the risk for consumers

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ABSTRACT

To enhance food safety, whole carcass decontamination during slaughter has been considered as a control measure to reduce pathogen concentrations on meat. The effect of such decontamination is usually measured in terms of the mean log reduction in concentration. However, the variation in this reduction may also contribute to the overall impact of the decontamination measure. Therefore, this study focuses on the relative contribution of mean and variation for the effect of decontamination in the slaughter-line expressed in terms of the effect on human health risk.

A stochastic risk model is developed to assess the potential effects of pig carcass decontamination at the end of slaughter on the risk of salmonellosis for Danish consumers. *Salmonella* concentrations are represented by a lognormal distribution fitted to microbiological data, characteristic for *Salmonella* numbers on carcasses at the end-point of Danish slaughterhouses. Decontamination scenarios are represented by various gamma distributions with different means and standard deviations. The values chosen for these parameters are based on experimental data of the effect of real decontamination procedures applied to pork.

Results show that the variation of decontamination has a relevant effect on risk reduction for the consumer: the higher the variation, the lower the overall risk reduction. This effect is particularly evident for procedures with a lower mean reduction ($\leq$2.5 $\log_{10}$), but less so for highly efficient decontamination procedures (>2.5 $\log_{10}$ mean reduction). This difference is affected by the initial level of carcass contamination with *Salmonella*. With increasing mean and standard deviation of initial bacterial concentrations, it becomes increasingly relevant to account for the variation of the decontamination action, even if the mean decontamination effect is high.

We conclude that for decontamination procedures with an overall mean reduction effect of 1–2 $\log_{10}$, it is important to consider the variation in effect: if the variation is large, the final effect of decontamination can be considerably smaller than expected on the basis of the mean only and efforts should be put in place to reduce the variation of the procedure. However, when a treatment of high mean reduction (>2.5 $\log_{10}$) is used, the impact of variation becomes smaller and may be negligible.

1. Introduction

Zoonotic pathogens such as *Salmonella* carried by farm animals are inevitably spread to carcasses during slaughter. Physical (e.g. hot water, steam) or chemical (e.g. chlorine, lactic acid) carcass decontamination is a food safety control measure often applied at the end of the slaughter-lines before cooling, with the goal of reducing the level of pathogen contamination. Internationally, carcass decontamination of cattle, pigs and broilers, has been part of the routine slaughter process in many countries such as USA and Canada. In EU, chemical mitigation procedure has only recently been accepted (Anonymous, 2004). In Denmark, pig carcasses from

Abbreviations: QMRA, quantitative microbiological risk assessment; BPW, buffered Peptone water; MSRV, modified semisolid rappaport-vassiliadis; XLD, xylose-lysine-desoxycholat; MLE, maximum likelihood estimation; LOQ, limit of quantification; URF, underreporting factor; RR, relative risk; CPM, consumer phase model.

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farms that were found to be infected with *Salmonella* at serological level III, corresponding to 1% of the Danish production, are treated with 80 °C hot water for 15 s giving an approximate 100 fold reduction in *Escherichia coli* (Alban & Sorensen, 2010).

Studies of bacterial reduction achieved by decontamination of pigs and cattle at slaughter are commonly measured by the effect on indicator organisms due to low prevalence of pathogens (Gill, McGinnis, Bryant, & Chabot, 1995). In poultry, however, *Campylobacter* is so prevalent that the effect of decontamination can be measured directly (Riedel, Brondsted, Rosenquist, Haxgart, & Christensen, 2009). The efficacy is most frequently reported as a mean log reduction and often the variation in effect is given (Dlusskaya, McMullen, & Gänzle, 2011; Gill, Bedard, & Jones, 1997; Morild, Christiansen, Sørensen, Nonboe, & Aabo, 2011). However, to the knowledge of the authors none has so far addressed the impact of the variation on the overall performance of the decontamination procedure in relation to food safety. Consequently, the efficacy of decontamination procedures is usually judged by their reported mean log reductions. Nevertheless, variation inherent to a procedure (e.g. standard deviation of log reduction) should not be neglected, as it may have an influence on the procedure's adequacy to be implemented as part of a control measure in a slaughter-line. Further, the impact on the overall performance of a procedure may also depend on the target microorganism, the initial microbiological concentration and the level of mean reduction.

In this study, we develop a theoretical exercise that takes into consideration both mean log reduction and variation in effect of decontamination, and uses *Salmonella* as an example. The values chosen for mean and standard deviation are based on a previous study being part of the DECONT project (Christiansen et al., in prep). They have measured the efficacy of different hot water based decontamination actions in terms of mean and variation in reduction of *E. coli*, *Yersinia enterocolitica* and *Salmonella* Typhimurium on pork meat. Here, we define different decontamination scenarios based on the mean effects and standard deviations measured in that study for *Salmonella*. This approach supports selection of realistic scenarios of decontamination relating to an epidemiologically relevant pathogenic microorganism often found in pork meat.

Apart from costs (Jensen, Lawson, & Lund, 2013) and consumer perception (Korzen, Sandøe, & Lassen, 2011) as part of the basis for deciding for decontamination, the direct effect on the microorganisms and the expected effect in terms of consumer risk reduction are key parameters (Alban & Sorensen, 2010). The effect of decontamination procedures, normally given as mean log reductions of microbiological concentration, does not necessarily provide insight on the effect in terms of consumer risk reduction. Consumer risk depends both on the probability of exposure to the hazard, the ingested dose and the severity of the health effect following exposure. Hence, to estimate the effect of decontamination on health risk, one first needs to link the concentration on the meat after slaughter to exposure and then has to apply a dose response relation. The non-linear dose response relationship (Anonymous, 2002) implies that the risk cannot be expected to be linearly related to concentration.

In this study, risk reduction is assessed for different decontamination effects in relation to a baseline scenario where no decontamination is applied; we use relative risk reduction to compare the impact of decontamination procedures characterized by different mean reduction effects with different variations. The exercise is performed with four scenarios of initial microbiological concentration to investigate how the impact of variation of reduction effect depends on the initial level of carcass contamination.

Our aim is to estimate consumer risk reduction as a measure of the effect of carcass decontamination at pig slaughter and to suggest a basis for standardized risk based comparison of effects of decontamination procedures. Based on quantitative carcass data on *Salmonella* generated in the DECONT project, we investigate how the variation in the effect of a decontamination procedure impacts the risk for the consumer, depending on the initial microbiological concentration, the mean reduction effect and the level of variation of the effect.

2. Materials and methods

2.1. Sampling procedure and sample preparation

As part of the DECONT project carcass swabs and faecal material were sampled from 2822 pigs in five Danish slaughterhouses, all with a daily slaughter capacity of about 2500 pigs per slaughter-line and with pigs usually originating from between 25 and 50 farms. Each slaughterhouse was sampled six days evenly distributed over a two year period from May 2005 to May 2007. On each sampling day approximately 120 pigs were sampled per day, by selecting about every twentieth pig in the slaughter-line. To allow sampling, carcasses were directed to a separate conveyer. Carcass swabs were taken at the end of the slaughter-line, just before cooling. Sixteen layer 10 × 10 cm gauze swabs moisturized in 15 ml Buffered Peptone Water (BPW) (Oxoid) were used to swab all carcasses with an approximate pressure of 2 kgp, covering approximately 2800 cm^2 (1400 cm^2 from each side of the carcass) taken from the forepart via the brisket through the mid-section line to the pelvic region as described by Nauta et al. (2013). After swabbing, the swab was placed in a stomacher bag. Preparation of carcass swabs: 75 ml of peptone water were added to the stomacher bag containing the swab pre-moisturized with 15 ml peptone water, and this mix was stomached for 60 s. For both the qualitative and the semi-quantitative analysis, 11 ml homogenate were added to 4 ml concentrated BPW to achieve a 1× BPW concentration and then added further 135 ml 1× BPW. After stomaching, a 10 fold dilution was prepared for the sample prepared for the semi-quantitative analysis.

2.2. Microbiological analysis

The microbiological analysis was performed according to Nauta et al., (2013) with some precisions. The homogenate from carcass swab samples were all first analysed qualitatively for *Salmonella*. 10 ml homogenate was kept at 4 °C ± 1 °C to allow semi-quantitative analysis of a 10-fold dilution series of the homogenate from positive samples. All prepared samples were pre-enriched by incubation at 37 °C for 18–24 h. After pre-enrichment, selective indicative culturing for *Salmonella* was performed using the Modified Semisolid Rappaport-Vassiliadis (MSRV) method (Anonymous, 2007). Negative and blind control samples were one portion of BPW tested first and for every 60 samples. Positive control samples were 15 ml of BPW with addition of 50–200 cfu of *S. enterica* serovar Adabraka.

From *Salmonella* swarming zones, a loop full was streaked onto the indicative media Xylose-Lysine-Desoxycholat agar (XLD-agar) (Oxoid) and black presumptive colonies were subcultured on non-selective Luria Bertani-Agar,, Lennox (Oxoid) with subsequent confirmation of the *Salmonella* diagnosis by serotyping according to the Kaufmann-White scheme (Grimont & Weill, 2007) following standard procedures of the *Salmonella* reference laboratory.

2.3. QMRA

A quantitative model was developed to assess the risk of human salmonellosis in Denmark, attributed to the ingestion of pork meat.