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Short communication

The additional costs of segregated transport to slaughter to decrease *Salmonella* prevalence in pork—A simulation study

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ABSTRACT

A stochastic simulation model was used to assess the additional costs related to segregated transport to slaughter. This control measure was assumed to be implemented within a producers' association to decrease *Salmonella* prevalence in pork. Calculations were based on the additional shipments caused by the separate transport of low- and high-prevalence herds and on the additional transport distance caused by changed routing. The results showed that there is not necessarily a considerable increase in the number of shipments due to herd status separation for transport. The percentage of shipments changed due to segregated transport varied between 43% and 69% depending on the threshold prevalence. The additional costs per slaughtered pig varied between 0.07€/pig and 0.58€/pig under the given assumptions. Costs were governed by the percentage of changed shipments and the additional distance of a changed shipment. Due to the fact that the percentage of changed shipments is related to the distribution of herd prevalence within the producers' association, there is no cost-effective threshold in general. Different producers' associations incur different costs caused by segregated transport to slaughter at the same threshold prevalence. The current study supports producers' associations in evaluating the additional costs of segregated transport for their members.

1. Introduction

Human salmonellosis is one of the most important food-borne diseases worldwide (WHO, 2005). Cases are frequently related to pork consumption. According to estimates by the European Food Safety Association (EFSA), about 10% of slaughter pigs are infected with *Salmonella* in Europe (EFSA, 2008). Differences in prevalence between countries are high. The EFSA found no pigs infected with *Salmonella* in lymph nodes in Finland, whereas in Spain the prevalence was about 29%. Several studies reveal the importance of transport to slaughter and lairage before slaughtering for prevalence in pigs and pork. Berends et al. (1996) stated that the percentage of animals excreting *Salmonella* at the end of the finishing period could double during transport and lairage. This is in accordance with Hurd et al. (2002), who demonstrated that rapid infection during transport and holding is a major reason for increased prevalence in swine. Especially the time spent in lairage before slaughtering seems to play a crucial role in infection and contamination (Swanenburg et al., 2001a; Belœil et al., 2004). Furthermore, if the proportion of *Salmonella*-free farms increases, transport and lairage will be the only remaining infection sources for pigs originating from these farms (Stärk et al., 2002). Hence, the most effective strategies reducing *Salmonella* prevalence in pork have to include transportation and lairage (van der Gaag et al., 2004) in order to avoid transmission of bacteria as much as possible. Segregated transportation to slaughter affects transport combinations due to herd separation according to prevalence before transport, but also lairage due to the preferred slaughtering of low-prevalence herds at the

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beginning of a slaughter day. Previous studies have shown that segregated transport to slaughter has the capability to reduce *Salmonella* infection at lairage (Hotes et al., 2011) and is useful to decrease the prevalence of *Salmonella*-contaminated pork after slaughter (Swanenburg et al., 2001b). Whether segregated transport is to be implemented as *Salmonella* control measure in pork production depends not the least on the additional costs incurred by the separate transportation of pigs from low- and high-prevalence farms. Hence, the objective of the present study was to evaluate the additional costs related to segregated transport to slaughter via a simulation study.

2. Material and method

2.1. Applied simulation model

The present study was based on a stochastic model, which simulated the spread of non-clinical *Salmonella* from farrowing farm to a slaughterhouse over a 1-year period. Comparable to all-in/all-out production, a 1-week time increment was defined as the basic unit for regrouping tasks and moving pigs between branches of production. Four mutually exclusive health states were distinguished during a pig's lifetime: susceptible pigs free of *Salmonella*; seronegative, shedding pigs; seropositive, shedding pigs; and seropositive non-shedding but *Salmonella*-bearing pigs (Lurette et al., 2008). The model described a typical trade network of Northern Germany, consisting of 50 farrowing farms with a mean of 180 sows per farm (Landwirtschaftskammer Schleswig-Holstein, 2007) (herd size varying from 100 to 350 sows). The simulation distinguished between farrow-to-finishing farms, conventional farrowing farms and fattening farms. On average, 13 farrow-to-finishing farms and 45 finishing farms fattened the pigs to slaughter weight. All pigs were slaughtered at a central slaughterhouse at 27 weeks of age. Transport to the slaughterhouse considered optimal routing, meaning that a lorry collected pigs from up to three farms, up to a maximum capacity of 180 pigs per lorry. The program was written in the object oriented language C++. Each scenario was repeated 30 times.[1]

2.2. Segregated transport to slaughterhouse

The idea of segregated transport was to separate herds with high *Salmonella* prevalence from herds with low *Salmonella* prevalence to avoid infection during transport and contamination during slaughtering. Therefore, low-prevalence herds were transported and slaughtered at the beginning of the slaughter day. Segregated transport has already been implemented for poultry flocks participating in the German *Salmonella* monitoring system (QS GmbH, 2010). To simulate segregated transport for fattening pigs, three different thresholds of *Salmonella* prevalence were considered: 40%, 20% and 10%. This was due to the fact that thresholds of 20% and 40% are used for the German *Salmonella* monitoring system to categorise fattening farms. The threshold of 10% was additionally considered because it represents the mean *Salmonella* prevalence of the European Union (European Food Safety Authority, 2008). Slaughter pigs of farms categorised as low-prevalence farms (slaughter pig prevalence $\leq$ threshold) were not allowed to be transported with pigs of high-prevalence farms (slaughter pig prevalence > threshold).

2.3. Calculation

To evaluate the impact of segregated transport to slaughter three questions were of interest.

1. Does segregated transport increase the number of shipments due to a decreased lorry load?The simulation model was applied to determine the number of additional shipments. The number of shipments generated by the scenario without herd separation (default scenario) was compared with the number of shipments generated as if herd separation had been considered. Three simulation scenarios considering segregated transport to slaughter were analysed. Scenario Prev40% differentiated herds with *Salmonella* prevalence less than or equal to 40% (low-prevalence herds) from herds where prevalence exceeded 40% (high-prevalence herds). Similarly, scenario Prev20% discriminated at a threshold prevalence of 20% and scenario Prev10% discriminated at a threshold prevalence of 10%. All scenarios were repeated 30 times. The mean number of shipments for each scenario was compared with the mean of the default scenario via *t*-test. To meet multiple comparisons, the *p*-values were accomplished with the Bonferroni adjustment. The significance level was set to 5%.
2. How many shipments have to be changed due to herd status separation (changed combination of farm origins for one load) for transport to slaughter?The percentage of shipments, which changed due to segregated transport, was assessed by comparing the number of all possible transport combinations (number of shipments possible) with and without separate transport.

$$\text{Changed shipments (\%)} = 1 - \left(\frac{\text{number of shipments possible considering all low-prevalence farms} + \text{Number of shipments possible considering all high-prevalence farms}}{\text{number of shipments possible without segregated transport}} \right) \times 100$$

3. What are the additional costs of segregated transport to slaughter?Additional costs of segregated transport were related to the additional distance caused by changing the route of transportation. However farm coordinates were not available due to data privacy restrictions in

[1] A detailed description of the simulation model, the input parameters and the evaluation via sensitivity analysis is available from the author.