Evaluation of the association between pen fecal accumulation and prevalence of *Salmonella enterica* shedding in swine

Funk JA¹, Davies PR¹, Nichols, MA¹, Morrow WEM²

¹North Carolina State University, College of Veterinary Medicine, 4700 Hillsborough St., Raleigh, NC 27606, USA.  
²North Carolina State University, Department of Animal Science, PO. Box 7621, Raleigh, NC 27606, USA

One of the recommended control measures for *Salmonella enterica* is improved or adequate farm hygiene.¹, ², ⁶ Although loosely defined, a component of good hygiene practice is to minimize animal contact with feces. Increased exposure to feces would be expected to increase the likelihood of transmission and fecal shedding of *Salmonella enterica*. There are indications in the literature that decreased animal contact with feces may result in a decreased risk for *Salmonella enterica* infection. Davies et al. (³, ⁴) demonstrated increased mean prevalence in open-flush gutter and dirt lot systems when compared to pigs housed on total slatted flooring systems. Paradoxically, three-site, all-in/all-out pig flow systems did not have a significantly different mean *Salmonella enterica* prevalence when compared to one-site continuous flow farms. A similar incongruity is the evidence that in poultry barns, birds placed on used litter had lower risk of *Salmonella* shedding than birds placed on clean litter.⁵ Proposed mechanisms of this result are colonization with competitive flora from the used litter as well as an inhibitory environment for *Salmonella enterica*. The subjective nature of determining adequate hygiene as well as the presence of apparently contradictory results regarding hygiene and prevalence of *Salmonella* shedding in animals warrants inquiry into the question of what is good hygiene in respect to *Salmonella* shedding in animals.

The interest in pen level risk factors for Salmonella prevalence was also an impetus to this investigation, as previous research results had suggested clustering of *Salmonella* prevalence at pen level. This study investigates the association between pen fecal accumulation and prevalence of fecal shedding of *Salmonella enterica* in market swine.

Materials and Methods

A finishing site with five barns was selected. Each barn had partially slatted floors, 40 pens, and 1000 head inventories. Partially slatted floors were selected for investigation as flooring systems with the highest likelihood of fecal accumulation due to the solid portion of the floor and anecdotal reports of dunging on solid portions of the floor instead of the intended slatted portions. The barns were managed all-in/all-out and cleaned and disinfected between groups of pigs. Once weekly for 15 weeks each pen (n=200) was assigned a fecal accumulation score from 0-3. A score of 0 indicated negligible fecal accumulation and 3 indicated heavy fecal accumulation. All fecal accumulation scores were based on the amount of accumulation on the solid portion of the pen floor. The sick pens (4 per barn) were excluded from data analysis due to the low and changing inventory of pigs present during the study's duration. At the end of 14 weeks, 3 barns were selected for sampling. The barns with the highest, lowest and a moderate average pen fecal accumulation score were selected. Within each barn, 10 pens were selected for sampling. Pens sampled included the five pens with the lowest ("clean pens") and five pens with the highest pen scores ("dirty pens") within each barn. Within each selected pen, 10g fecal samples were obtained from 12 pigs. Fecal samples were cultured as previously described. Statistical analysis of relative risk for fecal shedding of *Salmonella enterica* when exposed to high fecal contamination was calculated using Epi Info 6.0. Mantel-Haenszel weighted relative risk was calculated by stratifying by barn.

Results

The average 15 week pen scores for fecal accumulation in the high, moderate, and low scoring barns were 1.57, 1.07, and 0.93 respectively (Table 1). Prevalence of pigs shedding *Salmonella* was 23.1% (83/360). The serotypes isolated from each barn are indicated in Table 2. Only one barn (high fecal contamination) had more than one serotype isolated. In the high fecal accumulation barn, all S. derby isolates were from pigs housed in a single pen. The number of pigs positive per pen ranged from 0-11 (Figure 1). The distribution of the number of pigs positive per pen for each barn and in clean and dirty pens are demonstrated in Figures 1 and 2 respectively. The pen prevalence for the high fecal accumulation score barn as well as for dirty pens tended to be lower than the lower scoring barns or clean pens. The number of pens positive for *Salmonella* shedding (at least one positive fecal sample) per barn and their fecal accumulation status are demonstrated in Table 3.
Overall, there was a negative association between pen high fecal accumulation score and the relative risk of a pig shedding *Salmonella*. For ease of relative risk ratio interpretation, the exposure was inverted to define the lower level of fecal accumulation as the exposure of interest. There were 56 and 27 pigs positive for *Salmonella* in “clean” and “dirty” pens respectively. Adjusted relative risk (stratified by barn, p<0.001) was 2.04 (1.45-4.39). Individual barn relative risk values were: 4.33 (1.92-9.76, p<0.05), 0.88 (0.34-2.07, p>0.05), and 3.0 (1.16-7.73, p<0.05) for the barns with the lowest, moderate and highest average pen fecal accumulation scores. Crude relative risk for a pen to have at least one pig identified as shedding *Salmonella* if a member of a clean pen was 1.33 (0.82-2.16, p=0.44).

**Discussion**

The results of this study were counterintuitive. Increased fecal accumulation, as a proxy measure of hygiene, would be expected to be associated with an increased risk of fecal shedding in swine. The impact of pen clustering effects of shedding of *Salmonella enterica* in pigs has a strong effect on the relative risk estimation when the *Salmonella* status of individual pigs is taken into consideration. The more conservative estimate based on pen *Salmonella* status (considered positive if at least one animal was shedding *Salmonella*) was equivocal, indicating that fecal accumulation in pens was not important for pen status. The low number of observations in this preliminary investigation, particularly when pen status is the outcome of interest results in a lack of power for discrimination.

Adequate hygiene is considered important for the reduction of risk of *Salmonella* shedding in swine production units. The definition of adequate hygiene is a subjective measure. This leads to difficult interpretation for risk factor analysis as well as instituting good production practices on farms. Measurement of hygiene is plagued with difficulty, from the subjectivity of the definition, to assessing over what range of defined hygiene to investigate. In recognition of the limited scope as well as the subjective interpretation of fecal accumulation, pens with extreme values were selected for determination of fecal shedding of *Salmonella* in an attempt to measure truly different levels of fecal exposure. In barns with the most extreme values for fecal accumulation, the relative risk for a pig to shed *Salmonella* was significantly increased when it was housed in a clean pen. In the moderate score barn, the relative risk was equal regardless of pen exposure. This may in part be explained in measurement of hygiene and variability, as the moderate barn had the widest range of average pen fecal accumulation scores (Table 1).

The use of average pen scores over the finishing phase of production as the measurement of hygiene may not be appropriate for *Salmonella* prevalence at the end of the finishing phase. *Salmonella* shedding at any point in time may be more strongly associated with the level of fecal accumulation that occurred at a specific time period prior as opposed to the averaged value. In this study, pen and barn status as high or low for fecal accumulation was stable over the study duration (not shown). It may be that the results of this study are a result of infection with *Salmonella* in the early finishing stage and the level of *Salmonella* shed in the feces is either absent or below the sensitivity of the diagnostic method.

In this pilot study, we chose to use fecal accumulation and therefore increased exposure to feces as a measure of hygiene. This approach was chosen for the primary reason to attempt hygiene measurement that was more narrow in scope, as opposed to more subjective components of hygiene such as general farm cleanliness. This assumes that reduction of fecal exposure is the main goal of hygiene, and that increased fecal accumulation when hygiene is poor results in increased transmission and shedding of *Salmonella*.

If we believe that hygiene is a vital concern for *Salmonella* control, it is implicit that it is also a significant risk factor that needs to be included in epidemiological studies. Despite the limited nature of this study, it brings into question the definition of hygiene and it’s role in *Salmonella* control on farms. More investigation into appropriate hygiene measures for *Salmonella* control are needed.

### Table 1. Average pen fecal accumulation scores in each barn.

<table>
<thead>
<tr>
<th>Barn Score</th>
<th>Avg. Barn Pen Score (range)</th>
<th>Avg. “dirty pen” score (range)</th>
<th>Avg. “clean pen” score (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1.57 (1.07-2.57)</td>
<td>2.20 (2.07-2.57)</td>
<td>1.11 (1.07-1.14)</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.07 (0.14-2.57)</td>
<td>2.14 (1.71-2.57)</td>
<td>0.37 (0.14-0.50)</td>
</tr>
<tr>
<td>Low</td>
<td>0.93 (0.14-2.21)</td>
<td>1.86 (1.50-2.21)</td>
<td>0.23 (0.14-0.43)</td>
</tr>
<tr>
<td>Total</td>
<td>1.19 (0.14-2.57)</td>
<td>2.07 (1.50-2.57)</td>
<td>0.57 (0.14-1.14)</td>
</tr>
</tbody>
</table>

1999 ISECSP: Production Epidemiology 127
Table 2. Prevalence and serotype distribution in each barn.

<table>
<thead>
<tr>
<th>Barn</th>
<th># pigs positive (%)</th>
<th>Serotype distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>20 (16.7)</td>
<td>10 derby (50), 8 typhimurium copenhagen (20), 1 seftenberg (10), 1 london (10)</td>
</tr>
<tr>
<td>Moderate</td>
<td>30 (25)</td>
<td>30 typhimurium copenhagen (100)</td>
</tr>
<tr>
<td>Low</td>
<td>33 (27.5)</td>
<td>33 typhimurium copenhagen (100)</td>
</tr>
</tbody>
</table>

Figure 1. Frequency distribution of number of positive animals per pen in each barn.

![Frequency distribution of number of positive animals per pen in each barn](image)

Figure 2. Number of pigs positive per pen based on pen fecal accumulation status.

![Number of pigs positive per pen based on pen fecal accumulation status](image)
Figure 3. Farm A Cohort 2: Serotype distribution at each sampling period.

Figure 4. Farm B Cohort 1: Prevalence at each sampling period.
Figure 5. Farm B Cohort 1: Serotype distribution at each sampling period

References


