Risk Factors Associated with Shedding of Salmonella by U.S. Finishing Hogs

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**Introduction**

Salmonellosis has long been considered an important food-borne pathogen since being isolated in 1885 by Dr Daniel Salmon, Chief of USDA’s Bureau of Animal Industry. Non-typhoid Salmonella was recognized in the 1940’s as the most common cause of food poisoning due to bacteria. (9) Some of the more frequent Salmonella serotypes associated with food-borne illness include *S. enteritidis*, *S. heidelberg*, *S. newport*, *S. infantis*, *S. mbandaka*, and *S. agona*. (5) The potential for severe food-borne Salmonella outbreaks attributed to pork is evident in the Swedish epidemic which affected more than nine thousand people in 1954. (12)

It was during the 1950’s that a worldwide interest in Salmonellae ensued and many researchers documented an apparent rise of salmonellosis in people. (7) In the 1960’s, Salmonellosis in humans was considered to be the most common food-borne illness. The National Research Council of the National Academy of Sciences (NAS) convened a Committee on Salmonella in 1969 to conduct “a thorough analysis of the causes and the means of preventing salmonellosis.” (4) Almost three decades later, Salmonellosis is still considered to be one of the most frequent food-borne illnesses and is estimated to have the largest economic impact on the US public of all food-borne pathogens. (3, 4)

Salmonellosis clearly is a perplexing problem that has challenged researchers and public health officials for decades and the complex ecology of the organism has hampered the identification of a simple means for effective control. Renewed interest in the role of pork in food-borne salmonellosis has been galvanized by the confluence of several recent trends, including increase public concern over microbiological food hazards, the industrialization of the US pork industry, and expanded trade of pork and pork products. (2)

The USDA’s National Animal Health Monitoring System (NAHMS) conducted a national study of swine health and management in the top 16 swine states, which contain nearly 91% of the U.S. hog inventory. (1) A primary objective was to generate information regarding the presence of Salmonella on the farm by describing shedding patterns and identifying on-farm factors that may be useful in the control of Salmonella on the farm. This paper presents the final logistic regression model containing the most salient variables associated with the shedding of Salmonella by finishing hogs in the United States. The ultimate goal is to contribute to the body of knowledge for reducing the risk of food borne illness due to the consumption of contaminated pork.

**Methods**

The full design of the NAHMS Swine ‘95 study has been presented elsewhere. (8) Of the 418 producers participating in the NAHMS Grower/Finisher study, 160 were conveniently selected to contribute 50 fecal samples for isolation of Salmonella. The 25 gram fecal samples were collected from the floor of pens containing late finisher hogs and sent to USDA’s National Veterinary Services Laboratories (NVSL) and National Animal Disease Center (NADC) for isolation and serotyping. (6)

Samples were collected on one of two visits made during a 10 week window beginning July 17 and November 6, 1995. Questionnaires were completed on each visit to provide additional health and management data and to capture data related to the collection of feed and fecal samples. Data was entered, validated, and analyzed using the SAS program. (10)

The outcome evaluated in this analysis was the Salmonella status of the farm determined by the presence of at least one Salmonella positive fecal sample. Univariate comparisons were made between the outcome variable and selected management variables. Associations with a p value <0.25 passed the screening phase into the second analysis phase (multivariate analysis) for development of the logistic regression model.

The transmission of Salmonella among animals and humans is extremely complex and highly variable. Thus, it is not surprising to find a diverse list of factors in the literature postulated to affect shedding of Salmonella on the farm (Table 1). These risk factors can be grouped into five major areas: feed, general farm characteristics, hog management, sanitation / biosecurity / waste management, and other health conditions.
Table 1: List of potential risk factors for Salmonella spp in swine.

**Animal Feed**
- heat treatment of feeds, e.g. pelleting; extrusion
- good feeding practices (clean)
- animal protein in feed
- many dietary changes, e.g. phase feeding

**General farm characteristics**
- season
- herd size
- ventilation
- confinement
- flooring
- exclusion of visitors
- use of veterinarian

**Sanitation / biosecurity**
- rodent control
- exposure to dog, cat, wildlife
- general farm hygiene
- isolation of new stock
- purchased replacement breeding females
- cleaning & disinfection of pens

**Hog management**
- pen density
- use of antibiotics
- use of subtherapeutic antibiotics
- AI/AO
- SEW
- MBW
- age of pig
- size variation in pen

**Health**
- vaccination for Salmonella
- coinfection with PRV, APP, or PRRS

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**Results**

A total of 6655 samples were collected from 988 pens on 152 operations. At least one positive sample was found on 58 operations (38%) and a total of 414 serotypes were isolated from 398 samples (6%). More than 60% of the positive operations had two or more pens that were positive (Table 2).

Table 2: Number of farms by the percent of pens on farm with at least one positive fecal sample for Salmonella.

<table>
<thead>
<tr>
<th>Percent of pens positive</th>
<th>Number of farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>94</td>
</tr>
<tr>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

Of the more than 2400 serotypes of Salmonella that exist, the 10 most frequent serotypes shed by finish hogs accounted for 85% of the isolates found in this study. Some of the more frequent serotypes isolated from swine are *S. derby, S. agona, S. typhimurium copenhagen, S. brandenburg*, and *S. mbandaka*.

The final model is presented in Table 3. Two of the variables in the final model were related to feed characteristics. An operation that does not mix the finisher diet on the farm was 2.5 times more likely to be positive than an operation that mixed the finisher diet on the farm. Those operations feeding a non-meal finisher diet had a 26-fold increase in risk of being positive compared to those operations feeding a meal finisher diet.

When putting together a load of pigs to send to the market, a producer may or may not empty an entire pen or building. The risk of being positive was 2.5 times greater for those producers that market all animals in a pen or building compared to those who never do. Producers which culled

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Table 3: NAHMS Swine '95 variables in the final logistic regression model.

<table>
<thead>
<tr>
<th>Factor (comparison level)</th>
<th>Level</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix finisher diet on farm (yes)</td>
<td>No</td>
<td>2.5</td>
</tr>
<tr>
<td>All out finisher (never)</td>
<td>Some, most, all</td>
<td>2.5</td>
</tr>
<tr>
<td>Percent culled for respiratory (0)</td>
<td>0.01 - 0.25</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.25</td>
<td>0.2</td>
</tr>
<tr>
<td>Pen type re: sex of finishers (only mixed sex pens)</td>
<td>Only single sex pens</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Both types of pens</td>
<td>5.4</td>
</tr>
<tr>
<td>Region (Southeast)</td>
<td>Northeasteral</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Midwest</td>
<td>0.2</td>
</tr>
<tr>
<td>Meal finisher diet (yes)</td>
<td>No</td>
<td>26.4</td>
</tr>
</tbody>
</table>
pigs prior to slaughter for respiratory problems were less likely to be positive. Compared to those producers which culled no pigs for respiratory problems, when 1-25% and more than 25% of the culled pigs were due to respiratory problems the risk of being positive was reduced by 1/3 and 1/5 respectively.

Those operations in the Southeast\(^1\) were 5 times more likely to be positive than operations in Midwest\(^2\) and Northcentral\(^3\) states. Finisher pens were classified as containing either all gilts, all barrows, or mixed. Operations which had only single sex pens were 2.8 times more likely to be positive than operations with all mixed sex pens.

While farms with single sex pens were at higher risk of being classified as Salmonella positive, the highest risk category was for farms with both single sex and mixed sex pens. In addition to the possible effect of split sex feeding itself, the adverse impact on the gut environment may arise from increase sorting of pigs on farms with single-sex pens. This sorting may be more dramatic on operations with both single-sex and mixed-sex pens.

This study generates several possible factors associated with the shedding of Salmonella by finishing hogs. Further studies should be conducted to confirm these findings and further elucidate the specific mechanisms.

**Discussion**

The operation, specifically the finisher barn, was used as the unit of analysis for this study. Salmonella was isolated from more than one third of the farms tested and 62% of the positive farms had two or more positive pens. However, Salmonella is probably shed infrequently as only 6% of the samples were positive.

Risk factors for clinical Salmonellosis in pigs include exposure to contaminated rodents, feed, pigs, and stressors such as transport and high animal density. (13) In this study, risk factors for shedding of non-clinical Salmonella serotypes are generally related to the gut environment. The strongest association with farm Salmonella status was with finisher feed form; non-meal feed being of higher risk. While the pelleting process is thought to eliminate Salmonella from feed, this does not preclude recontamination of pellets or prohibit their influence on the likelihood of a pig shedding Salmonella already present in the gut.

A separate but significant effect was seen by the use of feed mixed off farm. This may reflect differences in the byproducts used, processing techniques (e.g. expanded feeds), or increase risk of contamination associated with trucking of feed.

Salmonella is a secondary pathogen to respiratory disease. There appears to be a protective effect for producers which culled a large proportion of grower/finisher pigs for respiratory problems. This may be attributed to a reduction in the number of “high-risk animals” regarding Salmonella infection. The risk associated with all-out movement of finishers is unexplained and may represent confounding or random error in the data analysis.

The greater likelihood of Southeast farms being positive may be due to climatic or environmental factors or a surrogate measure of differences in management practices such as waste collection (e.g. flush systems versus deep pit) and herd size.

1 Missouri, Kentucky, Tennessee, North Carolina, Georgia  
2 South Dakota, Nebraska, Kansas, Minnesota, Iowa, Illinois  
3 Wisconsin, Michigan, Indiana, Ohio, Pennsylvania

**References**


