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Ruth Cronje, and Jan Swanson;
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Sarah Summerbell

# Lairage is a hazard for *Salmonella* infection in market swine

H. Scott. Hurd DVM, PhD[1]; J.D. McKean DVM, JD[2]; R.W. Griffith DVM, PhD[2]; M.H. Rostagno DVM, PhD[3]

1National Animal Disease Center, ARS, USDA, Ames, IA; 2College of Veterinary Medicine, Iowa State University, Ames, IA; 3Present address: Federal University of Lavras, Minas Gerais, Brazil

The pork industry is concerned about *Salmonella* contamination in pork. As one packing company executive stated, "The food safety issue is a matter of life and death for our industry . . . Food safety must come first, above all other issues, including productivity and profitability." However, the industry still needs proven control methods. Pork plants have the lowest HACCP compliance rates, lower than poultry, ground beef, or cow and bull products (FSIS 2000). For small plants, only 47% of carcass sample sets collected in 1999 met the current standard of 8.7% *Salmonella* prevalence. Producers also recognize the importance of reducing *Salmonella*, but are limited by lack of clear interventions steps.

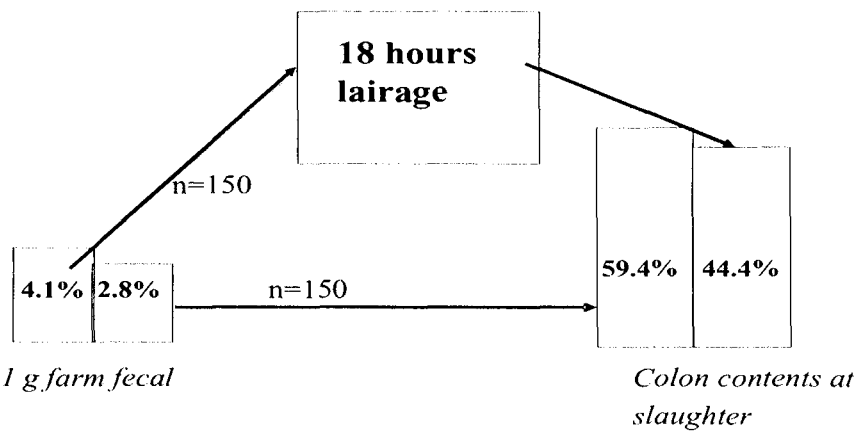
Many researchers have reported a higher *Salmonella* prevalence for pigs tested at slaughter, compared to when they are tested on-farm (Morgan et al., 1987; Berends et al., 1997). Virtually all pigs must be transported and most are held for at least two hours after transport to improve meat quality (Berg 1999). Considerable evidence is accumulating that much *Salmonella* infection is occurring in these last few hours of life. The antemortem holding pens appear to be the primary source of this preharvest infection. This report will summarize the accumulated evidence that lairage, as currently practiced in the USA, is a significant *Salmonella* hazard.

## No direct effect of stress

The stress of transport has been suggested as a reason for increased *S. enterica* shedding from farm to market. The physiological changes associated with stress might encourage the recrudescence of latent carriers or it might increase the susceptibility of noncarriers to new infection. However, no studies have demonstrated a direct increase in *S. enterica* shedding or infection attributable to these physiological changes.

In support of this hypothesis, we demonstrated no difference between directly shipped pigs and those stressed by mixing, fasting, and 18 hours lairage in a clean disinfected facility (Hurd et al. 2001a). After transport and 2 hours holding at the abattoir, control (farm-direct) animals had higher isolation rates than did pigs held for 18 hours, transported, and held 2 hours (78.3% versus 65.2%). Figure 1 compares fecal and colon isolation rates for direct shipped and lairaged (18 hours) animals. Only 3.4% of these pigs were positive by fecal culture on-farm. A single *Salmonella enterica* serotype (Derby) was identified on-farm over the 10 week study period. However, less than 24 hours later, 71% of these pigs were positive when culturing various slaughter samples. Additionally, 17 different serotypes were identified over the 10 week study period. Interestingly, the predominant serotype varied weekly through the 10 sampling weeks (Agona and Anatum, week

Figure 1. Comparison of *Salmonella* isolation rates for pigs shipped directly to slaughter with those fasted and held for 18 hours in a clean, disinfected facility



1; Derby, week 2; Typhimurium, weeks 3 and 6; Manhattan, week 8; Uganda, week 9).

This field study utilized 300 market swine from a single pork-production facility. Thirty pigs were tested at the production site during each of the 10 sampling periods. Half of tested pigs were moved to a clean and disinfected holding facility for ~18 hours before both groups were transported to a commercial high-capacity (16,000 head/day) abattoir. After slaughter, carcass swabs, ventral thoracic and subiliac lymph nodes, and various intestinal tissue samples were cultured for *Salmonella.*

## Evidence for a non-farm source of infection

To standardize the samples collected on-farm and at the abattoir, we conducted another study and found more evidence that the holding pens were a significant source of *Salmonella* infection (McKean *et al.* 2001; Hurd et al., 2002). As with the lairage study, the number of different serotypes isolated was much higher for those samples collected at the abattoir (n=17) compared to the farm (n=8). More serotypes were isolated from pigs necropsied at the abattoir than were found in pigs necropsied on-farm, even though the same tissues were collected at both locations.

For abattoir necropsied pigs, the average *Salmonella* prevalence was seven times (39.9%) higher than on-farm collected samples (5.3%) ($P<.001$). Figure 2 compares isolation rates for on-farm and abattoir collected samples by sample type (fecal, cecal contents, lymph nodes).

We conducted this study using six Iowa herds enrolled in the Accelerated Pseudorabies Eradication Program (APEP). Market pigs (pen-mates) were randomly assigned 48 hours before depopulation to be necropsied either on the farm of origin or at the abattoir, after transport in disinfected trailers and 2–3 hours holding. The same samples (1g feces, ileocecal lymph node, cecal content, superficial inguinal lymph node) were collected at both locations. Abattoir-collected samples were obtained, before entry on to the kill floor, by the same necropsy methods as used on-farm.

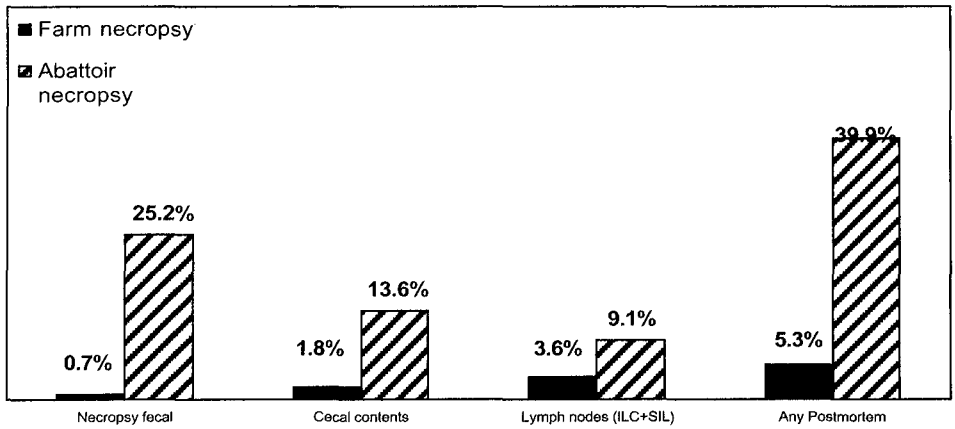
## Rapid infection is possible

Previous studies pointed to the possibility of rapid infection after pigs left the farm. To determine if rapid infection—via oral exposure—was feasible, we conducted two experiments at the USDA National Animal Disease Center. The first experiment demonstrated that market swine can become infected in the ileocecal lymph nodes and gastrointestinal tract after only 2 hours of exposure to a *Salmonella*-contaminated floor (80% positive) (Hurd et al. 2001b). A follow-up study showed that intestinal contamination, without lymph node invasion, can occur 30 and 60 minutes after exposure (50% positive) (Hurd et al. 2001c).

Most (80%) of the animals necropsied after 2 hours' exposure were positive for the marked strain. After 3 hours, 60% of the pigs were positive. One pig even had a positive mandibular lymph node. After 6 hours, all (100%) of the animals had at least one tissue sample test positive. At 30 and 60 minutes, 50% of the necropsied pigs were culture-positive in the cecum, ileum, or rectum. Compared to other experimental inoculation studies, the exposure dose of *Salmonella* was relatively low, 1.5 X $10^3$ CFU/gram of feces.

These experiments were designed to simulate the exposure at the antemortem holding pen. Crossbred market weight swine (~92kg) were exposed to feces containing a marked (nalidixic acid-resistant) strain of *Salmonella enterica* Typhimurium. The contaminated feces were deposited on the floor by two pigs that had been intranasally inoculated 4 days previously. These shedding pigs were then removed and *Salmonella*-negative pigs placed in the room with feces remaining from the shedders. Exposed pigs were autopsied after 2, 3, and 6 hours of exposure; 30 and 60 minutes in second experiment.

Figure 2. Percent pigs *Salmonella*-positive by sample collected at abattoir and farm necropsy



## Holding pens are *Salmonella* contaminated

In another study, we demonstrated that the holding pen environment is highly contaminated with *Salmonella* (Rostagno, et al., 2001). Similar results have been reported from the Netherlands (Swanenburg, 2001). In two typical midwestern high-capacity pork-processing plants (7,800–16,000 head/day), we isolated *Salmonella* from 100% of pens tested; 33% of waterers were *Salmonella*-positive. One half of these pens had been high-pressure washed before sample collection.

We also compared the *Salmonella* serotypes isolated from:

- the pens before study pigs were placed,
- the truck floors after shipping and unloading, and
- slaughter tissues collected from these study pigs.

Serotype diversity analysis indicates that pigs are picking up new serotypes from the pens. In the pig tissues, twenty-six percent of samples from study pigs contained *Salmonella* serotypes found only in the pens but not in the trucks, demonstrating that pens can serve as a ready infection source.

## Further evidence and future work

Preliminary analysis of a recently completed study in cull sows showed that time spent in holding pens increased *Salmonella* prevalence, regardless of transport. In this study sows were collected from a buying station, transported 6–8 hours, and randomly assigned to immediate harvest or 2 hours' wait in the holding pen before harvest. *Salmonella* was isolated from 57% of sows held in the pens compared to 43% not held in the pen ($P<.05$).

Future work will compare holding and no-holding in market pigs. These results will be presented at the meeting.

This summary presents reasonable evidence that lairage (holding), as currently practiced in the USA (and most of the developed world), is a significant hazard for *Salmonella* infection and contamination in pork. This research presents new possibilities for control. Effective reduction of *Salmonella* at the antemortem holding pen should decrease the risk of *Salmonella* contamination at later steps in the pork production chain. Since antemortem pens are a source of *Salmonella* for all incoming swine, this potential control point must be addressed before on-farm reduction can be expected to reduce pork contamination.

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