

CONTROL OF SALMONELLA IN THE PORK PRODUCTION CHAIN

Julie Funk, DVM, MS, PhD
Associate Professor, Large Animal Clinical Sciences
Director, Online Professional Master of Science in Food Safety
Michigan State University
B51A Food Safety & Toxicology Building
East Lansing, Michigan, 48824
E-mail: funkj@cvm.msu.edu

ABSTRACT

Salmonella remains an important foodborne pathogen of concern to public health and therefore, the swine industry. Significant strides have been made at decreasing *Salmonella* contamination in one link of the pork chain, namely, at slaughter and processing. It is expected that standards at slaughter and processing will become more stringent, creating pressure from packers and processors to reduce prevalence of *Salmonella*-positive swine through on-farm interventions. In spite of the widely acknowledged value of controlling *Salmonella* in the live animal reservoir, and copious research endeavors, there is still much to learn about the control of *Salmonella* pre-harvest, as well as discerning the most cost-effective approaches to approaching control in the pork chain. This presentation is focused predominantly on on-farm interventions, as well as discussion of the needs for further information on cost-effective interventions across the pork chain.

INTRODUCTION

Salmonellosis remains a major foodborne disease threat to public health. In the United States, during 1998-2002, *Salmonella* represented the most commonly reported bacterial cause of foodborne outbreaks and illnesses, as well as the second largest etiologic cause of death among bacterial foodborne pathogens (Anonymous, 2006). Although significant strides have been made in reducing the incidence of bacterial foodborne illnesses (*Campylobacter*, *Yersinia enterocolitica* and Shiga Toxigenic *Escherichia coli*) with reductions of ~20-50% relative to 1996-1998 rates, incidence of human salmonellosis has had a modest decrease of only 9% in that same period in the US (Anonymous, 2006). In Canada, the number of reported cases of *Salmonella* for 2004 was 4,953, which represents a decrease from 1998 of more than 50%, but *Salmonella* remains the second most common bacterial foodborne pathogen after *Campylobacter* for those of which swine serve as a reservoir. There is a need to further pursue effective interventions for salmonellosis.

Significant strides have been made at decreasing *Salmonella* contamination in one link of the pork chain, namely, at slaughter and processing. The Pathogen Reduction: Hazard Analysis and Critical Control Point (HACCP) System in the US established performance standards at slaughter and processing plants, which has resulted in decreased contamination of product with salmonellae. It is expected that standards at slaughter and processing will become more

stringent, creating pressure from packers and processors to reduce prevalence of *Salmonella*-positive swine through on-farm interventions.

In spite of the widely acknowledged value of controlling *Salmonella* in the live animal reservoir, and copious research endeavors, there has been little progress in identifying cost-effective interventions for *Salmonella* pre-harvest. Of the potential interventions that have shown evidence of consistent effects in both observational and experimental studies, they predominantly require the producer to incur costs without identifiable direct economic incentive. In addition to effectiveness, there is a real need to identify cost-effectiveness of interventions across all phases of the farm to fork continuum. It is certain that there will be no magic bullet for *Salmonella* control, but an integrated approach that hopefully will result in cost-effective reduction throughout the chain.

POTENTIAL CONTROL POINTS IN THE PORK CHAIN

Humans and Other Animals as Vectors

Biosecurity related practices regarding swine farm personnel and visitors have been associated with decreased *Salmonella* risk for swine. Researchers have found that hand washing and access to toilets and hand washing facilities and the presence of spaces where clothes and footwear could be changed prior to entry into pig areas were associated with reduced *Salmonella* seroprevalence in Danish market swine but were not identified as being associated with *Salmonella* seroprevalence in Dutch herds. It has also been reported that herds with relatively more humans on site daily were at increased risk having high *Salmonella* fecal shedding. Recently, Rajić et al. (2006) reported the unusual finding where if boots were disinfected prior to entry, there was a decreased prevalence of *Salmonella* as compared to facilities in which boots and coveralls were provided—unexpectedly—farms that require shower-in/shower-out procedures were at an increased risk to shed *Salmonella* as compared to farms where boots were provided. These counter-intuitive results are not uncommon in the evaluation of hygiene on farms. Nonetheless, whether personnel hygienic practices are directly related to *Salmonella* risk or whether they simply serve as a proxy measure of a pork producer's overall attitude about biosecurity is unclear, but it does suggest that improved personnel hygiene may be an important intervention for the reduction of *Salmonella* levels. The relatively small cost incurred may be off-set by decreased transfer of other performance impairing pathogens.

The literature is mixed regarding the risk of other domestic species on sight, with few studies finding a positive association. Rodents, birds and invertebrate animals are all known to be potential carriers of *Salmonella*, but their actual risk posed to swine is unclear.

Environmental Contamination

Contamination of the resident environment of animal housing has been implicated in many studies as a source of *Salmonella* infection. *Salmonella* is capable of surviving at least 6 years or more in the environment, and the challenges of cleaning and disinfection of animal

housing are well documented. Mack et al. (unpublished) found that enhanced cleaning and disinfection protocols over standard protocols decreased the contamination of buildings based on aerobic plate counts—but was not associated with decreased *Salmonella* shedding by pigs at the end of the finishing phase. Mannion et al. (2007) recently reported that high prevalence farms tended to have more residual contamination of feeders and equipment after barn cleaning than low prevalence farms, suggesting more stringent cleaning would be associated with decreased prevalence.

Pig Flow

Inconsistency in the hygiene hypothesis: Pig flow practices that are well recognized as important for reduction of production impairing diseases in swine (all-in/all-out pig flow) are often suggested for *Salmonella* control, yet there are few studies that identify that this practice is associated with decreased *Salmonella* prevalence. The biological premise is that the combination of cleaning and disinfecting between groups with age group segregation decreases the potential of *Salmonella* exposure and infection. It has been described that Danish farms that had an area to change clothing and boots prior to entering or leaving the pig area in combination with all-in/all-out production were nearly three times less likely to be seropositive for *Salmonella* than farms that did not have these management practices in place. Farms that had just a changing area or all-in/all-out flow, but not both, did not have a lowered risk. On the other hand, in another study of Danish swine, all-in/all-out pig flow was associated with increased *Salmonella* seroprevalence, although this result was based on a crude odds ratio, not adjusted for other management practices on the farm. *Salmonella* prevalence can be quite high on farms with all-in/all-out production. In a study of US swine farms that were three-site production systems, managed all-in/all-out, the *Salmonella* prevalence in finishers ranged from 0% to more than 70%. A recent report by Rajić et al. (2007) of Alberta swine finishers reported that farrow to finish farms with finishers on-site had lower *Salmonella* prevalence than farms with multiple site production. Furthermore, there was no difference in prevalence between those farms that practiced all-in/all-out flow as compared to those that had continuous flow production. The limited and contradictory evidence in the literature for all-in/all-out pig flow as a means of *Salmonella* control warrants further investigation prior to its recommendation for that specific purpose.

Feed

It is well recognized that animal feeds and feedstuffs can be contaminated with *Salmonella*. It has been demonstrated in experimental settings that animals can become infected as a result of consuming *Salmonella* contaminated feed. There is no doubt that appropriate process control and decontamination steps are needed during feed processing to reduce contamination of feedstuffs in order to avoid dissemination of contaminated feed to herds. There is justification to question the relative importance of the role of contaminated feed in the epidemiology of *Salmonella* on swine farms. Most notably, *S. Typhimurium*, a *Salmonella* serovar often associated with food borne disease in humans is infrequently isolated from feeds in the US or elsewhere. In a multi-country survey in Europe *Salmonella* was isolated from feedstuffs in 17.6% of herds and 6.9% of all samples. Yet, the *Salmonella* serotypes isolated from the feeds were not the same serotypes isolated from pigs on those farms.

Many epidemiological studies have found that pigs fed pelleted rations were at increased risk of high *Salmonella* seroprevalence compared to those fed diets in meal form. This is one of the more consistent risk factors associated with *Salmonella* in observational studies. A recent study by Rajic et al. (2007) in Alberta swine indicated that pigs fed pelleted rations were at increased risk for shedding *Salmonella* as compared to meal diets. Additionally, diets that are acidified either as a result of the addition of whey, organic acids or are fermented have been associated with reduced *Salmonella* prevalence. Conversely, wet, but not fermented, diets have been associated with increased *Salmonella* prevalence. These results with acidification are variable.

Vaccine

A recent systematic review of the literature regarding the efficacy of vaccination to reduce *Salmonella* in live and slaughtered swine was recently published (Denagamage et al., 2007). In general, from a qualitative standpoint, vaccination is associated with reduced *Salmonella* prevalence in swine at or near slaughter. Unfortunately it also highlighted the fact that few published studies were of a quality sufficient to judge internal validity of the projects, decreasing the ability to assess the value of the intervention.

Thermal Environment

Several investigators have reported that cases of human salmonellosis are strongly associated with high ambient temperature in a period ranging from 1-5 weeks prior to the onset of the human case (Bentham and Langford, 1995, Bentham and Langford, 2001, D'Souza, et al., 2004, Fleury, et al., 2006, Kovats, et al., 2004). This suggests that “upstream” factors in the food chain are impacted by high ambient temperature resulting in an increased risk of salmonellosis. Although these upstream factors may include failure in maintaining temperature in the cold chain during processing, shipping and handling by retailers and consumers, it may also reflect risk associated with high ambient temperature on farms that results in increased risk of *Salmonella* transmission and shedding by animals. Previous work by our group and others has indicated that there is an association between season and/or environmental temperature and *Salmonella* prevalence in finishing swine (Christensen and Rudemo, 1998, Funk, et al., 2001). Recent work by our group has demonstrated that 10-12 week old pigs that are cold-stressed and market-age pigs that are heat stressed (18-22 weeks old) are at higher risk to be *Salmonella* positive (Schultz et al., 2007)

Antimicrobial Use

Most research regarding *Salmonella* shedding and antimicrobial resistance subsequent to antimicrobial therapy have been conducted in laboratory facilities involving experimental infection with *Salmonella* (reviewed by Exponent, 2000). In field investigations of the use of subtherapeutic chlortetracycline (CTC) in finishing pigs on US farms, our group has seen no effect (Funk et al., 2006) increased shedding (Funk et al., 2007) and increased shedding (Mack et al., unpublished) associated with the use of subtherapeutic CTC. Impact on shedding may be associated with the antimicrobial resistance profile of the farm's resident *Salmonella*.

Cost-Effectiveness

There is minimal data regarding evaluation of cost-efficacy of different interventions on *Salmonella* control. Goldbach and Alban (2006) Compared 4 strategies for *Salmonella* control in the Danish pork industry: hot-water decontamination of carcasses; sanitary slaughter for farms with high *Salmonella* prevalence; use of home-mixed feeds; and use of acidified feed for slaughter pigs. Only hot-water decontamination had a positive net-present value. Alban and Stärk (2005) modeled the projected impact of different interventions on *Salmonella* on carcasses. The variables with maximum effect on the *Salmonella* prevalence on the final carcass were (1) number of herds with a high prevalence of *Salmonella*, (2) singeing efficiency, (3) contamination and cross-contamination at degutting and (4) cross-contamination during handling. Interestingly, improvement in any one intervention had no effect—several interventions were necessary to achieve the largest reduction, suggesting that at least from the stand point of efficacy; both pre- and post-harvest interventions may be required to achieve decreased carcass contamination. Further efforts on efficacy and cost, as well as policy discussions on what segments bear the cost, are critical to control of *Salmonella* in the pork chain.

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** Where references are not cited, the reader is referred to the review paper by Funk and Gebreyes, 2001 for references. Copies available from the author by email request.