Food Safety Begins at the Farm

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ASL-R1512

Summary and Implications

The Hazard Analysis Critical Control Point (HACCP) system is rapidly being developed and applied for prevention of foodborne hazards in meat and meat products at slaughter and processing, and is being studied for application at production, product distribution, and marketing levels. We are identifying microbiological control points in swine production, with studies in four herds reported here. The identification of critical control points for microbiological hazards in swine production cannot be identified at the present level of research, and the terms Best Management Practices and Good Production Practices are most applicable on-farm HACCP principles at this time.

Introduction

Research and the education emanating from studies in the Food Safety Consortium are strongly HACCP based and extend from producers' farms to consumers forks. The HACCP is a foodborne hazard prevention approach focusing on physical, chemical and microbiological hazards (11). In the long trail from the farm to the fork for our meat and poultry and meat and poultry products, important hazard analyses focus on production, transport from farms, slaughter and processing, product distribution, and sales to consumers. The application of HACCP is most developed at processing levels, but HACCP principles are being studied for application throughout the food chain (4,11).

Physical hazards may enter the food chain anywhere from farm to fork. Those that enter at the farm, including broken injection needles, shotgun pellets, breaks in bones, and slivers of wood, metal, or glass can be prevented only at production level. Chemical hazards enter our foods almost exclusively during production. The important focus on preventing animal drug, including antibiotic, residues, agricultural chemical residues, and pest control poisons in meat and meat products, must be during production. Microbiological hazards enter the food chain along its entire length. Major microbiological hazards in meats and meat products include foodborne parasites, mycotic and bacterial toxins, pathogenic bacteria from infected/carrier animals, environmental bacteria, and human source bacteria.

The microbiological hazards of importance in animal production include pathogens in four categories. Category 1 includes pathogens that enter the food chain only in living animals. If not present in animals from the farm, these pathogens, including *Trichinella spiralis, Toxoplasma gondii,* and *Cysticercus* cysts of *Taenia* spp. will not be present in meat. Category 2 includes pathogens that enter the food chain in living animals but also may multiply on meat and may cross-contaminate products. If the animals entering processing were all free of these pathogens, including *Yersinia enterocolitica,* enterotoxigenic *Escherichia coli,* zoonotic *Salmonella* spp., and *Campylobacter jejuni/coli* (this last species contaminates but does not multiply on meat), they would not be in the food chain. Category 3 includes pathogens that thrive in the environment, including *Listeria monocytogenes* and *Clostridium perfringens*; that enter the food chain wherever environmental contamination may occur. Category 4 pathogens are carried by animal and product handlers from producers through food servers who serve as sources of contamination, as occurs with *Staphylococcus aureus*.

The prevalence of foodborne pathogens in and on living animals at production level are beginning to be intensively investigated. This report focuses principally on *Salmonella* spp. with preliminary assessments of other potentially foodborne pathogenic bacteria in swine. Principal data were gained in longitudinal studies of eight swine farms, plus related published reports providing data at production level (1).

Materials and Methods

An average of 34 finishing swine was sampled monthly on eight midwestern farms over a 1 year period. Sera were tested using the mix-ELISA (10). Fresh fecal samples (minimum 1 g) were cultured for *Salmonella* spp. with typing by National Veterinary Services Laboratory.

Results and Discussion

Twenty-seven percent of the individual swine and 65% of the test groups had seroprevalence of *Salmonella* antibodies greater than 10%. Three of these herds that were further culture assayed for *Salmonella* spp. in mesenteric lymph nodes collected at slaughter identified direct association of serological and cultural prevalence. The predominant serotypes identified were *S. derby* (20%), *S. heidelberg* (12%), *S. anatum* (5%), *S. typhimurium* (4%), and S. *choleraesuis* (4%) (1).

In the Swine Grower/Finisher National Animal Health Monitoring System (NAHMS) 1995 Swine Grower/Finisher Survey, *Salmonella* spp. were cultured from 398 (6%) of 6,655 fecal samples from 152 herds. The predominant serotypes identified were *S. derby, S. typhimurium, S. typhimurium Copenhagen, S. agona, S. brandenburg, S. mbandaka, and S. heidelberg* (5).

The predominant serotypes of *Salmonella* reported among 3,632 total isolates by National Veterinary Services Laboratory (NVSL), which also included *S. choleraesuis*, in FY1996, are similar to these studies. The eight most prevalent serotypes reported from swine were *S. derby, S. typhimurium, S. typhimurium Copenhagen, S. choleraesuis* and *S choleraesuis* var Kunzendorf*, S. anatum, S. mbandaka*, and *S. schwartzengrund* (7).

The six most prevalent *Salmonella* serotypes reported in human isolates by the Centers for Disease Control and Prevention (CDC) are zoonotic foodborne types, including *S. typhimurium*, *S. enteritidis*, *S. heidelberg*, *S. hadar*, *S. montevideo, and S. agona*. The three that are most prevalent in swine among animal sources, *S. typhimurium, S. heidelberg,* and *S. agona*, were all prominent in the studies we are reporting, as well as in the NAHMS and NVSL reports (2).

Multiple *Salmonella* serotypes are frequently cultured from swine in the same herds. In studies in four herds reported here, 3, 3, 7, and 6 serotypes, respectively, were identified (1,6). In the NAHMS survey, 32.8% of the 152 test herds yielded 2–6 serotypes (5).

Control points (CPs) are beginning to be identified for hazards at production level. In swine production, progress in hazard analysis and control for physical and chemical hazards are identifying management/production practices that fulfill requirements for critical control points (CCPs). For foodborne microbiological hazards the pathogenesis of live animalClive pathogen complex environmental interactions are limiting us to identification of CPs and may lead our continuing emphasis to best management/good production practices that achieve pathogen reduction but not pathogen elimination.

In the hazard analyse of pathogenic bacteria in feeds on swine farms, one reported study identified 2.8% of 1,264 feed and feed ingredient samples as contaminated with *Salmonella*, including *S. worthington*, *S. agona, S. anatum*, *S. montevideo, S. senftenberg, S. arkansas, S. infantis, S. orion, S. mbandaka, S. kentucky* and *S. oranienberg* (9). In studies currently being developed, 54 swine feed samples cultured so far have yielded *L. monocytogenes* in 30%, C. *perfringens* in 9%, and *S. aureus* in 2%, but no *Y. enterocolitica*. Control points being identified for *Salmonella* reduction in swine feeds include on-farm milling and storage of feeds, fineness of grind or pelleting of feeds, and incorporation of specific acids or non-starch polysaccharides into the feeds (1,9). Identification and characterization of maintenance of specific S*almonella* serotypes as CPs in swine feeds merit investigation.

Weaning practices may emerge as CPs for microbiological hazard control. In studies of four herds reported here, physical removal of weaned pigs from infected sows interrupted transmission of *Salmonella*. Not yet identified are the roles of maternal antibodies, segregated early weaning, sanitation, and the prospect that interruption of early transmission enhances later infection in the grower/finisher hogs (1).

Type of nursery is identifiable as a CP. In the eight-farm study, pigs reared in isolated nurseries had 44% lower seroprevalence for *Salmonella* in the nursery. This lower prevalence continued to market weight, providing some evidence for continued benefit for early interruption of transmission (1).

Pig flow management, including (a) all-in, all-out movement of pigs from (b) single farrowing or (c) nursery units with (d) rapid filling into (e) separated nursery or (f) grow/finish units are being identified as CPs. In six of the eight herds in this study, specific comparisons could be made that identified a 1.4 odds ratio for all-in, all-out movement of nursery pigs into grow/finish units, and a 12.8 odds ratio for transfer of pigs from single nursery sources to fill grow/finish units within 3 days (1).

The chronicity of infections by different serotypes of *Salmonella* merits study as a CP. Three reported studies have indicated that *S. typhimurium* and *S. newport* persist in carrier swine all the way to market, whereas *S. heidelberg* carrier states in swine may be transient (12,13).

Cyclical or seasonal patterns of *Salmonella* infections in swine merit study as CPs. In the eight-herd, 12-month study reported here, the mean *Salmonella* seroprevalence in finishing hogs was 2.9-fold higher for June through December than for January through May (1). In individual herds in the study, four showed seroprevalence averaging greater than or equal to 4.8-fold above the mean, one between February and March, one between August and October, one between April and July, and one during August and September. Three of these herds showed stable *Salmonella* seroprevalence below 10%. One herd showed a declining seroprevalence over a 5 month period, January through May (1).

The environmental fate of potential foodborne pathogens in water and waste water as CPs merits extensive investigation. In the eight-farm study reported here, grow/finish swine in units with recycled lagoon water flushing under slats had higher *Salmonella* seroprevalence than those in units using fresh water (1). In another reported study in which recycled lagoon water flushing open gutters was used, *Salmonella* seroprevalence was higher than where fresh water flushes were (3). In an anaerobic lagoon study that we conducted using diffusion chambers that could be filled with effluent from the lagoon, contaminated with study microorganisms, immersed at selected depths in the lagoon, and monitored for the fate of the experimental organisms, *S. typhimurium* was rapidly inactivated by active lagoon flora, but when pasteurized lagoon effluent was placed in the chambers, the introduced *Salmonella* multiplied by 5 $\log_{10}$.

In the eight-herd study, prompt removal of dead pigs from units was identified as a CP, with increased *Salmonella* seroprevalence in herds on farms where dead pigs were not removed daily (1).

Control of flies, birds, and rodents in swine production units merits intensive investigation as S*almonella* CPs. In two reported studies, serotypes of *Salmonella* found in swine were isolated from flies and rodents on the same premises.

Vaccination of swine against foodborne pathogens merits study as CPs for reduction of those pathogens for which vaccines are available. Finishing swine in one herd reported here vaccinated with attenuated live *Salmonella* vaccine SC54 14 days after placement yielded fewer isolates of *Salmonella* B and C1 serogroups on culture of ileocecal lymph nodes collected at slaughter than control pigs from the same herd (1).

Studies for application of HACCP principles for CPs at production level are very much in their initial stages, but preliminary investigations are showing that they have practical merit. For category 1 microbiological hazards, all CPs are on farm, including *T. spiralis* in swine, *T. gondii* in all food animal species, and *Cysticercus* spp. in cattle or swine.

For category 2 microbiological hazards, the first CPs are on farm. In addition to *Salmonella* spp. in all species, E. coli O157:H7 in ruminant species and *C. jejuni/coli* in any species are important foodborne pathogens. Preliminary serological evidence in the eight herd study indicated that seroprevalence

of *Y. enterocolitica* O:3 and *Salmonella* fluctuated together over time. For category 3 microbiological hazards, the CPs extend from farm to fork. *Listeria monocytogenes* and *C. perfringens* of environmental origin contaminate animal surfaces and pass through animal digestive tracts. This role of animals on farm in the transmission of these microbiological hazards that are very prevalent in the farm environment, including in animal feed, on the rest of the food chain is very inadequately studied. For category 4 microbiological hazards, the CPs increase as human handling occurs. Coagulase-positive *S. aureus* is prevalent through the human population, and meats and meat products are contaminated from human skin and nasal carriers. Reported studies have indicated that prevalence of *S. aureus* increases on carcasses and on meat through processing, but the role of contamination of live animals as a CP on farm, on products at consumer level is unknown.

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