

## **General Analysis of Animal/Meat Systems: Factors that Affect Food Safety Risks in these Systems**

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**Introduction:** Minimizing the risk to public health via the food supply requires a comprehensive approach. The production of meat and poultry follows a continuum from the farm(s) to a packer/processor and on through a distribution system prior to consumption by the public. At each of these steps there is the potential for introduction of food safety hazards, and interventions need to be tailored to the steps where they will be most effective. These steps will vary between hazards, so the assessment of hazard introduction needs to be tailored for each specific hazard within each specific commodity.

**Types of Hazards:** Food safety hazards can be classified in four general categories. These categories include physical hazards, toxins, parasitic pathogens, and microbial pathogens (bacterial and viral). Each of these hazards needs to be considered separately when assessing food safety risks or when designing a food safety intervention program.

For the purpose of this paper I will divide the food chain into three segments: pre-harvest, peri-harvest and post-harvest.

### **Definitions:**

**Pre-Harvest:** Pre-harvest includes the time in an animal's life from birth to loading onto transport to the packing plant.

**Peri-harvest:** Accounts for the time after an animal leaves the farm up to and including stunning.

**Post-Harvest:** From the time following stunning until consumption of the product. Includes in-plant and distribution processes.

**Overview of the Food System – Pork Example:** During the past 3 decades pork production has changed significantly from small producers raising pigs on a single site, from farrow (birth) to finish (market hog), in unconfined or partially confined facilities to larger, more specialized producers raising pigs in confinement. In 1988 producers marketing 5000 or more animals per year had a 7% market share while in 2000 that market share had risen to 51%<sup>1</sup>.

Most large producers utilize what is referred to as multi-site production. This system was designed to protect animal health and minimize labor needs. An excellent review of the evolution of multi-site production by Dr. Hank Harris is

available from Iowa State University Press. I will outline a typical example of a multi-site system to illustrate the points in the food system where risks occur or interventions could be applied.

In all stages of multi-site production biosecurity is emphasized. Many operations require that people entering the facilities shower and change into barn specific clothing and footwear. Others may also require “downtime” between the last contact with other pigs and entry into a facility.

In multi-site production the breeding herd is kept at a separate location from the market animals. Many producers acquire their gilts (females that have not yet had a litter of pigs) from a genetics supplier. Most producers practice artificial insemination, thus the only boars kept on the farm would be for estrus detection. Gilts may be acquired as either newly weaned animals or when they approach breeding age. Gilts typically go through an isolation and acclimation period prior to entry into the breeding herd. After breeding, females would be housed in a gestation barn. Just prior to parturition, the animals are moved as a group into a farrowing room. This room will be managed in an all-in-all-out manner, which means that all the animals will enter the room on the same day and leave the room on the same day. No new animals will be introduced until the room is completely emptied, washed and disinfected.

Weaning of the young pig usually occurs at around three weeks of age. This allows the pigs to be weaned while they still have some protective passive immunity from the sow. It is desirable to have a very tight range of weaning ages, as an example 18-21 days of age would be considered a typical range. The pigs are assembled as a cohort and moved to a nursery. The nursery in multi-site production is often at a geographically removed location. Ideally the nursery will be filled with pigs from a single site, allowing for an age and immune-status matched cohort. The nursery is also run as an all-in-all-out facility.

The pigs stay in the nursery approximately two months, and then move as a cohort to a finishing facility. This facility will have been emptied, washed, and disinfected prior to the arrival of the pigs from the nursery. After the pigs reach market weight, the finisher may be emptied over a period of weeks to allow for marketing as individuals reach the desired weight. However, there will be no new pigs introduced until the building has been completely emptied and cleaned.

Prior to marketing feed may be withheld overnight to decrease the amount of stomach content at slaughter. Market hogs will be transported via truck, which may be owned by the producer or a contract trucker, and transported to a packing plant. Most producers have protocols for washing trucks prior to transport of the animals to the plant, in large part to prevent the truck from bringing animal health pathogens back to the farm. Pork slaughter plant daily capacity in the United States is around 380,000. At the plant, after unloading, the

pigs are kept in pens and “rested” a minimum of two hours prior to stunning. This rest period has been shown to improve meat quality.

At slaughter the pig is stunned to render it insensible, and then exsanguinated. After that the carcass moves through the process of scalding, dehairing, singeing and polishing, and on to the “clean” kill floor. Steps along the “clean” kill floor include evisceration, carcass splitting, head removal, final trimming, wash, and carcass chilling prior to fabrication. At fabrication the carcasses are cut into the muscle cuts and variety meats. Cuts are either boxed, packed into combo bins which would include meat from numerous carcasses, or packaged for case ready sales. The combo bins may be sent out to processors for further processing, or processed in-house for plants that produce ready-to-eat meats. Boxed cuts are usually distributed through a wholesaler, while case ready products would typically be distributed to a retail chain warehouse.

The final step in the process is the purchase of the meat products by the consumer, either at retail or through consumption of prepared meat at a food service establishment.

**Introduction of Hazards and Points of Intervention:** The above section demonstrated the points along the food system chain. This section will discuss the likely points of introduction of specific hazards along the chain. Some of the hazards have discrete points of entry into the food system chain, while others may enter and/or multiply throughout the entire process.

**Physical Hazards:** There are two points in the food system chain where physical hazards are likely to enter. The first is during the pre-harvest portion due to items such as broken injection needles. The second point of concern with physical hazards is at the plant with items such as machinery pieces, splinters from pallets, or other miscellaneous physical hazards. Thus, an approach which focuses on preventing introduction of physical hazards on the farm, and at the plant will cover the risk throughout the entire system.

**Residues and Toxins:** Violative drug residues occur only due to actions taken in the pre-harvest portion of the food system. Thus intervention, in this case correctly using medications and recording drug use, tracking treated animals, and observing adequate withdrawal times, during pre-harvest will protect the entire food system. Toxins, on the other hand may be more difficult to control. Using dioxin as an example, the producer may have some potential interventions to reduce levels of dioxin in animal diets. Animals raised on pasture have a greater risk of exposure to dioxins due to environmental exposure. Animal fats in the diet may also serve to recycle dioxin to new animals. However, there are also some societal issues to reduce dioxin exposures such as decreasing the types

or amounts of dioxin or dioxin like compounds substances used and limiting the burning of household refuse.

**Parasitic Pathogens:** Over the last 50 years parasitic pathogens in pork have declined dramatically. Current surveys suggest that the seroprevalence of *Trichinella spiralis* is approaching zero, and that seroprevalence of *Toxoplasma gondii* in market hogs is under 1%<sup>2</sup>. In the case of *Trichinella spiralis*, a corresponding decrease in the number of human cases of trichinellosis has also been observed. The risk factors for entry of *T. spiralis* into a herd are well understood. Many of these same risk factors apply to *T. gondii* with the additional risk factor of exposure to cat feces. The risk of water as a potential source of *T. gondii* is less well established.

Due to the fact that the risk factors for *T. spiralis* are well understood and that this is a pathogen which does not multiply post-harvest a pre-harvest control program has been established<sup>3</sup>. The only post-harvest responsibility of the Trichinae Control Program is sero-monitoring to assure compliance with the pre-harvest controls.

Many of the risks for introduction of these pathogens were removed in the move to multi-site and confinement production. However, as niche markets for meat with attributes such as raised in free-range production expand, interventions at the post-harvest level may need to be implemented to address the increased risk.

**Microbial Pathogens:** Due to the variety of microbial pathogens in animals or meat that may also be a human food safety risk, this paper will focus on two species of bacteria: *Salmonella* and *Campylobacter*. While both of these pathogens cause gastroenteritis in humans and are ubiquitous in the farm environment, there are significant differences in the epidemiology of these pathogens in the food system.

There are over 2000 distinct *Salmonella* serotypes that have been identified. Current regulatory efforts in food safety do not consider serotype, thus relegating all serotypes to equal risk. The United States Centers for Disease Control and Prevention reports on *Salmonella* isolates in the United States<sup>4</sup>. Of isolates reported in 2002 the top 20 serotypes represented 80% of all human isolates, and the top 3 serotypes accounted for 51% of human *Salmonella* cases reported. While serotypes may change position within the top 20, there have been only three new entries in to the top 20 since 1992, and two of those were in the top 27 in 1992<sup>5</sup>.

While there is some obvious correlation between serotypes found in animals and humans, there are also some obvious disconnects. As an

example, of non-clinical swine isolates *S. derby* is the leading serotype with more than twice the number of isolates as the second leading serotype, *S. typhimurium*. However, *S. derby* makes up a small proportion (0.52%) of the human isolates reported in 2002. There may be multiple explanations for this finding including that consumption patterns or cooking habits may minimize human exposure. Or, alternatively *S. derby* may be less pathogenic to humans than serotypes such as *S. typhimurium*. As we address the risk to humans throughout the food system, it may be desirable to consider serotype specific interventions and measurements.

Current regulatory efforts to control *Salmonella* also do not address the quantity of pathogen on a product. There is no data collected that would allow risk to be assessed in relationship to the amount of *Salmonella* on a product. Levels of risk likely vary by quantity and serotype, both attributes that are not currently measured in the regulatory food safety system.

Entry of *Salmonella* in the pork chain may occur at any stage, and come from a variety of inputs into the food system. Effective interventions to control *Salmonella* during the pre-harvest period are not well defined. In addition, recent studies<sup>6</sup> suggest that even groups of pigs with low pre-harvest prevalence of *Salmonella* experience increased prevalence during the peri-harvest period. Agreement between on farm pig *Salmonella* status and postslaughter carcass contamination is poorly correlated<sup>7</sup> Carcass contamination with *Salmonella* does not appear to be effected by chilling in the same manner as *Campylobacter*, and *Salmonella* have the ability to multiply on the carcass causing issues with cross-contamination. With this knowledge it may be most effective to initiate interventions during the peri- and post-harvest portions of the food system.

*Campylobacter* was the second leading bacterial cause of human gastroenteritis, after *Salmonella*, identified by the 2002 FoodNet summary<sup>8</sup> and is ubiquitous in the pork production system. Most foodborne illness is caused by the serotype *C. jejuni* while the predominant serotype found in pigs is *C. coli*. The epidemiology of *Campylobacter* within pork production systems is less well understood than that of *Salmonella*. There has been little work done to develop or validate pre-harvest intervention strategies for *Campylobacter* reduction in pork. However, it has been observed that within the plant *Campylobacter* isolations vary greatly before and after chilling, leading to the conclusion that chilling is an effective post-harvest intervention for *Campylobacter* control in pork products. This also is illustrated by the very low levels of *Campylobacter* identified on pork products in the National Antimicrobial Resistance Monitoring System (NARMS) Retail Meat studies.

Both *Salmonella* and *Campylobacter* are common in the pre-harvest pork production environment. There are seldom animal health concerns related to these pathogens (with the exception of some serotypes of *Salmonella*), and cost-effective and predictable pre-harvest interventions have not been identified. The contrast in epidemiology of *Salmonella* and *Campylobacter* in the pork chain points to the need for multiple points of intervention for entry of *Salmonella* into the pork chain during the peri-harvest and post-harvest phase with special emphasis placed on prevention of recontamination and avoidance of temperature abuse which would allow for multiplication of the organism. The experience with *Campylobacter* suggests that the chill step is a highly effective, targeted process that limits the risk of *Campylobacter* in pork. Similarities exist in the control of these pathogens, such as the need to have processes in place to limit fecal contamination of meat. One similarity that needs to be noted with both pathogens includes the unaddressed question if all serotypes of an organism present an equal human health risk.

**Food System Needs to Address Risks:** Systematic research to identify risks and develop targeted interventions that are measurable by public health outcomes is desirable. At the post-harvest level, under HACCP, control points must be verified and monitored. At the pre-harvest level, while risks may have been identified, few interventions have been verified. For those interventions that have been verified, most have been verified at the point the animal leaves the production facility, and not for the effect of this intervention on the level of contamination on the final product. To date, peri-harvest interventions have received less attention than pre- or post-harvest interventions. This systems approach is extremely difficult to achieve due to the amount of variation within and between segments of the food system.

Numerous data gaps exist through out the food system. There are few on-farm monitoring systems for foodborne pathogens. One system that has recently been developed is the Collaboration in Animal Health and Food Safety Epidemiology (CAHFSE). CAHFSE is a collaboration between the following USDA agencies: ARS, APHIS, and FSIS. The goal of the project is to monitor the prevalence of food safety pathogens, antibiotic sensitivities, and animal health pathogens of interest on farms over time. Animals from those farms will be followed to the packing to collect food safety data from final product. Currently CAHFSE is underway with 12 pork producers in each of 4 states participating in the project. Producers were selected from different types of production systems to help identify the influence of facility types and management on food safety. While this sample size will provide interesting data, a statistically significant sample of producers across all the major commodities would be desirable.

Post-harvest monitoring is largely either regulatory in nature or proprietary data. The FSIS performance standard testing data is often cited as an indication of

prevalence of pathogens. This regulatory testing scheme is not statistically designed to give either national or plant prevalence estimates. Data may exist in plants that could provide that information, but due to regulatory considerations is not made available.

A new tool that may provide some useable data is the NARMS Retail Meat survey. Although this system is designed to monitor antimicrobial resistance, by default it also determines pathogen prevalence in the samples collected. While samples are taken from retail meats, following the potential for contamination, mishandling or temperature abuse, these samples do represent the product that the consumer is purchasing. Thus, while it may not be reasonable to use this information to assess specific plants, it may be a fair representation of overall risk to the consumer.

**Summary:** This paper has described the potential types of food safety hazards in meat. The different stages of the food system were defined. Food safety hazards need to be addressed during the stage of production in which an intervention is the most effective. In the cases of parasitic pathogens, physical hazards or violative drug residues pre-harvest interventions are either the only intervention or the intervention most likely to be effective. In the case of microbial pathogens, it will be necessary to identify pathogen specific interventions to apply at targeted points through the pork chain. There are data gaps that exist on prevalence of pathogens throughout the food system, the differing levels of risk due to serotype or quantity of pathogen, and the impact of interventions on public health outcomes. These data gaps need to be considered in the context of the food system and on impact to public health.

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<sup>1</sup> Lawrence J and Grimes G. 2000 Pork Industry Structure Study.

<sup>2</sup> Swine 2000. National Animal Health Monitoring System, United States Department of Agriculture

<sup>3</sup> Trichinae Herd Certification. <http://www.aphis.usda.gov/vs/trichinae/>

<sup>4</sup> CDC *Salmonella* Annual Summary 2002. Accessed at <http://www.cdc.gov/ncidod/dbmd/phlisdata/salmonella.htm#2002>

<sup>5</sup> [http://www.cdc.gov/ncidod/dbmd/phlisdata/salmtab/2002/SalmonellaTable8\\_2002.pdf](http://www.cdc.gov/ncidod/dbmd/phlisdata/salmtab/2002/SalmonellaTable8_2002.pdf)

<sup>6</sup> Hurd, H. S., McKean, J. D., Wesley, I. V., and Karriker, L. A. (2001). The effect of lairage on *Salmonella* isolation from market swine. *J Food Prot* **64**, 939-44.

<sup>7</sup> Gebreyes W.A., Davies P.R., Turkson, P., et al. (2004). *Salmonella* enterica serovars from pigs on farms and after slaughter and validity of using bacteriologic data to define herd *Salmonella* status. *J Food Prot* **67**, 691-697.

<sup>8</sup> [http://www.cdc.gov/foodnet/annual/2002/2002executive\\_summary.pdf](http://www.cdc.gov/foodnet/annual/2002/2002executive_summary.pdf)