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# Where does contamination occur and what interventions work?

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## Introduction

Food safety is the subject of significant attention from the scientific community, regulating bodies, and consumer groups. Companies cannot afford to have a weak food safety program. A successful food safety program uses process control quality management systems, which incorporate “hurdle technology,” where multiple interventions are used to impact the environment for hazards (Jay 1992, Leistner and Rodel 1976).

## Types of contamination

Currently the most widely implemented food safety program is HACCP (Hazard Analysis Critical Control Points). Most teachings of the HACCP process reference three types of hazards or contamination: biological, physical, and chemical (Pierson and Corlett, 1992). Each step in the process is reviewed to determine if any of these three categories of hazards are present.

Biological hazards include bacterial, viral, and parasitic contaminants. Key bacterial hazards in fresh pork are *Salmonella* and generic *E. coli*, with *Campylobacter* and *Yersinia* identified as emerging organisms. *Trichinella spiralis* and *Toxoplasma gondii* are parasites that have been associated with pork. *Listeria monocytogenes* is an organism of great concern, but is considered to enter the food chain primarily from post-processing contamination in ready-to-eat products as it is readily killed by heat. Viruses such as Norwalk-like and Hepatitis may become more of a concern in the near future as methodologies for virus isolation from product evolve.

Chemical contaminants may arise from naturally occurring chemicals such as toxins or biogenic amines, or from added chemicals, which might be commonly found in a plant environment. Processors frequently rely on certifications from suppliers of live animals or plant chemicals to address issues associated with chemical contaminants. Chemical hazards associated with the plant environment must be addressed in plant control measures and considered as potential hazards in each HACCP plan.

Physical hazards are extraneous matter or foreign objects and include any physical matter not normally found in food, which may cause illness (including psychological

trauma) or injury to an individual (Pierson and Corlett, 1992). Bone, cartilage, and hypodermic needles are most common complaints from physical sources in pork.

## Sources of hazards

Other authors have addressed hazards associated with contamination on the farm and at lairage; this paper will concentrate on food safety issues at the plant. In a working food safety system, however, these issues cannot be so neatly separated and it is imperative to be aware of hazards present throughout the entire pork chain. If hazards and risks from each area are understood, then informed decisions may be made regarding where to allocate resources to ensure the provision of a safe product.

## Control and measures of contamination

It is widely agreed that a food safety management system such as HACCP is an effective tool used to affect food safety. Process control of hazards is more effective than end product testing, which is better used as a verification step (Swanson and Anderson, 2000). Implementing it with regulatory oversight has faced challenges, but is still cited as having improved food safety and reduced the presence of pathogens. FSIS has reported decreases in *Salmonella* prevalence in swine carcass swabs obtained during compliance testing and the number of positives has remained lower than in agency baseline studies and surveys conducted before HACCP implementation (Anonymous, 1999; Anonymous 2002 (a)). The differences in pre- versus post-HACCP *Salmonella* prevalence on carcasses were suggested to reflect changes owing to HACCP implementation.

Having a food safety plan such as HACCP requires extensive documentation and support. Many prerequisite programs are also a critical foundation and include:

- GMPs
- sanitation standard operating procedures (SSOPs)
- pest control
- incoming ingredients and packaging materials
- metal detection

- restricted ingredient control programs
- temperature control

Process control plans are designed to expect deviations and to guide a concrete set of actions should they occur. These generally include corrective actions—which are designed to address the deviation immediately—and preventative measures intended to prevent the deviation from reoccurring stemming from the same root cause.

Documentation of these activities is also crucial, as is the implementation of a document control program. Documents, revisions, distributions, and copies should be controlled so that the appropriate version is always available to those who must implement the program.

## Plant sources of contamination

### Hog receiving

Antibiotic residues are a hazard for which controls are available. Many plants require that producers send letters of guarantee or demonstrate participation in Pork Quality Assurance Level III (Anonymous, 2000). Some plants use rapid testing methods to verify absence of residues.

“Downer” animals have garnered attention recently owing to spongiform encephalopathies. Closer attention is being paid to these animals during antemortem inspection, particularly with respect to neurological functions. Additionally, animals are scrutinized for signs of foreign animal diseases such as food and mouth disease.

### Slaughter operations

Several excellent studies review the contribution of slaughter processes to microbial status of carcasses and meat (Gill, 1995; Dickson, 2002). Slaughter is a critical process as this is where contamination from skin or viscera may occur during dressing of carcasses. Borch et al. described the process of swine slaughter as “an open process with many opportunities for the contamination of the pork carcass with potentially pathogenic bacteria; however, it does not contain any point where hazards are completely eliminated” (1996). Bacterial contamination of carcass surfaces has been attributed to a variety of sources, including hides, intestinal content, tools and equipment, and the hands of workers (Hansson, 2001; Berends et al., 1997).

Each step in the process must be evaluated to assess risk. Research literature may be used to provide support and guidance in the evaluation of specific hazards. In some cases, studies may be required to assess a hazard or intervention fully, because it is essential to note that the hygienic effects of apparently similar processes or programs may produce significantly different results, and processes must be considered on a plant-by-plant basis (Gill et al., 2000).

Bacteria are generally regarded to be associated with the surface of carcasses and not within the deep muscle tissues (Gill, 1998). It has been reported in the literature that singeing reduces the bacterial population on the skin of swine (Hansson 2001; Borch et al., 1996), with Berends et al. reporting that scalding and singeing can result “... in virtually complete elimination of the skin contamination that existed before slaughter” (1997). However, bacteria may be introduced to the carcasses via evisceration and subsequent handling.

Key areas for contamination potential are exsanguination, evisceration, and head removal. Exsanguination or sticking is the first point at which the carcass is breached. Sticking knives must be regularly sterilized and stick wounds must be either removed from the carcass prior to the splitting of the sternum, or carefully avoided during splitting, and subsequently removed after the carcass is opened.

Evisceration includes removal of the bung, opening of the carcasses and removal of the viscera, usually to a separate stainless steel pan. The bung removal is an important step, and may greatly influence the extent of the contamination of the carcass with fecal matter (Borch et al., 1996). Several of these cuts are “blind” in that it is not possible to see if viscera are punctured or torn until after they are removed. Therefore, it is critical to keep equipment sanitized during these processes to minimize cross-contamination. Sanitation of knives and saws is generally done with 180°F water. Contamination of individual carcasses as a result of the evisceration process is addressed by interventions and controls later in the process such as steam vacuuming, trimming, carcass washes, and steam pasteurization.

### Carcass washes

A number of substances have been evaluated as additives to final carcass washes (Dickson, 1998; Dickson and Anderson 1992). Among these are hot water (Gill et al., 1995), lactic acid (Praisai et al., 1992), and other organic acids (including acetic and citric acid). Some plants are testing acidified sodium chlorite for use in carcass washes (Delmore, 2002).

In addition ozonated and electrolyzed oxidizing water (Cutter 2001) are being reviewed for washes as well for equipment sanitation. Steam pasteurization is used predominantly in beef but units are available for pork. However, discoloration of exposed muscles such as the *psaos major* is a concern (Eilert, 2001).

### Head/Offal

Biological hazards are associated with offal items, as they are comprised of the internal organs associated with the head and gut. Viscera products may include the natural flora of the animal, while various head meat components and lymph nodes may be unavoidably contaminated by

organisms associated with the mouth and gullet. The natural incidence of the high levels of bacteria present in these items is generally acknowledged, with Gill indicating, “offals have traditionally been regarded as being of intrinsically poor microbiological quality” (1998). A survey conducted by Zerby et al. indicated that while there were high levels of many pathogens in these products, some interventions are available (1998). Organic acids and various chemical and heat treatments have been applied to offal items with data indicating some interventions may prove successful (Delmore et al., 2000). However the low value of these products makes the widespread introduction of costly intervention strategies unlikely at this point.

### Chilling

Carcasses are typically chilled to <45°F and a common method is blast chilling where sub-zero temperature and high air velocities accelerate the chilling curve. The effect of this process on bacteria has been mixed. Jones et al. showed no impact of blast chilling on mesophilic bacteria (1991), however Cutter showed that either conventional chilling or blast chilling were more effective on high levels of pathogens than the low levels typically seen on pork carcasses (2000). In particular a reduction on *Campylobacter* was documented when carcasses were blast chilled.

Any bacteria that may be associated with the carcass surface will be exposed to temperatures that are conducive to growth as the carcass passes through what is considered the danger zone of 140–45°F (Anonymous, 2001). However, they are also exposed to harsh and potentially lethal stresses simultaneously. Stresses include desiccation resulting from rapid air movement associated with chilling and subsequent drying of the carcass surface, as well as temperature shock from the holding cooler environment. All of these stresses are antagonistic to the growth of bacteria and can lead to decrease in populations.

These stresses associated with chilling swine carcasses have been reported in the literature to actually reduce levels of coliforms and *E. coli* on the surfaces of swine (Gill et al., 2000). While the conditions during carcass chilling may produce temperatures that would allow for bacterial growth, rapid proliferation of bacteria is unlikely due to the harsh conditions discussed above.

However some plants still use conventional chilling, which is often supplemented by spray chilling. This presents additional challenges owing to the very wet environment and some companies have utilized acid washes as these carcasses enter the fabrication room.

### Fabrication and trim blending

With the exception of hot boning operations, internal muscle tissues are typically cooled to temperatures of 45°F

or below prior to fabrication. Gill indicates that there is no absolute hygienic need to reduce the internal temperature of all carcasses below 7°C (45°F) during carcass cooling, as deep tissues are essentially sterile (1998). However, the decrease in internal temperatures provides a meat surface which is at a temperature that will not permit significant growth of bacteria of concern should the internal meat surfaces become contaminated during the fabrication process. In addition, reducing temperatures below 45°F is a good insurance policy against possible increases in temperature during processing, and contributes to extending the shelf life of the products.

Contamination of product during fabrication and further processing may originate from carcasses or the environment. However, it has been suggested that the impact of contamination via carcasses should be limited if an effective HACCP/GMP program is implemented (Borch et al., 1996). However, our internal data show that trimmings, which are comprised of fat and lean from many different cuts and locations, may have significantly higher TPC levels and an increased incidence of pathogens. Interventions have been researched to reduce these levels (Castelo, et. al. 2001), but do not seem to be widely implemented, probably because most of this raw material goes into product that will be thermally processed.

The environment—and the sanitation of equipment and contact surfaces—has received increased scrutiny from both plant and regulatory personnel as a potential source of contamination. Hygienic monitoring of equipment using swabs or ATP bioluminescence technology to monitor presence of bacteria has become the industry standard.

### Other contributors

Additional sources of contamination of products are employees, equipment, water, air, packaging materials, and added ingredients. Pre-requisite programs outlined earlier should be in place to address these issues. Adherence to these standards should be regularly evaluated for compliance through audits and preventative actions designed to address non-compliance.

### New technologies and next steps

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The slaughter and fabrication process can be performed in such a manner as to prevent contamination and it has been argued that “assuming that the microbiological objectives have been achieved in the slaughter process, and the fabrication process is maintained at a reasonable level of hygiene, further interventions may be unnecessary (Anonymous, 2002(b)). Nevertheless, extensive research is being conducted to find and evaluate additional interventions to provide an added level of assurance. In addition, work is being done to improve the sanitation of equipment, including fabrication with bacteriostatic

constituents into the materials of belts, tools, and other devices.

Many new technologies are focused on consumer-ready products, such as ground patties and ready-to-eat products such as deli meats and frankfurters. Some examples include:

- post-packaging thermal treatments
- irradiation
- ultra high pressure processing
- new sanitizers, such as peroxyacetic acid
- chlorine dioxide, chlorine
- biological antimicrobials (e.g., bacteriocins)

It appears food safety will continue to receive significant attention from consumers, the meat industry, academicians, and regulators. To determine the best interventions, researchers are working to identify mechanisms and characteristics of pathogens in all portions of the pork chain. Companies acknowledge the need to continually improve food safety processes, and are committing the resources to implement interventions as they become available.

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