Managing Food Safety Contamination Risks in Meat Processing

Matthew Taylor, Ph.D., Associate Professor of Food Microbiology,
Texas A&M University Department of Animal Science

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Introduction

Easily missed with all of today's discussion over plant-based meat alternatives is that market appetite for "traditional" processed meat is growing significantly. Our swelling population, the increase of dual-working families with less discretionary time, faster food service and delivery mechanisms, and the sustained distribution of meat to parts of the world previously lacking access to it are just some factors contributing to a forecasted 7% worldwide growth rate of processed meat[1].

This rapid expansion of how much people buy, prepare and consume meats has naturally resulted in larger amounts of these foods passing through a single processing facility. As a result, contamination continues to enter the food supply and people are still becoming ill due to meat they ingest. Recalls and outbreaks proliferate and the regulatory boundaries governing these activities tighten. It is incumbent upon meat manufacturers, therefore, to shore up their food safety programs, paying particular attention to the hygienic breakdowns that can happen during the high-risk activity of slaughter as well as the steps that follow.

While that may seem like a daunting task, it should be noted that the processed meat industry has a legacy of inspiring positive, long-term food safety improvement that's been held up as an example to the broader food industry in the prevention of contaminated goods from reaching consumers. Take, for example, HACCP. Though first pioneered by NASA and others in the 1960s to keep astronauts healthy in space, the Hazard Analysis and Critical Control Points (HACCP) system didn't become the internationally recognized scientific approach for identifying, monitoring and correcting health hazards (like contamination) until decades later. Its industry adoption actually stems from the 1993 *E. coli* O157:H7-contaminated beef scare involving Jack in the Box fast-food franchises. That outbreak, which resulted in four deaths, 178 debilitations and hundreds of sicknesses, shook U.S. food processors and regulators, and remains one of the most powerful food safety-impacting events in history[2].

But it also inspired Jack in the Box to become the first restaurant chain to implement HACCP in all of its establishments. The franchise recognized early on that the cause of its foodborne illness outbreak, like many others to come before and after it, would not be solved, as it was unable to be detected by traditional post-mortem meat inspection. What was needed, instead, was heightened process control to prevent such occurrences by embedding specific, quantifiable interventions (safety checks of incoming products, defined cooking and storage temperatures, frequent site auditing, etc.) to meet problems when and where they might occur.

Despite what could have been the company's demise, Jack in the Box's renewed food safety system became the paradigm by which others began to benchmark. Within a few years, all USDA FSIS-inspected facilities — upstream and downstream throughout the entire supply chain — were required to maintain and submit HACCP plans to the agency for approval. Industry groups were contracted by the government to develop broad-purpose HACCP templates, such as The International Meat and Poultry HACCP Alliance's "Generic HACCP Model for Beef Slaughter[3]." By 1998, prerequisite programs such as good manufacturing practices and good hygiene practices were classified as "essential" to HACCP for their abilities to reduce food products' chances of being contaminated by the facility.

An additional area where the meat industry instigated positive change was the North American Meat Institute's (NAMI) contributions toward sanitary design.

[1] Shahbandeh, M. (n.d.) Global Meat Industry – Statistics & Facts. Retrieved from https://www.statista.com/topics/4880/global-meat-industry/
[2] Update: Multistate Outbreak of Escherichia coli 0157:H7 Infections from Hamburgers – Western United States, 1992-1993. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/00020219.htm.
[3] Generic HACCP Model for Beef Slaughter (1996, June 19). Retrieved March 1, 2020, from http://haccpalliance.org/alliance/haccpmodels/beefslaughter.pdf

Throughout the 1980s and early ’90s, meat processors were well aware that another dangerous bacterium — *Listeria monocytogenes*, which thrives in cold, moist environments and has been shown to persist in food processing environments for long periods of time — was plaguing its foods. As frustrations grew over perpetual, ineffective cleaning and sanitizing of known *Listeria* growth niches, NAMI’s now-famous 10 Sanitary Equipment Design Principles[4] were eventually created to minimize microorganism harbourage sites, eliminate pest entry into production facilities and prevent contamination of food.

The usefulness of these principles, years later, can be seen by how they’ve been repeatedly applied to food segments beyond protein. Trade groups including the Grocery Manufacturers Association (now Consumer Brands Association) and the American Institute of Baking have leveraged NAMI’s principles to adapt and adopt their own sanitary equipment procedures for use with low-moisture foods, produce items, dairy products, nuts and more.

HACCP and sanitary design remain cornerstone food safety approaches used and lauded by meat processors. Nevertheless, more attention and improvements are called for in today’s evolved marketplace. Consumers are desiring clean-label products. At the same time, they’re expressing interest in raw food delicacies. USDA FSIS is evolving and tightening its regulatory oversight. As consumption of convenience meats grows and changes, and as the microorganisms that threaten them mutate and evolve, processors must redouble their efforts to maintain sanitary production, particularly in the “hot spots” during and after slaughter where meat is most susceptible to contamination.

[4] *Sanitary Equipment Design Principles: Checklist & Glossary (2014, January). Retrieved March 1, 2020, from https://www.meatinstitute.org/ht/a/GetDocumentAction/i/97261*

From Abattoir to Zoning: Key Contamination Challenges

▸ Animal Harvest

Meat-yielding animals contain very low microbial loads in their muscle, the main component people consume. However, they carry considerable microorganisms in their gastrointestinal tracts and excrement, in their mouths and on the exterior of their bodies. From a HACCP standpoint, it’s well-established that missteps in the handling and slaughter, dressing and dissection (hide removal, evisceration, etc.) of these ruminants before their parts are fabricated into consumer cuts and products can cause major food safety dilemmas.

Placing emphasis on the activities that occur within abattoirs is not meant to understate the importance of maintaining strong sanitation practices in the receiving and holding areas that precede them. In fact, assessing the prevalence of mud and feces on incoming animals, defining procedures for higher risk animals that are older or non-ambulatory, restricting employee movement from dirty to clean areas and more are very important.

That said, after animals are humanely stunned and exsanguinated, significant attention must turn to the safe science of removing the hide and splitting edible components that will be consumed from those parts that won’t and shouldn’t be consumed. One study shows that more than 6% of slaughtered cattle hides bore the dangerous *E. coli* O157 bacterium, so it’s vital that processors at this stage not only follow hygienic hide and pelt removal practices but strategically sample their carcasses with regulatory performance standards in mind and leverage the results to determine and improve process control.[5]

As carcasses are eviscerated, viscera can release numerous, unwanted microorganisms (gram-positive bacteria such as *Listeria*, gram-negative bacteria such as *E. coli*, *Salmonella* and *Campylobacter*, and numerous yeasts and molds), which can spread, attach and adhere to other parts.

[5] *Source Tracking of Escherichia coli O157:H7 and Salmonella Contamination in the Lairage Environment at Commercial U. S. Beef Processing Plants and Identification of an Effective Intervention, Author: Arthur, Terrance M, Journal: Journal of food protection, ISSN: 0362-028X, Date: 09/01/2008, Volume: 71, Issue: 9, Page: 1752-1760*

In addition, beef processors must be intentional to remove specified risk materials like brains, eyes and spinal cords which, in the case of cattle, sometimes contain misfolding proteins that cause degenerative, fatal brain disorders.

Steps like bunging and bagging are still often manually performed today, even in highly mechanized plants. When these activities are improperly or messily managed, or when sanitary dressing is poorly applied, the contents of organs like stomachs and intestines, as well as fecal matter, easily transmit harmful adulterants.

Of course, cross-contamination is also too often introduced by surfaces within the abattoir, whether that be dirty gloves, unclean knives or other equipment. Processors can suffer if they don't frequently sanitize evisceration machinery, utensils, implements and materials, or train and manage employees' compliance with established personal hygiene practices and good manufacturing practices.

They're also vulnerable to breakdowns in routine cleaning and sanitation of the evisceration environment. Floors are among the most contaminated surfaces, yet pictures showing ground-level evisceration can easily be found all over the internet. Carcasses, no matter how heavy, must be elevated as soon as possible, certainly by the time the animal's protective cover has been opened or removed.

▸ Further Processing

Following primary processing and inspection of the carcasses post-mortem, meat processors must remain vigilant in detecting and dealing with pathogens, whether they are transient pathogens surviving on the raw food materials that travel through the facility or resident pathogens such as *Listeria* that get into the plant and grow — potentially into biofilms. Processors will also want to look for other, non-pathogenic microorganisms as well as soil residues that nourish bacteria, as they can all enter the facility through numerous ways (workers, additional ingredients, packaging, etc.) and adhere to various contact surfaces.

Environment-introduced contamination threatens meat consumers as much as contamination that may happen during initial processing, so processors will want to establish hygienic zones with room separations to buffer, for example, the raw sectors of the facility from the RTE areas. They'll then want to incorporate equipment with compatible food contact surface materials that can be easily cleaned, sanitized and accessed.

Many processors continue to employ older equipment that possesses troublesome niches where organisms can hide. Consider, for example, a conveyor that has rolled surface edges that are hard to clean, hollow rollers where dirt and water can fill, interlock-style belts with tiny closed hinge points that are tough for crews to get at, and stands and other features that make unnecessary or excessive contact with at-risk surfaces such as the ground or spill-off. Some facilities have equipment with surfaces that tend to be problematic, like wood which is far worse than stainless steel or specialized plastics from a sanitary perspective.

▸ Facility Design and Layout

Of course, breakdowns in sanitary food processing run deeper than just the equipment. Problems can actually begin long before the first food item enters a facility. Some of the gravest mistakes occur when the company initially selects and prepares a site for its processing operations and/or blueprints its manufacturing layout. Consider the cautious tale of one organization whose product was compromised after employees tracked microorganisms in from the dirt parking lot via their shoes. Similarly, standing bodies of water limit drainage and foliage can attract birds, insects and other pests that bring fecal pathogen risk into the plant.

Inside the plant, any number of specific decisions over physical amenities also foil food safety and quality efforts. It starts with the building foundation, which obviously is rarely (if ever) sampled. However, if not properly flanged, this introduces the possibility of rodents burrowing under the facility's slab. Walls made from poured concrete may not be feasible, but processors must realize that the alternative could be extensive caulking or the possibility of pests and insects entering through seams or junctions.

Floors and doors should also be constructed purposefully with the right materials and with cleaning in mind. Flooring that could be coated with an epoxy — or that is epoxied but not maintained — can lead to avoidable problems. And if it isn't seal-curved against walls and formed to slope toward drains (which also must be sanitarily designed), water can accumulate. In terms of materials, brick and tile can be problematic for upkeep, enabling moisture to pool in cracks and potentially harbour serious microorganisms like *Listeria monocytogenes*. Basic concrete is tricky too, as moisture can erode and cause damage (i.e., spalling). Doors must be cleaned also, and if they don't provide proper air curtains, hazardous aerosols may invade and compromise food.

Overhead areas and walkways are sometimes overlooked, much to the chagrin of processors when regulators or other third parties sample their environment. Some manufacturers have regretted making their catwalks and access platforms from materials that aren't as sanitary as, say, stainless steel. Also, unclean ceilings can shed debris to the production line and exposed HVAC prone to condensation can drip onto food or food contact surfaces. This can be a particular concern in chilled RTE environments where drip pans and condenser coils are common and produce moist harbourage sites for *Listeria* and other microorganisms. As much as possible, ducting (as well as electrical) should be installed out of processing areas.

And finally, flawed facility design is more than having the right physical plant, as important as that is. When meat processors aren't continuously mindful of their overall traffic path such that everything flows unidirectionally from the receiving and preparation areas to processing, packaging, warehousing and eventually shipment, things go awry. Employee traffic patterns are a critical aspect of this issue. Unfortunately, too many recalls have been caused by workers moving throughout different areas of the facility in the wrong way at the wrong time. When manufacturers don't aggressively enforce critical lines of separation or instill captive footwear programs or vestibules for donning or doffing their protective equipment, they put themselves at risk.

This risk may be food safety-related or may cause problems with product spoilage. Sanitary design and practices benefit the processor not only in protecting food safety but also in maximizing microbiological quality and shelf life.

Underlying Issues

As established, there are countless mistakes associated with maintaining sanitary food production that can be made by multiple roles within the organization. However, what are some of the familiar themes that most often facilitate contamination? Not surprisingly, it frequently comes to cutting corners that involve people and processes.

Oftentimes, food safety professionals are not brought into the conversation early enough when companies begin to make decisions about building, renovating, outfitting or retrofitting environments that house processing. This can be especially prevalent in today's rapidly evolving industry where shorter construction timelines are more common and building projects often limit involvement to designers, engineers and operations team members.

Another problem that emerges is that meat processors sometimes fail to gain more specific, and ultimately more informative, data in their food safety sampling and testing, and become content with merely having the core data they need to either pass or fail. For example, processors in the U.S. are quite accustomed to collecting samples of *E. coli* from the carcasses in their abattoirs and taking action in accordance with USDA FSIS mandates. But in many cases, they fail to take inventory of the specific colony counts, which could actually tell them a lot more about how hygienic or non-hygienic their raw materials and/or processes are, that lead up to that step.

Finally, as more foodborne illnesses have been traced back to the processing environment, it's become apparent that the failures were in prerequisite programs like sanitation procedures and good manufacturing practices. In some cases, these programs have been used for years without strategic review. In instances when they have been updated, it has often been iterative in nature. The modifications are merely “bolted on” to address new needs or requirements that may have emerged without enough consideration for how those updates may affect other aspects. This can lead to poorly coordinated programs and ineffective use of resources.

A Better Path for a More Sanitary Environment

Clearly, sanitary design is a process that should start immediately when meat processors first consider setting up or changing facilities, equipment or flow paths. It should involve a cross-functional team that includes representation and input from, at minimum, quality assurance, microbiology, regulatory, sanitation and plant management when making decisions as large as where a plant will be located to as small as the finish specifications of a particular piece of equipment. Third-party consultants who have observed trends in various other organizations or bring experience in safe processing and sanitary design can be wise to enlist as well.

The team should scrutinize documentation such as floor plans, specific details on equipment and their location and proposed position, sanitation and sampling performance results, and industry and regulatory guidance. They should also work to develop strong partnerships with their equipment suppliers to convey and troubleshoot specific concerns they may have related to installing or operating the equipment in their particular facility.

Specific to the critical environment that is the abattoir, processors are of course wary of regulatory mandates, such as those imposed by USDA FSIS to maintain written sampling procedures and records surrounding generic *E. coli*. Dedicated inspection program personnel spend constant and considerable energy making sure each carcass and its attached parts are free of visible fecal material and stopping slaughter lines if necessary (in line with the USDA FSIS “zero tolerance” standard[6]), sampling specified parts of livestock for generic *E. coli*, and ensuring samples are analyzed by validated laboratory methods and correctly reported.

It’s not always about how often *E. coli* is found, but often how much is found. Safety-minded meat processors will keep inventory on their *E. coli* colony counts, incorporating other fecal pathogen-relevant indicator or index organism tests and reanalyzing their entire pre-processing and slaughter environment to bring forth improvements.

▸ Environmental Monitoring

The other important realization for food processors, including those involved with RTE meat, has been the need to intensify and expand the scope of Environmental Monitoring Programs (EMPs). EMPs traditionally have involved collecting and testing samples from the resident environment to validate the effectiveness of cleaning, sanitation and various control programs and verify them as continuously effective.
For example, scheduled or incident-triggered “seek and destroy” missions can more comprehensively validate that surface cleaning and sanitization are effective by completely disassembling and then sampling the furnishings of the post-cook environment.

As organisms like *Listeria monocytogenes* and others are discovered with greater prevalence and regularity, and new technologies in the war on unwanted microbes have advanced, sophisticated processors are incorporating a broader range of test targets into their EMPs and using them more generally to monitor environments for unhygienic conditions that may lead to food safety breakdowns. For instance, they may supplement their traditional environmental monitoring tests with ATP testing, as well as details about sanitizer concentrations and applications in order to monitor and verify cleaning and sanitation and develop pertinent corrective actions in the event performance thresholds are not met.

Another example is Total Plate Count (TPC) tests, which many processors rely on to verify and validate sanitation in areas subject to environmental contamination, such as hard-to-clean niches within production lines. These quantitative tests recover culturable microorganisms under aerobic conditions and can also be used to validate and verify general sanitation and to give a sense for the total microbial load present on defined processing environment surfaces versus tolerable limits.

This holistic approach to EMPs, where different aspects are integrated and coordinated, can increase the program's effectiveness and efficiency. EMPs should include a standardized sampling site list that encompasses all sites tested as well as record-keeping and analyses of all environmental monitoring data (ATP, TPC, allergen monitoring, pathogen monitoring, etc.). They should be supported with clear, electronic record-keeping, as well as regular in-person reviews of all data.

To learn more about EMPs and their applicability to specific food safety and quality hazards or targets like pathogens, allergens and spoilage organisms, download The Environmental Monitoring Handbook for the Food and Beverage Industries developed through a collaboration between 3M Food Safety, Cornell University and other industry experts.

10 Sanitary Equipment Design Principles

1. **Cleanable to a microbiological level:** Food equipment must be constructed to ensure effective and efficient cleaning. The equipment should be designed to prevent bacterial ingress, survival, growth, and reproduction on both product and non-product contact surfaces of the equipment.
2. **Made of compatible materials:** Construction materials used for equipment must be completely compatible with the product, environment, cleaning and sanitizing chemicals, and the methods of cleaning and sanitation.
3. **Accessible for inspection, maintenance, cleaning and sanitation:** All parts of the equipment shall be readily accessible for inspection, maintenance, cleaning and sanitation without the use of tools.
4. **No product or liquid collection:** Equipment should be self-draining to assure that liquid, which can harbour and promote the growth of bacteria, does not accumulate, pool or condense on the equipment.
5. **Hollow areas should be hermetically sealed:** Hollow areas of equipment, such as frames and rollers, must be eliminated wherever possible or permanently sealed. Bolts, studs, mounting plates, brackets, junction boxes, nameplates, end caps, sleeves and other such items must be continuously welded to the surface—not attached via drilled and tapped holes.
6. **No niches:** Equipment parts should be free of niches such as pits, cracks, corrosion, recesses, open seams, gaps, lap seams, protruding ledges, inside threads, bolt rivets and dead ends.
7. **Sanitary operational performance:** During normal operations, the equipment must perform so it does not contribute to insanitary conditions or the harbourage and growth of bacteria.
8. **Hygienic design of maintenance enclosures:** Maintenance enclosures and human machine interfaces, such as push buttons, valve handles, switches and touchscreens, must be designed to ensure food product, water or product liquid does not penetrate or accumulate in and on the enclosure or interface. Also, physical design of the enclosures should be sloped or pitched to avoid use as a storage area.
9. **Hygienic compatibility with other plant systems:** Any required subsystem, such as exhaust, drainage or automated cleaning systems, must also meet the sanitary design principles and not create insanitary conditions.
10. **Validated cleaning and sanitizing protocols:** Procedures for cleaning and sanitation must be clearly written, designed, and proven effective and efficient. Chemicals recommended for cleaning and sanitation must be compatible with the equipment and the manufacturing environment.

[4] *Sanitary Equipment Design Principles: Checklist & Glossary (2014, January). Retrieved March 1, 2020, from https://www.meatinstitute.org/ht/a/GetDocumentAction/i/97261*

[6] *USDA FSIS Directive 6420.2, Rev. 1, Verification of Procedures for Controlling Fecal Material, Ingesta and Milk in Livestock Slaughter Operations (2017, April). Retrieved March 1, 2020, from https://www.fsis.usda.gov/wps/wcm/connect/478aca76-37c5-4dc3-9925-1556402d8daf/PHIS_6420.2.pdf?MOD=AJPERES*

Takeaways and Target Behaviors

In today's increasingly meat-eating society and accelerated business landscape, the meat industry has the unenviable yet critical task of making sure they continue to deliver acceptably safe food to the marketplace. While they mustn't let down their guard in any stage of processing — from the initial receipt and holding of animals to the eventual shipment of consumer-ready cuts — it's time for the industry to enhance its sanitary slaughter practices to make sure life-threatening contamination doesn't occur. Similarly, their attention to, and validation and verification of, the sanitary design of any processing steps that ensue is paramount.

Repeated cleaning and sanitation that produces consistent failures against accepted limits simply cause "firefighting" without getting to the root of the problem. Willingness to invest in and improve fundamental processing steps, spaces and equipment, greater adherence to sanitary design principles and more expansive interpretations of environmental monitoring programs are key to reducing foodborne illnesses caused by today's increasingly popular meat offerings.

The final step involves ongoing training of the workforce, incentivizing them to raise and scientifically investigate all food safety-relevant concerns and findings so that there's a clear line of sight and degree of trust between the boardroom and the frontline.

Four Key Takeaways

1. Foodborne disease resulting from consumption of microbial pathogen-contaminated meat products still occurs in the U.S. and abroad.
2. HACCP and other food safety verification systems have brought forth transformational improvements in product safety since their introduction.
3. Sanitary design of the food processing establishment, the equipment within, and the incorporation of scientifically valid food safety interventions interact to produce safe, high-quality products.
4. An environmental monitoring program can help meat processors apply a risk-based approach of sampling to identify potential *Listeria monocytogenes* harbourage sites, quantify microbial hygiene in the post-lethality processing environment and detect the potential for product contamination by pathogens like *Listeria monocytogenes* and *Salmonella*.

See more about meat testing at:
3M.ca/FoodSafety/Meat

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3M Food Safety Division
3M Canada
P.O. Box 5757
London, Ontario N6A 4T1
1-800 364-3577
3M.ca/FoodSafety