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Supporting Documentation Materials for HACCP Decisions

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Introduction

This material has been developed to aid you, the meat and poultry processor, in the scientific documentation of the HACCP decisions during hazard analysis, validation of plans, and corrective actions by giving examples of processing steps from scientific publications and regulatory documents. Organized by HACCP process category, this material will assist you after your specific hazards and critical control points of your process(es) have been identified. The table of contents on the previous page will direct you to the location of each process category. Be advised that not all possible hazards are covered in this manual, and many steps that are included in this information may not necessarily be hazards in your process.

This manual includes published scientific research. The research that has been done does not necessarily comply with current regulations, nor are all of the parameters normal processing conditions. Some of the treatments discussed are not within the legal limits; other treatments may not be approved at any level. Some of the research in this manual shows that certain conditions are not effective in reducing or eliminating risk; other conditions may create a probable risk. This information is here not only to validate existing processes, but also to demonstrate the effectiveness, or lack thereof, of process steps that may be added to your process in the future.

Much of the information included here focuses on biological hazards. Physical and chemical hazards are addressed, but only briefly. One topic of major interest in the food industry as a whole is allergens. Allergens are not a defined class of substances, but there are 8 categories of foods that have been scientifically recognized and accepted by the United Nations Joint Food and Agriculture Organization (FAO) and the World Health Organization (WHO) Food Standards Programme in 1995. These categories are: Cereals containing Gluten; Crustacea; Eggs and egg products; Fish and Fish products; Peanuts; Milk and Milk products; Tree nuts; and Soybeans. Foods in these main categories affect people in two main ways. Food intolerances are a reaction to the chemical composition of the food itself. Food sensitivities are immune responses the body has to proteins in the food. Either manner that a person reacts to an allergen is highly individualistic, varying in degree, onset time, location of reaction and the amount of the food needed to trigger the response. Because of this concern, it is important that processors think “up front” about allergens and the possibility of cross-contact between products that may have allergens labeled and those that do not. It is also of utmost importance that all ingredients are correctly labeled on products, especially those ingredients that contain protein such as those listed in the 8 categories above.

The information from published articles has been compiled into the following tables for the easiest use. Once you find the correct process category, the table will help you find the specific step you wish to document. Again, there are many steps listed that may not apply to your process, and specific steps in your process may not be included. The first column, labeled "**Process Step**," in the table indicates the point or step of each process flow, in which scientific or regulatory documentation is available. Not all steps in a process will be found here, and individual processors may have other process steps in their HACCP plans; the processes listed here have been specifically addressed by scientific research. The second column identifies the "**Potential Hazards**" that have been addressed in published scientific literature for each process step. The third column, labeled "**Process Parameters**," describes the conditions that are applied in various scientific publications. This table is designed so that a processor can go to the processing point or step of interest, then move across to the potential hazards and process parameters that best match their particular process. The reference will only be valid if the steps you take match the criteria in this column. The column lists the specific product that was tested. If you are looking for turkey information, broiler information may not necessarily apply. If you are processing pork, beef information may not apply. Upon identifying one or more process parameters that are appropriate for the operation, the fourth column, labeled as "**Decision Criteria**," will describe the results of the research, or the regulatory requirements. In the fifth, or last column, labeled "**Scientific Documentation**," the actual source of the information described in the three columns to the left is listed.

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
This column indicates the point or step of each process flow, in which scientific or regulatory documentation is available.	This column identifies the potential hazards that have been addressed in published scientific literature, for each process step.	This column describes the conditions used in the research that is described in various scientific publications.	This column describes the results of the research, or the regulatory requirements.	This column describes the actual source of the information, described in the three columns to the left. Where available, a website is given to allow internet access to publications.

Where available, a website is given to allow internet access to publications. If a website link is not provided, publications can be accessed from either the National Agricultural Library (Website: http://www.nal.usda.gov/, E-mail: lending@nal.usda.gov or phone: 301/504-5879) or through inter-library loan, at your local library. When requesting publications at either location, you will need to provide the information that is listed under the column "**Scientific Documentation**" (author, title, year, journal name, volume, page numbers, etc.).

The following is an example of how one might use this manual:

You need to validate or examine the decision you made to select the critical limit that you have chosen for the cooking step in a Fully Cooked, Not Shelf Stable HACCP plan. You would go to the Fully Cooked, Not Shelf Stable Process section (see page 89) and look for "cooking" in the far left column, **Process Step** (see page 111). Next, look at the second and third columns (**Potential Hazards** and **Process Parameters**) to find hazards and processing procedures that match what you are doing. Once you have found **Process Parameters** that fit your process, read the **Decision Criteria** in the next column to the right to find the results of published research that should help you in your decision. Finally, the **Scientific Documentation** column will give the information that you would need if you wanted to read the entire article. If the process parameters do not fully match your specific process, a further review of published research is necessary.

This is a living document. New research is continually being published and other publications are always being brought to our attention. Though this compilation is extensive, it is not exhaustive. Our intentions are to update this manual regularly and the updated versions will be available at The Ohio State University Meat Science web page at: http://www.meatsci.osu.edu

Glossary

Glossary

Aerobic - Bacteria that require oxygen to grow or will grow in the presence of oxygen.

Anaerobic – Bacteria that do not utilize oxygen to grow, or will not grow in the presence of oxygen.

Bacteriocin – A substance that is produced by specific bacteria that is toxic to closely related strains of the same specific bacteria and either kills or slows the growth of those other specific bacteria.

Coliform – Bacteria that most often inhabit the intestine of animals, do not utilize oxygen, but can grow in its presence. Bacteria that are classified as coliforms have the same shape, and many of the same characteristics. These bacteria are used as indicators of sanitary quality in many food products.

Detection limit – The lowest threshold amount of bacteria that must be present in a sample to be found. Detection level depends upon methods used.

Direct plating – The application of a sample, or dilution thereof, to solid media usually containing agar and other material used to grow and enumerate bacteria.

D-value – The amount of time needed to destroy one log unit of a specific bacteria at a specific temperature in a specific medium.

Enrichment – Addition of nutrient rich broth so that certain bacteria or type of bacteria increases in number to result in a bacterial cell count that is higher than the detection limit. This is used to detect only the presence or absence of the bacteria, not the amount present.

Enterobacteriaceae – Large group of bacteria that are closely related and are commonly found in fecal material of warm blooded animals. They include coliforms and pathogens such as Salmonellae.

F-value – Measured in minutes, the D-value of a specific organism at 250˚F (121˚C) multiplied by the desired log reduction.

Germination – The process of a spore becoming a vegetative cell.

Inhibition – The slowing or stopping of bacterial growth.

Lag time – Time that bacteria take to become acclimated to a new environment before starting to multiply. Bacteria divide and their numbers grow exponentially, 1 becomes 2 becomes 4 becomes 8.

Lethality – The effectiveness of a treatment to destroy or kill bacteria.

Log unit – A unit of 10^x used to count bacteria. The difference between 10^6 (1,000,000) and 10^7 (10,000,000) is one log unit (9,000,000), the difference between 10^6 and 10^5 (100,000) is also one log unit (900,000).

Glossary

Mesophiles – Bacteria that have optimum growing temperatures between 77ºF (25ºC) and 104ºF (40ºC).

Microflora – Bacteria, molds and yeasts.

Pathogen – Organisms that cause illness. These organisms include bacteria, protazoa, or viruses.

pH - Level of acidity or alkalinity in a product. The pH scale ranges from 1 to 14 with 7 considered neutral, 1 the most acidic and 14 the most alkaline. Fresh meat usually has a pH near 5.6.

Psychrotrophs - Bacteria that have optimum growing temperatures between 68ºF (20ºC) and 86ºF (30ºC) but can grow at temperatures as low as 32ºF (0ºC).

Residue – Usually refers to the presences antibiotics or pesticides that are still detectable in carcasses at slaughter.

Shocked (heat shocked) – Occurs when a product is heated but the temperature is not high enough to destroy the bacteria. This results in bacteria that are injured for a while but in most cases can repair itself and becomes more resistant to heat the next time the product is heated. Heat shocked can also refer to the process by which a spore is induced into germination. When a product is heated thoroughly the vegetative cells are destroyed, but the spores are undamaged by the heat. The spores then germinate into vegetative cells once the temperature has decreased to an optimum level.

Significant difference – Statistical difference in results due to treatments.

Spore – A highly resistant, dormant form that some bacteria can change into. Spores are usually very resistant to heat, long periods of dryness, and other adverse conditions that normal vegetative cells cannot survive. Most must be heat shocked to germinate into normal, vegetative cells. Most of the time spores have a toxin associated with them, either within the spore covering, or released at the time of germination or when becoming a spore (sporulation).

Strain – A specific subset of bacteria. For example, ***Escherichia*** is the genus, ***coli*** is the specie and **O157:H7** is the strain.

Thermotolerant – Bacteria that can withstand higher than normal temperatures.

Toxin (enterotoxin, mycotoxin, neurotoxin) – A compound produced by a bacterium or fungi (molds and yeasts) that can cause illness in other living organisms. Specific examples include enterotoxins which affect the intestine, mycotoxins are those toxins produced by fungi, and neurotoxins attack the nervous system.

Transdermal synergists – Compounds that work with other compounds against bacteria when applied to the surface of a carcass.

Glossary

Treatment – The method of processing that is being tested. A good research study will compare various treatments, such as levels of salt in a product, to a control, in this example the control maybe no salt added. All other conditions should remain the same for all samples tested except the specific treatment.

Vegetative cell – The normal bacteria cell. This is in contrast to a spore. Vegetative cells are susceptible to destruction or damage from heat, additives, and other factors that can damage and destroy them relatively easily.

Bacteria and Parasite

Aeromonas hydrophilia – A pathogenic psychrotroph that produces an enterotoxin.

Bacillus cereus – A spore-forming, pathogenic bacterium that forms an enterotoxin. *B. cereus* is an aerobic spore-former, unlike the common clostridium spore formers which are anaerobic.

Campylobacter jejuni – A common pathogenic bacterium that forms an enterotoxin. It needs very low levels (about 5%) of oxygen and too much will inhibit growth, and about 10% carbon dioxide is required for growth. Campylobacter is the most common cause of food borne illness in the United States, commonly associated with diarrheal illness.

Clostridium botulinum – A spore-forming, pathogenic bacterium that forms a neurotoxin when in an anaerobic environment. *C. botulinum* is a concern mainly in canned foods.

Clostridium perfringens – A spore-forming, pathogenic bacterium that forms an enterotoxin in the spore coat. *C. perfringens* must be ingested in large quantities while a vegetative cell and then will sporulate in the intestine.

Clostridium sporogenes – A spore-forming, non-pathogenic bacterium that mimics other clostridium bacteria in growth conditions. *C. sporogenes* is often used in research where use of the pathogenic bacteria is infeasible.

Escherichia coli – A common coliform bacterium. Generic *E. coli* is used as an indicator bacterium for fecal contamination. The strains O157:H7 and O128 are among the few strains of *E. coli* that have been found to be pathogenic. These two strains have different growth characteristics than generic *E. coli*, and must be detected using different methods.

Lactobacillus plantarum – A non-pathogenic bacterium that is commonly used in starter cultures. *L. plantarum* and many other Lactobacillus species are noted for their production of lactic acid, which lowers pH and gives distinctive flavors.

Leuconostoc – A non-pathogenic bacterium that is used in starter cultures. *Leuconostoc* species produce lactic acid used to lower pH and give distinctive flavors.

Listeria monocytogenes- A pathogenic bacterium that grows well in many adverse conditions. *L. monocytogenes* is considered a psychrotroph, and likes to grow in damp cool places such as drains and on floors. *L. monocytogenes* is the only specie of *Listeria* that is considered pathogenic. Presence of *L. monocytogenes* on carcasses is usually attributed to contamination by fecal matter during slaughter.

Pediococcus acidilactici – A non-pathogenic bacterium that is used in starter cultures. *P. acidilactici* produces lactic acid, which lowers pH and produces distinctive flavors.

Salmonellae, *Salmonella* spp., *S. seftenberg,* and *S. typhimurium* – A pathogenic bacterium that is a common cause of gastrointestinal foodborne illness. Salmonellae grow rapidly in optimum conditions and all of the numerous species are considered pathogenic. Other notable Salmonella species are *S. typhi,* which causes Typhoid fever, and *S. enteritidis,* a frequently occurring specie, second only to *S. typhimurium.*

Staphylococcus aureus – A pathogenic bacterium that produces a very heat stable enterotoxin known for producing severe abdominal cramps, vomiting and diarrhea in humans.

Trichinella spiralis – A parasite (round worm) that lodges in certain muscles while in the larva form. *T. spiralis* is of most concern with pork, however it can be found in other game meats such as bears, canines, and marine mammals, that consume meat.

Yersinia enterocolitica – A pathogenic bacterium that is commonly found in the lymph system of the pig. *Y. entercolitica* is a psychrotroph and produces an enterotoxin.

Physical Hazards

This category crosses all process categories.
It includes lead, other metals, glass, and any other physical hazards that may occur.

Physical Hazards

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
All process steps	P – Any foreign material	Opportunity for any physical contamination to occur	Monitoring equipment must be sensitive enough to detect contamination as small as 1/32" (0.8mm). The presence of any visible foreign material needs to be addressed. Visual inspection is a necessity when no other metal detection or x-ray devices are employed. A visible inspection is prudent in addition to machines due to the nature of detection devices and the many types of materials that may cause a physical hazard.	FSIS directive 7310.4 Revision 2, 12/28/93 This directive has been cancelled; however, it provides a basis for contamination monitoring.
	P – Contamination with glass, metal, wood, plastic or other miscellaneous foreign objects	Contamination of products during processing	FDA Health Hazard Evaluation Board concludes that hard or sharp objects that at maximum dimension are 7mm or longer but less than the Consumer Product Safety Commission's standard for choking hazard (able to be compressed into a 1.25 inch diameter by 2.25 inch long cylinder), represent a potential physical hazard.	Olsen, A.R., 1998. Regulatory Action Criteria for filth and other extraneous materials, I. Review of hard or sharp foreign objects as physical hazards in food. Regulatory Toxicology and Pharmacology 28 (3) 181-198.
			FDA Health Hazard Evaluation Board concludes that hard or sharp objects that at maximum dimension are 7mm or less represent a possible physical hazard, especially if a special-risk group is the intended consumer of the product.	

Physical Hazards

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
All process steps	P and/or C – Lead hazard	Contamination of muscle tissue with lead shot	Though whole lead shots are removed from the meat, a trace amount of residue remains. However, the amount of lead residue is not of health concern unless excessive amounts of the contaminated product are eaten daily over a long period of time. Although scientific documentation is limited it is advised that processors are aware that lead toxicity is always a concern and should be addressed.	Burger, J., R.A. Kenamer, I.L. Brisbin Jr., and M. Gochfeld. 1997. Metal levels in mourning doves from South Carolina: potential hazards to doves and hunters. Environmental Resources. 75 (2) 173-186. AND Johansen, P., G. Asmund, and F. Riget. 2001. Lead contamination of seabirds harvested with lead shot – implications to human diet in Greenland. Environmental Pollution. 112 (3) 501-504.

Slaughter Process

Includes: beef, and pork

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Animal Receiving/ holding	C – Antibiotic and pesticide residues	Slaughter of hogs and cattle	There have been "no reports of residue-related human illness in the United States associated with consumption of commercially available meat or poultry." Monitoring for the presence of violative chemical residues is done by USDA and the slaughter establishments. Industry educational programs such as the Pork Quality Assurance (PQA) Program (National Pork Producers Council, 1994) have promoted residue prevention on the farm. In addition to the end producer efforts to address residues, slaughter establishments can request letters of guarantee and copies of relevant animal treatment records (Pork Slaughter model, Draft USDA FSIS April, 1997).	Kindred T. P., and W.T. Hubbert. 1993. Residue prevention strategies in the United States. Journal of the American Veterinary Medicine Association. 202 (1) 46-49.
			There is a low risk of antibiotic and pesticide residues in meat.	National Residue Monitoring program, 1999. To access on the internet: http://www.fsis.usda.gov/OPHS/red99/

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Animal Receiving/ holding	C- Antibiotic and pesticide residues	Slaughter of all animals	Current data in 1998 showed that approximately 1% of animal products in US and Europe contain antibiotic residues at very low levels. Though due to low prevalence of the positive results, about 90% are expected to be false positives.	Mitchell, J.M., M.W. Griffiths, S.A. McEwen, W.B. McNab, and A.J. Yee. 1998. Antimicrobial Drug Residues in Milk and Meat: Causes, Concerns, Prevalence, Regulations, Tests, and Test Performance. Journal of Food Protection. 61 (6) 742-756.
	B –Contamination with *Salmonella* spp., *Listeria monocytogenes, Campylobacter* spp., *Clostridium perfringens, and Yersinia enterocolitica*	Co-mingling and resting of animals prior to slaughter	Feed withdrawal and holding animals 2 to 6 hours prior to slaughter has been shown to reduce the incidence of ruptured viscera and cross-contamination.	Miller, M.F., M.A. Carr, D.B. Bawcom, C.B. Ramsey, and L.D. Thompson. 1997. Microbiology of pork carcasses from pigs with differing origins and feed withdrawal times. Journal of Food Protection. 60 (3) 242-245.
	P – Foreign material	Slaughtering animals with the possible presence of needles, buckshot etc.	There is a low incidence of occurrence.	National Beef Quality Audits, 1991, 1995, 2000.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Pork carcass scalding	B – *Escherichia. Coli*, *Salmonella* and *Campylobacter* survival	Scalding in water at or below 145°F (63°C)	*E. coli*, *Salmonella* and *Campylobacter* were not killed with 122°F (50°C) water typical in a scalding tank. The carcasses must still be singed to kill the pathogens.	Gill, C.O., and J. Bryant. 1993. The presence of *Escherichia coli*, *Salmonella* and *Campylobacter* in pig carcass dehairing equipment. Food Microbiology 10 (4) 337-344.
		Scalding in water to 145°F (63°C)	*E. coli*, *Salmonella* and *Campylobacter* are killed at 145°F (63°C).	
		Scald water at less than 140°F (60°C)	*Salmonella* spp. were only found when scald water was less than 140°F (60°C).	Kampelmacher, E.H., P.A.M. Guinee, K. Hofstra, and A. Van Keulen. 1961. Studies on *Salmonella* in slaughter houses. Zentralbl. Veterinaermed. Reihe. 8:1025-1032.
Beef carcass pre-eviscer-ation and evisceration	B- Fecal contamination with *E. coli* O157:H7, and *S. typhimurium*	Post hide removal, pre-evisceration wash of beef carcasses with distilled (not tap) water	A pre-evisceration wash makes the surface of the carcass less tactile, therefore allowing any ensuing contamination easier to remove. *E. coli* O157:H7, and *S. typhimurium* count was 0.7 log units less after washing.	Dickson, J.S. 1995. Susceptibility of preevisceration washed beef carcasses to contamination by *Escherichia coli* O157:H7 and salmonellae. Journal of Food Protection. 58 (10) 1065-1068.
Hide removal/ evisceration	B- Fecal contamination with *E. coli*, and Enterobacteriaceae	Steam vacuuming beef carcasses at 162°F (72°C), followed by a hot water spray of 203°F (95°C), at 24 psi, and/or an 11 second spray of 2% lactic acid at 131°F (55°C)	Fecal contamination will be removed by steam vacuuming when accompanied by either or both of the hot water or lactic acid treatments. *E. coli*, Enterobacteriaceae, and total and thermotolerant coliforms were consistently reduced to less than 1.0 log.	Castillo, A., L.M. Lucia, K.J. Goodson, J.W. Savell, and G.R. Acuff. 1999. Decontamination of beef carcass surface tissue by steam vacuuming alone and combined with hot water and lactic acid sprays. Journal of Food Protection. 62 (2) 146-151.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B- Fecal contamination with *E. coli*, and *S. typhimurium*	Rinse beef carcasses with low pressure (10 psi), followed by high pressure (250 psi) 95°F (35°C) water	After a known fecal contamination, washing with water reduces the *E. coli* O157:H7, and *S. typhimurium* by 2.6-3.0 log units; however, it allows bacteria to be spread to the area outside of the visible contamination area.	Hardin, M.D., G.R. Acuff, L.M. Lucia, J.S. Oman, and J.W. Savell. 1995. Comparison of methods for decontamination from beef carcass surfaces. Journal of Food Protection. 58 (4) 368-374.
		Trimming visible contamination from beef carcasses	Trimming away contamination was equivalent to water washing in reducing visible contamination and more consistent in reducing *E. coli* O157:H7 to non-detectable levels than washing with water. However, contamination was still detectable outside of the initial area that was visibly contaminated.	
		Rinse beef carcasses with low pressure (10 psi) followed by high pressure (250 psi) 95°F (35°C) water, then spraying the area with a fine mist of 131˚F (55˚C) 2% acetic acid for 11 seconds	The addition of the 2% acetic acid treatment with the water wash, reduced *E. coli*, and *S. typhimurium* count 2.4 to 5.1 log units inside the contaminated area and to < 0.5 log units outside the initial contamination area to below detection level more effectively than just the water wash, or trimming.	Hardin, M.D., G.R. Acuff, L.M. Lucia, J.S. Oman, and J.W. Savell. 1995. (continued)

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B- Fecal contamination with *E. coli*, and *S. typhimurium*	Rinse beef carcasses with low pressure (10 psi) followed by high pressure (250 psi) 95°F (35°C) water, then spraying the area with a fine mist of 131˚F (55˚C) 2% lactic acid for 11 seconds	The addition of the 2% acetic acid treatment with the water wash, reduced *E. coli*, and *S. typhimurium* count 3.0 to 5.0 log units inside the contaminated area and to < 0.5 log units outside the initial contamination area to below detection level more effectively than just the water wash, or trimming.	Hardin, M.D., G.R. Acuff, L.M. Lucia, J.S. Oman, and J.W. Savell. 1995. (continued)
	B – *S. typhimurium* contamination	Spraying pork carcasses with 2% or greater lactic acid solution at 52˚F (11˚C) for at least 60 seconds.	The cold lactic acid treatment eliminated *S. typhimurium* when contaminated with 1 log unit but was less than 50% successful in removing contamination when inoculated with 2 log units.	Van Netten, P., D.A.A. Mossel, and J. Huis In't Veld. 1995. Lactic acid decontamination of fresh pork carcasses: a pilot plant study. International Journal of Food Microbiology. 25 (1) 1-9.
	B – *S. typhimurium* contamination	Spraying pork carcasses with 2% or greater lactic acid solution at 131˚F (55˚C) for at least 60 seconds	The hot lactic acid treatment eliminated *S. typhimurium* when contaminated with up to 2 log units.	Van Netten, P., D.A.A. Mossel, and J. Huis In't Veld. 1995. (continued)
	B – Contamination with *Salmonella*, *Yersinia*, and *Campylobacter*	Spray pork carcasses with 1/5% acetic, citric, or lactic acid	No significant microbiological difference was made with these treatments on *Salmonella*, *Yersinia*, and *Campylobacter*.	Fu, A.H., J.G. Sebranek, and E.A. Murano, 1994. Microbial and Quality Characteristics of Pork Cuts from Carcasses Treated with Sanitizing Sprays. Journal of Food Science. 59 (2) 306-309.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B – Contamination with *Salmonella* spp., and *Campylobacter* spp.	Spray pork carcasses with 2% lactic acid spray (20 psi, ca. 150 ml per half carcass)	Incidence of *Salmonella* spp. and *Campylobacter* spp. decreased 95 to 99% with this treatment.	Epling, L.K., J.A. Carpenter, and L.C. Blankenship. 1993. Prevalence of *Campylobacter* spp. and *Salmonella* spp. on pork carcasses and the reduction effected by spraying with lactic acid. Journal of Food Protection. 56 (6) 536-537.
	B – Aerobic and anaerobic pathogen survival and growth	Spray pork carcasses with 55˚F (12.8˚C) tap water followed by 2% acetic acid solution at 55˚F (12.8˚C) both at 200 psi	There was a 0.8 log decrease in the microflora present one hour after treatment, and the inhibition continued through the 28th day of storage when there was a 0.9 log difference between those loins sprayed with acetic acid and those not sprayed at all. Over all there was still a 4 log growth over the 28 days for all treatments.	Cacciarelli, M.A. W.C. Stringer, M.E. Anderson, and H.D. Naumann. 1983. Effects of washing and sanitizing on the bacterial flora of vacuum-packaged pork loins. Journal of Food Protection. 46 (3) 231 – 234.
	B –Aaerobic and anaerobic pathogen survival and growth	Spray pork carcasses with 55˚F (12.8˚C) tap water followed by 200 ppm sodium hypochlorite solution (adjusted pH to 6.0 with phosphoric acid) at 55˚F (12.8˚C) both at 200 psi.	A 0.6 log reduction was detected one hour after treatment, however by 21 days after slaughter there was no difference in growth between those sprayed with sodium hypochlorite solution and those that were not sprayed at all (approx. 6.9 log count of microorganisms).	Cacciarelli, M.A. W.C. Stringer, M.E. Anderson, and H.D. Naumann. 1983. (continued)

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Hide removal/ evisceration	B –Aaerobic and anaerobic pathogen survival and growth	Spray pork carcasses with 55˚F (12.8˚C) tap water at 200 psi.	A 0.6 log reduction was detected one hour after treatment, however by 21 days after slaughter there was no difference in growth between those sprayed with water and those that were not sprayed at all. (about 6.9 log count of microorganisms).	Cacciarelli, M.A. W.C. Stringer, M.E. Anderson, and H.D. Naumann. 1983. (continued)
Steam Vacuuming	B- Bacterial Contamination	Beef Carcasses steam vacuumed of knife trimmed to remove visible fecal contamination	Total aerobic bacteria were reduced approximately 1.5 log units with both knife trimming and steam vacuuming. When there was no visible contaimination steam vacuuming reduced the aerobic plate count by about 0.5 log units	Kochevar, Sherri L., John N. Sofos, Robert R. Bolin, James O. Reagan, and Gary C. Smith 1997. Steam Vacuuming as a Pre-Evisceration Intervention to Decontaminate Beef Carcasses. Journal of Food Protection. 60 (2) 107-113.
Dehairing	B- *Salmonella* contamination	No post-dehairing rinse of pork carcasses	Carcass sides should be washed with high-pressure spray inside and out and immediately placed in chill room with minimal handling and the meat temperature maintained at or below 45˚F (7.1˚C) to reduce the prevalence of *Salmonella.*	Newel, K.W., and L.P. Williams. 1971. The control of *Salmonella* affecting swine and man. Journal of the American Veterinary Medical Association. 158 (1) 89-88.
		Post-dehairing rinse of pork carcasses		
	B-*E. coli* survival	Rinse polished pork carcasses for 40 seconds with water at 140°F (60°C) or less	This treatment results in approximately a 2 log reduction of bacteria including *E. coli*.	Gill, C.O., D.S. McGinnis, J. Bryant, and B. Chabot. 1995. Decontamination of commercial polished pig carcasses with hot water. Food Microbiology. 12 (2) 143-149.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dehairing	B- *E. coli* survival	Rinse polished carcass for 40 seconds with water at 167°F (75°C) to 194°F (90°C)	Treatment resulted in a 4 to 8 log reduction of bacteria. (However, the carcass was discolored).	Gill, C.O., D.S. McGinnis, J. Bryant, and B. Chabot. 1995. (continued)
		Rinse polished carcass for 40 seconds with water 185°F (85°C)	Treatment resulted in 1 to 3 log reduction of *E. coli.*	
Evisceration, head trimming	B- *Yersinia enterocolitica* contamination	Circumanal incision and removal of intestines; excision of the tongue, pharynx, and the tonsils; incision of the mandibular lymph nodes and deboning of head meat	Prevent *Yersinia enterocolitica* contamination as the organism is able to grow in refrigerated foods.	Kapperud, G. 1991. *Yersinia enterocolitica* in food hygiene. International Journal of Food Microbiology. 12 (1) 53-66.
	B – *E. coli*, coliforms and aerobic bacteria contamination	Washing carcasses with water at 104°F (40°C) and pH 7.5 and trimming after skinning and evisceration of beef carcasses	*E. coli*, coliforms and aerobic bacteria deposited on surface during skinning and evisceration are not reduced by trimming, and washing.	Gill, C.O., M. Badoni, and T. Jones. 1996. Hygienic effects of trimming and washing operations in a beef-carcass-dressing process. Journal of Food Protection. 59 (6) 666-669.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Final Trim	B – Fecal, milk and ingesta contamination to carcasses	Final trim of beef, pork and lamb carcasses before final rinse	Zero tolerance for visible fecal, milk and ingesta contamination.	FSIS Directive 6420.1 To access on the internet, go to: http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6420-1.pdf
	B – *E. coli O157:H7* contamination	Trimming beef carcass	Trimming beef carcass reduced *E.coli* O157:H7 by 3.1 log units (5.14 logs initial).	Phebus, R.K., A.L. Nutsch, D.E. Schafer, R.C. Wilson, M.J. Reimann, J.D. Leising, C.L. Kastner, J.R. Wolf, and R.K. Prasai. 1997, Comparison of steam pasteurization and other methods for reduction of pathogens on surfaces of freshly slaughtered beef. Journal of Food Protection. 60 (5) 476-484.
		Trimming beef carcass combined with warm water wash 95ºF (35ºC)	Trimming beef carcass combined with warm water reduced *E.coli* O157:H7 by 4.7 log units (5.19 logs initial).	
Carcass Wash	B – Contamination of carcasses with bacteria	Lamb carcasses were cleaned using sterile cloths.	Bacteria count was 4 log units.	Kelly, C.A., B. Lynch, and A.J. McLoughlin. 1982. The Effect of spray washing on the development of bacterial numbers and storage life of lamb carcasses. Journal of Applied Bacteriology. 53, 335 – 341.
		Lamb carcasses washed with 50°F (10°C) water for 120 seconds at 7.7 kg/cm^2	Bacteria count was less than 4 log units.	
		Lamb carcasses washed with 176°F (80°C) water for 120 seconds at 7.7 kg/cm^2	Bacteria count was 3.3 log units.	

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – Contamination of carcasses with bacteria	Lamb carcasses washed with 176°F (80°C) water with 450 ppm chlorine for 120 seconds at 7.7 kg/cm^2	Bacteria count was less than 3 log units.	Kelly, C.A., B. Lynch, and A.J. McLoughlin . (continued)
		Spraying beef carcasses immediately after rail inspection and again after and an 8 hour spray chill cycle with any combinations of the following: water, 200ppm chlorine, or 3% lactic acid solution	Spraying the carcass with the lactic acid solution both times showed the greatest bacterial reduction. When lactic acid rinse was used for one of the rinses the bacteria were reduced more than not using lactic acid	Kenney, P.B., R.K. Prasai, R.E. Campbell, C.L. Kastner, and D.Y.C. Fung. 1994. Microbiological Quality of Beef Carcasses and Vacuum-Packaged Subprimals: Process Intervention during Slaughter and Fabrication. Journal of Food Protection. 58 (6) 633-638.
		Rinse beef carcass with 200 – 250 mg/L sodium hypochlorite (pH 6.0) at 3.5 kg/cm^2 or 14.0 kg/cm^2; .83 L/minute or 3.4 L/minute and moving 2 cm /second or 10 cm /second for 2, 15, or 30 seconds.	Each combination using sodium hypochlorite rinse reduced bacteria at least 0.1log (0.83 L/minute, 3.5 kg/cm^2, 10 cm/second) to 72.0 log (3.4 L/minute, 14.0 kg/minute, 2 cm/second). As time of spray increased from 2 to 15 and 30 seconds, the log reduction increased from less than .5 log reduction to greater than 1.0 log reduction.	Marshall, R.T., M.E. Anderson, H.D. Naumann, and W.C. Stringer. 1977. Experiments in Sanitizing Beef With Sodium Hypochlorite. Journal of Food Protection. 40 (4) 246 – 249.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – Contamination of carcasses with bacteria	Lamb carcasses dressed and rinsed with 60°F (15°C) water for 15 seconds then subjected to steam condensation or immersed in 194°F (90°C) water for 8 seconds	There was no difference between these two treatments. Aerobic plate counts were reduced 1 log unit as compared to carcasses that were not treated.	James, C., J.A. Thornton, L. Ketteringham, S.J. James. 2000. Effect of steam condensation, hot water or chlorinated hot water immersion on bacterial numbers and quality of lamb carcasses. Journal of Food Engineering. 43 (4) 219-225.
		Lamb carcasses dressed and rinsed with 60°F (15°C) water for 15 seconds then subjected immersed in 194°F (90°C) water with 250 ppm free chlorine by NaOCl for 8 seconds	Aerobic plate counts were reduced 1.6 logs as compared to carcasses that were not treated.	

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – Contamination of carcasses with *Bacillus cereus, C. perfringens, E. coli, Micrococcus varians, Proteus vulgaris, Pseudomonas florescens* and *fragi, Salmonella typhimurium* and *spp.*, *Stapylococcus aureus*, and *Enterococcus faecalis.*	Aqueus cholrine (using $Ca(OCl)_2$) to result in 3, 12.5, 50 or 200 ppm of chlorine on beef carcasses	15 seconds of exposure to 3 ppm of chlorine destroyed *C. perfringens, E. coli, Micrococcus varians, Proteus vulgaris, Pseudomonas florescens* and *fragi, Salmonella typhimurium* and *spp.,* and *Stapylococcus aureus;* 12.5 ppm cholrine for 2 minutes or 50 ppm of cholrine for 15 seconds were required for a 7 log decrease in *Enterococcus faecalis*; and 200 ppm chlorine for 30 seconds resulted in a 6 log decrease of *Bacillus cereus*.	Kotula, K.L., A.W. Kotula, B.E. Rose, C.J. Pierson, and M. Camp. 1997. Reduction of aqueous cholrine by organic material. Journal of Food Protection. 60 (3) 276-282.
	B – *E. coli* O157:H7 contamination	Using 2% acetic acid on beef brisket fat for 12 sec immediately after being inoculated with fecal matter.	*E. coli* O157:H7 was reduced by 3.69 log units.	Cabedo, L., J.N. Sofos, and G.C. Smith. 1996. Removal of bacteria from beef tissue by spray washing after different times of exposure to fecal material. Journal of Food Protection. 59 (12) 1284-1287.
	B - *S. typhimurium*	Using 2% acetic acid on beef brisket fat when there was a 2 hr delay after inoculation.	*E. coli* O157:H7 was reduced by 2.5 log units.	N. Clayton, 2002. unpublished thesis from U. Kentucky.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B - *E. coli* O157:H7 contamination	50 ppm chlorine spray used on pork carcasses.	Spraying 50 ppm chlorine reduced *S. typhimurium* was reduced by 2.25 log units.	Gorman, B.M., J.N. Sofos, J.B. Morgan, G.R. Schmidt, and G.C. Smith. 1995. Evaluation of hand-trimming, various sanitizing agents, and hot water spray-washing as decontamination interventions for beef brisket adipose tissue. Journal of Food Protection. 58 (8) 899-907.
		50 ppm chlorine spray combined with hot water used on pork carcasses.	Spraying 50 ppm chlorine combined with a hot water rinse (10 sec) reduced S. typhimurium by 2.5 log units.	
	B - *E. coli* O157:H7 contamination	165º F (74º C) water wash followed by a 61º F (16º C) water wash on beef brisket adipose tissue.	165º F (74º C) water wash followed by a 61º F (16º C) water wash on beef brisket adipose tissue, resulted in a 3 log unit reduction.	Gorman, B.M., J.N. Sofos, J.B. Morgan, G.R. Schmidt, and G.C. Smith. 1995. Evaluation of hand-trimming, various sanitizing agents, and hot water spray-washing as decontamination interventions for beef brisket adipose tissue. Journal of Food Protection. 58 (8) 899-907. Smith. M.G., and A. Graham. 1978. Destruction of Escherichia coli and salmonellae on mutton carcasses by treatment with hot water. Meat Science. 2 (2) 119-128.
		61º F (16º C) water wash followed by a 165º (74º C) water wash on beef briskey adipose tissue.	61º F (16º C) water wash followed by 165º F (74º C) water wash brisket adipose tissue, resulted in a 2.6 log unit reduction.	

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B - *E. coli* O157:H7 contamination	Beef and sheep carcass surfaces flooded with water less than 131˚F (55˚C) water for 120 seconds	*E. coli* O157:H7 was reduced by less than 1 log unit when flooded by water less than 131˚F (55˚C) for up to 120 seconds.	Smith. M.G., and A. Graham. 1978. Destruction of Escherichia coli and salmonellae on mutton carcasses by treatment with hot water. Meat Science. 2 (2) 119-128.
		Beef and sheep carcass surfaces flooded with 140˚F (60˚C) water for 10 to 120 seconds	*E. coli* O157:H7 on beef was reduced by 1 log unit when flooded by water at 140°F (60˚C) for up to 120 seconds. After 10 seconds of flooding of sheep carcasses *E. coli* O157:H7 was reduced less than 1 log unit, when flooded for 60 to 120 seconds the log reduction was 2.5 log units.	
		Beef and sheep carcass surfaces flooded with 149˚F (65˚C) water for 10 to 120 seconds	*E. coli* O157:H7 was reduced by 1 log unit when flooded by water at 149°F (65˚C) for 10 seconds on beef carcasses and 2 log units on sheep carcasses. With flooding of both beef and sheep carcasses for 30 seconds and again 60 to 120 seconds *E. coli* O157:H7 was reduced 1 more log unit, with final reductions at 120 seconds of 3 log units on beef and 4 log units on sheep carcasses.	

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B - *E. coli* O157:H7 contamination	Beef and sheep carcass surfaces flooded with 158˚F (70˚C) water for 10 to 120 seconds	*E. coli* O157:H7 was reduced by 2 log units when flooded by water at 158°F (70˚C) for 10 seconds on beef carcasses, and a final reduction of 4 log units after 120 seconds. *E. coli* O157:H7 was reduced by less than 3 log units when flooded by water at 158°F (70˚C) for 10 seconds on sheep carcasses, and 4 log units after 30 to 120 seconds.	Smith. M.G., and A. Graham. 1978. (continued)
		Beef and sheep carcass surfaces flooded with 176˚F (80˚C) water for 10 to 120 seconds	*E. coli* O157:H7 was reduced by less than 3 log units when flooded by water at 176°F (80˚C) for 10 seconds on beef carcasses, and a final reduction of 4.5 log units after 120 seconds. *E. coli* O157:H7 was reduced by more than 3 log units when flooded by water at 176°F (80˚C) for 10 seconds on sheep carcasses, and 4.5 log units after 30 to 120 seconds.	
	B – 7 strains of *E. coli*	Sheep carcass surfaces submersed in 194˚F (90˚C) water for 10 to 120 seconds	*E. coli* O157:H7 on beef carcasses was reduced by more than 3 log units when flooded by water at 194°F (90˚C) for 30 seconds, and 4.5 log units 60 to 120 seconds. *E. coli* O157:H7 was reduced by 4.5 log units when flooded by water at 194°F (90°C) for at least 10 seconds.	Nettles Cutter, C., and G.R. Siragusa. 1994. Efficacy of Organic Acids Against *Escherichia coli* O157:H7 Attached to Beef Carcass Tissue Using a Pilot Scale Model Carcass Washer. Journal of Food Protection. 57 (2) 97 – 103.

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – 7 strains of *E. coli*	Beef carcass sprayed with a carcass washer (80 cycles per minute, 14 m/minute, 80 psi, and 4.8 L/minute) at 75.2°F (24°C) with 1%, 3%, or 5% acetic, lactic, or citric acid.	*E. coli* O157:H7 was reduced 1 to 1.5 log units with rinse of 1%, 3%, or 5% acetic, lactic, or citric acid.	Nettles Cutter, C., and G.R. Siragusa. 1994. Efficacy of Organic Acids Against *Escherichia coli* O157:H7 Attached to Beef Carcass Tissue Using a Pilot Scale Model Carcass Washer. Journal of Food Protection. 57 (2) 97 – 103.
	B – 7 strains of *E. coli* B – *E. coli* O157:H7 B – *Salmonella enteritidis* *B – Listeria monocytogenes* contamination	140º F (60º C) hot water wash on beef carcasses	7 strains of *E. coli* reduced greater then 1 log unit with a 140˚F (60˚C) carcass wash.	Smith, M. G. 1992. Destruction of bacteria of fresh meat by hot water. Epidemiology and Infection. 109 (3) 491-496.
		176º F (80ºC) hot water wash on beef carcasses for 10 seconds	176º F (80ºC) hot water wash on carcasses for 10 seconds, reduced the 7 strains of *E. coli* 3 log units.	

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – *Listeria innocua*	Electrolyzed oxidizing water with 80+ ppm free chlorine (40+ for *Listeria monocytogenes*) (pH range 2.3 to 2.6) at 39.2°F (4°C) , 73.4°F (23°C), 95°F (35°C) or 113°F (45°C) or water with chlorine added 70 to 80 ppm.	All cultures were negative even by enrichment after 10 minutes at 39.2°F (4°C) and 73.4°F (23°C), 4 minutes at 95°F (35°C), and 3 minutes at 113°F (45°C). Similar results (not published) were found with water and chlorine against *E. coli* O157:H7 and *Listeria monocytogenes.*	Dorsa, W.J., C.N. Cutter, and G.R. Siragusa. 1997. Effects of steam-vacuuming and hot water spray wash on the microflora of refrigerated beef carcass surface tissue inoculated with Escherichia coli O107:H7, Listeria innocua, and Clostridium sporogenes. Journal of Food Protection. 60 (2) 114-119.
		A hot water wash 165˚F (74˚C) at 20 psi, followed by 86˚F (30˚C) at 125 psi.	A hot water wash 165˚F (74º C) at 20 psi, followed by 86˚F (30˚C) at 125 psi, reduced *Listeria innocua* on beef carcasses by 2.5 log units.	

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – *E. coli O157:H7*	A hot water wash 165˚F (74˚C) at 20 psi, followed by 86˚F (30˚C) at 125 psi	A hot water wash 165˚F (74º C) at 20 psi, followed by 86˚F (30˚C) at 125 psi, reduced *E.coil O157:H7* on beef carcasses by 2.6 log units.	Dickson, J.S., and M.E. Anderson. 1991. Control of *Salmonella* on Beef Tissue Surfaces in a Model System by Pre- and Post-Evisceration Washing and Sanitizing, With and Without Spray Chilling. Journal of Food Protection. 54 (7) 514 – 518.
	B – *Salmonella* contamination	Wash beef carcass with 2% acetic acid at 73.4°F (23°C) or 131°F (55°C).	*Salmonella* was reduced 0.5 to 2 log units with 2% acetic acid at 73.4°F (23°C) to 131°F (55°C).	Cutter, C., G.R. Siragusa. 1994. Application of chlorine to reduce populations of *Escherichia coli* on beef. Journal of Food Safety. 15. 67-75.
	B – *E. coli* O157:H7 contamination	Beef carcasses sprayed (60 psi; 4.2 L/min) with sodium hypochlorite (NaOCl) solution with 50, 100, 250, 500, and 800 ppm of chlorine at 28°C	*E. coli* was reduced by less than .5 log units by these treatments but the reduction is not significantly different from water.	

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – *E. coli* O157:H7, *Listeria* and *Clostridium* contamination	Spray beef carcasses 80 psi, 32°C for 15 seconds with tap water (pH 7.34)	Initial wash with water reduced *E. coli* O157:H7 by more than 1.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	Dorsa, W.J., C.N. Cutter, and G.R. Siragusa. 1996. Effects of acetic acid, lactic acid and trisodium phosphate on the microflora of refrigerated beef carcass surface tissue inoculated with *Escherichia coli* O157:H7, *Listeria innocua,* and *Clostridium sporogenes.* Journal of Food Protection. 60 (6) 619-624.
	B – *E. coli* O157:H7, *Listeria* and *Clostridium* contamination	Spray beef carcasses 80 psi, 32°C for 15 seconds with 12% trisodium phosphate (pH 12.31)	Initial wash with water reduced *E. coli* O157:H7 by more than 2.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	
	B – Survival of *S. typhimurium*	Spray beef carcasses 80 psi, 32°C for 15 seconds with 1.5% lactic acid (pH 2.44)	Initial wash with water reduced *E. coli* O157:H7 by more than 2.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	N. Clayton, 2002. unpublished thesis from U. Kentucky
		Spray beef carcasses 80 psi, 32°C for 15 seconds with 3% lactic acid (pH 2.27)	Initial wash with water reduced *E. coli* O157:H7 by more than 2.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	
	B – Survival of *S. typhimurium*	Spray beef carcasses 80 psi, 32°C for 15 seconds with 1.5% acetic acid (pH 2.82)	Initial wash with water reduced *E. coli* O157:H7 by more than 2.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – Survival of *S. typhimurium*	Spray beef carcasses 80 psi, 32°C for 15 seconds with 3% acetic acid (pH 2.69)	Initial wash with water reduced *E. coli* O157:H7 by more than 2.5 log units and reduced *Listeria* and *Clostridium* by 3 log units.	N. Clayton, 2002. unpublished thesis from U. Kentucky
		A hot water treatment 127º F (53º C) for 10 seconds on pork carcasses, than a 10 second flame singe, 50 ppm chlorine or 2% lactic acid	A hot water treatment 127º F (53º C) for 10 seconds, than a 10 second flame singe, 50ppm chlorine or 2% lactic acid on pork carcasses resulted in the reduction of *S. typhimurium* by 3.7 log units.	
	B – *E. coli* O157:H7 and *Salmonella typhimurium* contamination	A hot water treatment 127º F (53º C) for 10 seconds on pork carcasses, than a 10 second flame singe, 50ppm chlorine or 2% lactic acid combined with additional hot water rinse.	A hot water treatment 127º F (53º C) for 10 seconds on pork carcasses, than a 10 second flame singe, 50ppm chlorine or 2% lactic acid combined with additional hot water rinse resulted in the reduction of *S. typhimurium* by 4.7 log units.	Castillo, A., Lucia, L.M. Kemp, G.K., and Acuff, G.R. 1999. Reduction of *Escherichia coli* O157:H7 and *Salmonella Typhimurium* on Beef Carcass Surfaces Using Acidified Sodium Chlorite. Journal of Food Protection. 62 (6) 580 – 584.
		2% lactic acid solution sprayed on pork carcasses	2% lactic acid solution sprayed on pork carcasses reduced *S. typhimurium* by 2.25 log units.	

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – *E. coli* O157:H7 and *Salmonella typhimurium* contamination B – *E. coli* O157:H7 and *Salmonella typhimurium* contamination	Flame singeing of pork carcasses, for 10 seconds.	Flame singeing of pork carcasses, for 10 seconds, reduced population of *S. typhimurium* by 2.2-3 log units.	Castillo, A., Lucia, L.M. Kemp, G.K., and Acuff, G.R. 1999. Reduction of *Escherichia coli* O157:H7 and *Salmonella Typhimurium* on Beef Carcass Surfaces Using Acidified Sodium Chlorite. Journal of Food Protection. 62 (6) 580 – 584. Castillo, A., Lucia, L.M. Kemp, G.K., and Acuff, G.R. 1999. (continued).
		Flame singeing of pork carcasses, for 20 seconds	Flame singeing of pork carcasses, for 20 seconds, reduced population of *S. typhimurium* by 3.1 log units.	
	B – *E. coli* O157:H7 and *Salmonella typhimurium* contamination	Apply carcass rinse of 1.5 L handwash (9 seconds at 69 kPa) and 5L automated cabinet wash for 9 seconds.	*E. coli* O157:H7 and S*almonella typhimurium* were reduced 2.3 log units.	Castillo, A., Lucia, L.M. Kemp, G.K., and Acuff, G.R. 1999. (continued).
		Apply carcass rinse of 1.5 L handwash (9 seconds at 69 kPa) and 5L automated cabinet wash for 9 seconds followed by a 140 ml spray solution of phosphoric acid	*E. coli* O157:H7 and *Salmonella typhimurium* were reduced 3.8 log units.	

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash		and sodium chlorite with a final concentration of 1200 mg/L (chlorous acid concentration of 164 mg/L) for 10 seconds at 69 kPa.		
	B – *E. coli* O157:H7 and *Salmonella typhimurium* contamination	Apply carcass rinse of 1.5 L handwash (9 seconds at 69 kPa) and 5L automated cabinet wash for 9 seconds followed by a 140 ml spray solution of citric acid and sodium chlorite with a final concentration of 1200 mg/L (chlorous acid concentration of 164 mg/L) for 10 seconds at 69 kPa.	*E. coli* O157:H7 and *Salmonella typhimurium* were reduced 4.5 log units.	Castillo, A., Lucia, L.M. Kemp, G.K., and Acuff, G.R. 1999. (continued).

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass Wash	B – *Listeria* contamination	Beef carcass sprayed in carcass washer (80 cylces/minute, 14m/minute, 60 psi, 4.2 L/min at 82.4°F (28°C)) with nisin (5000 activity units/ml pH 6.0) then stored at 39.2°F (4°C) for 1 day.	*Listeria* was reduced 2 to 3 log units when treated with nisin. This reduction was found on both the day of the treatment and the following day.	Nettles Cutter, C., and G.R. Siragusa. 1994. Decontamination of Beef carcass tissue with nisin using a pilot scale model carcass washer. Food Microbiology. 11 (6) 481 – 489.
	B- *Salmonella, Listeria monocytogenes, Aeromonas hydrophilia,* and *Campylobacter* survival and/or growth	Hot boned and vacuum packaged (40-45 minutes post mortem) and stored at 34˚F (1˚C)	Hot processed and packaged meat supported survival and growth (no log change to 2.5 log units of growth) of *Salmonella, L. monocytogenes, Aeromonas hydrophilia,* and *Campylobacter* despite immediate storage at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	Van Laack, R.L.J.M., J.L Johnson, C.J.N.M. van der Palen, F.J.M. Smulders, and J.M.A. Snijders. 1993. Survival of pathogenic bacteria on pork loins as influenced by hot processing and packaging. Journal of Food Protection. 56 (10) 847-851.
Carcass Treatment	B- *E.coli 0157:H7* and *L.innocua* contamination	Freezing beef in liquid nitrogen for 15 minutes	*E.coli 0157:H7* and *L.innocua* was found to transfer from inoculated samples to non-inoculated samples. *E.coli 0157:H7* did decrease 2.18 to 4.02 log units, *L.innocua* decreased 0.33 to 1.77 log units.	Berry, Elaine D., Warren J. Dorsa, Gregory R. Siragusa, and Mohammad Koohmaraie. 1998. Bacterial Cross-Contamination of Meat during Liquid Nitrogen Immersion Freezing. Journal of Food Protection. 61 (9) 1103-1108.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Pre-Rigor (hot) Deboning	B – *E. coli* survival	Pass pork carcasses through a freezing tunnel at – 4˚F (-20˚C) for 45 to 60 minutes prior to entering a conventional chiller (32 to 36˚F (0 to 2˚C))	The entire carcass (deep temperature) is reduced to below 45˚F (7˚C) during the chilling process and a bacterial hazard from *E. coli* is not likely to occur.	Gill, C.O., and T. Jones. 1992. Assessment of the hygienic efficiencies of two commercial processes for cooling pig carcasses. Food Microbiology. 9 (4) 335-343.
Chilling	B – *E. coli* survival	Pork carcasses are immediately placed into a conventional chiller at 30 to 36˚F (-1 to 2˚C) then sprayed with 41˚F (5˚C) water for 20 seconds spread over 10 minutes.	The surface of the carcass is reduced to below 45˚F (7˚C) during the chilling process, however the internal temperature (deep temperature) is reduced to approximately 50˚F (10˚C).	Gill, C.O., and T. Jones. 1992. Assessment of the hygienic efficiencies of two commercial processes for cooling pig carcasses. Food Microbiology. 9 (4) 335-343.
		Beef carcasses chilled in commercial chillers	The longest carcass to chill took 50 hours to reach 45°F (7°C) internally but the highest *E. coli* growth was recorded for the cooling curve that took 30 hours to chill to 45°F (7°C). However, in both cases the surface required only 20 hours chill to 45°F (7°C)	Gill, C.O., J.C.L. Harrison, and D.M. Phillips. 1991. Use of a temperature function integration technique to assess the hygienic adequacy of a beef carcass cooling process. Food Microbiology. 8 (2) 83-94.

Slaughter process

Process Step	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth of *E. coli* and *Salmonella typhimurium*	Mutton carcasses and meat held at 50°F (10°C) or lower	Lag time for *E. coli* and *Salmonella typhimurium* was 23.25 hours and generation time was 6.7 hours at 50°F (10°C) and increased infinitely as temperature decreased	Smith, M.G. 1985. The generation time, lag time, and minimum temperature o growth of coliform organisms on meat, and the implications for codes of practice in abattoirs. Journal of Hygiene Cambridge. 94 (1) 289-300.

Poultry Slaughter Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cloacal plugging	B – *Campylobacter* spp. contamination	Cloacally plugging chickens prior to electrocution	Cloacal plugging prior to electrocution resulted in 2.5 to 3 log units less *Campylobacter* spp.	Musgrove, M.T., J.A. Cason, D.L. Fletcher, N.J. Stern, N.A. Cox, and J.S. Bailey. 1997. Effect of cloacal plugging on microbial recovery from partially processed broilers. Poultry Science. 76 (3) 530-533.
Scalding	B – Contamination of skin and respiratory tract with *Campylobacter*	Chicken carcasses scalded for 110 seconds, 57 seconds, then 45 seconds with 15 seconds out of the scalder between each.	Scalding significantly reduced *Campylobacter* (about 4 log units) on the surface, however the presence of *Campylobacter* or *E. coli* in the respiratory tract were not effected.	Berrang, M.E., R.J. Meinersmann, R.J. Buhr, N.A. Reimer, R.W. Philips, and M.A. Harrison. 2003 Presence of *Campylobacter* in the respiratory tract of broiler carcasses before and after commercial scalding. Poultry Science 82 (12) 1995-1999.
	B – *Salmonella typhimurium* attachment to skin	Scalding chicken carcasses 1 to 2 minutes at 126˚F (52˚C), 133˚F (56˚C), or 140˚F (60˚C)	*Salmonella typhimurium* attached to chicken skin after scalding at 140˚F (60˚C) for 1 to 2 minutes were 1.1 to 1.3 log units higher than scalding at 126˚F (52˚C), or 133˚F (56˚C).	Kim, J.W., M.F. Slavik, C.L. Griffis, and J.T. Walker. 1993. Attachment of *Salmonella typhimurium* to skins of chicken scalded at various temperatures. Journal of Food Protection. 56 (8) 661-665.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – *Salmonella typhimurium* and *Campylobacter jejuni* attachment to skin	Scalding chicken carcasses 1 to 2 minutes at 126˚F (52˚C), 133˚F (56˚C), or 140˚F (60˚C)	*Salmonella typhimurium* attached to chicken skin after scalding at 140˚F (60˚C) for 1 to 2 minutes were 0.3 to 0.5 log units higher than scalding at 126˚F (52˚C), or 133˚F (56˚C), *Campylobacter jejuni* recovered from the 140˚F (60˚C) scalded carcasses were 0.7 log more than those scalded at 126˚F (52˚C), or 133˚F (56˚C).	Slavik, M.F., J.W. Kim, and J.T. Walker. 1995. Reduction of *Salmonella* and *Campylobacter* on chicken carcasses by changing scalding temperature. Journal of Food Protection. 58 (6) 689-691.
	B – *Salmonella typhimurium* and *Campylobacter jejuni* attachment to skin	Scald chicken carcasses 5 minutes at 122˚F (50˚C), 131˚F (55˚C), or 140˚F (60˚C)	When scalding at 122˚F (50˚C), there was no log change in *S. typhimurium*, and a 1.5 log decrease in *C. jejuni*. At 131˚F (55˚C), *S. typhimurium* was reduced 1 log unit, and *C. jejuni* was reduced 3 log units. At 140˚F (60˚C), both *S. typhimurium* and *C. jejuni* were reduced 2 log units.	Yang, H., Y. Li, and M.G. Johnson. 2001. Survival and death of *Salmonella* typhimurium and *Campylobacter jejuni* in processing water and on chicken skin during poultry scalding and chilling. Journal of Food Protection. 64 (6) 770-776.
	B – Salmonellae contamination	Effectiveness of scald water additives at 129 to 133˚F (54 to 56˚C) for 2 minutes	Positive incidence of salmonellae is reduced from 67% positive samples to 8% positive samples with 0.5% and 1% H_2O_2. 1% lactic or acetic acids, NaOH (ph=10.5) and 100 ppm Chlorine had little to no effect on percent positive samples.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – Salmonellae contamination	Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% acetic acid	*Salmonella typhimurium* was reduced less than 1.2 log units with 0.5% and 1% and was reduced 1.5 to 2 log units with 2% to 6% acid.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against *Salmonella typhimurium* attached to broiler chicken skin. Journal of Food Protection. 60 (6) 629-633.
		Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% citric acid	*Salmonella typhimurium* was reduced less than 1 log unit with 0.5% and was reduced 1.5 to 2 log units with 1% to 6% acid.	
		Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% lactic acid	*Salmonella typhimurium* was reduced less than 1 log unit with 0.5% and was reduced 1.5 to 3 log units with 1% to 6% acid.	
		Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% malic acid	*Salmonella typhimurium* was reduced less than 1 log unit with 0.5% and was reduced 1 to 2 log units with 1% to 6% acid.	

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – Salmonellae contamination	Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% mandelic acid	*Salmonella typhimurium* was reduced less than 1 log unit with 0.5% and 1% and was reduced 1 to 2 log units with 2% to 6% acid.	Tamblyn, K.C., and D.E. Conner. 1997. (continued)
		Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% propionic acid	*Salmonella typhimurium* was reduced less than 1.3 log units with up to 6% acid.	
		Scalding broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% to 6% tartaric acid	*Salmonella typhimurium* was reduced 0.5 to 1.5 log units with 0.5% to 2% and was reduced 1 to 2 log units with 4% and 6% acid.	

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Scalding	B – Salmonellae contamination	Scald broiler carcasses for 2 minutes at 122˚F (50˚C), with addition to scald water of 0.5% or 1% acetic, citric, lactic, malic or tartaric acids, plus, transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	*Salmonella typhimurium* showed less than 1.5 log reduction with all scald water treatments that contained acids and synergists, except for 0.5% citric acid, with 100 ppm sorbitan monolaurate; malic acid (both concentrations) with 125 ppm sodium lauryl sulfate showed a 2 log reduction and tartaric acid (both concentrations) with 100 ppm sorbitan monolaurate showed a 2.75 log decrease.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against *Salmonella typhimurium* attached to broiler skin. Food Microbiology. 14 (5) 477-484.
Defeathering	B – *Salmonella* cross contamination	Defeathering turkey carcasses conventionally (scalded in a triple pass tank for 1.3 minutes at 137.5˚F (58.6˚C)), Kosher (cold scalded 1 minute at 45˚F (7˚C)), or steam sprayed for 1.6 minutes with a combination of 140˚F (60˚C) water and steam.	There was no significant difference in positive samples of *Salmonella* between the three types of defeathering.	Clouser, C.S., S.J. Knabel, M.G. Mast, and S. Doores. 1995. Effect of type of defeathering system on *Salmonella* cross-contamination during commercial processing. Poultry Science. 74 (4) 732-741.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Defeathering	B – *Salmonella* and *Listeria monocytogenes* cross contamination	Defeathering turkey carcasses conventionally (scalded in a triple pass tank for 1.3 minutes at 137.5˚F (58.6˚C)), Kosher (cold scalded 1 minute at 45˚F (7˚C)), or steam sprayed for 1.6 minutes with a combination of 140˚F (60˚C) water and steam.	There was no significant difference between Kosher picking and the steam spray method, however incidence of *Salmonella* increased 50% with conventional picking. There was no *Listeria monocytogenes* detected associated with the picking process, however there was a significant increase in positive samples from those Kosher picked in the chilling process.	Clouser, C.S., S. Doores, M.G. Mast, and S.J. Knabel. 1995. The role of defeathering in the contamination of turkey skin by *Salmonella* species and *Listeria monocytogenes*. Poultry Science. 74 (4) 723-731.
Pre-evisceration wash	B – *Salmonella*, *Staphylococcus*, and *Clostridium* spp. contamination	Spray washing defeathered, uneviscerated chicken carcasses with tap water at 50 psi for 2.5 minutes	Spray washing after defeathering but before evisceration had no significant effect on the incidence of *Salmonella*, *Staphylococcus*, and *Clostridium* spp.	Lillard, H.S., D. Hamm, and J.E. Thompson. 1984. Effect of reduced processing on recovery of foodborne pathogens from hot-boned broiler meat and skin. Journal of Food Protection. 47 (3) 209-212.
Viscera removal	Cross-contamination by automatic viscera removal equipment	Wash automatic viscera removal equipment probe with plastic bristled brush rotating at 1700 rpm and sprayed rinsed with chlorinated water	The risk of cross-contamination is eliminated with this wash process between each carcass.	Thayer, S.G., and J.L. Walsh. 1993. Evaluation of cross-contamination on automatic viscera removal equipment. Poultry Science. 72 (4) 741-746.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
House inspection/ trim	B – Pathogen contamination from feces	Final trim of carcasses before final rinse	Zero tolerance for visible fecal contamination.	Directive 6150.1, for internet access, go to: http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir6150-1.pdf MPI Regulations, Sec. 381.65(e), for internet access, go to: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html
Reprocessing	B – Contamination from *E. coli* and *Salmonella*	Reprocessing prior to chilling according to USDA regulations	No overall log difference was found between initially processed and reprocessed chickens before chilling carcasses.	Blankenship, L.C., J.S. Bailey, N.A. Cox, M.T. Musgrove, M.E. Berrang, R.L. Wilson, M.J. Rose, and S.K. Dua. 1993. Broiler carcass reprocessing, a further evaluation. Journal of Food Protection. 56 (11) 983-985.
Dip/Rinse	B – *Salmonella* contamination	Spray chicken carcasses with 0.85% NaCl at 207, 345, or 827 kPa water for 30 or 90 seconds	There was less than 0.25 log reduction of *S. typhimurium* when sprayed up to 90 seconds and up to 827 kPa pressure.	Li, Y., M.F. Slavik, J.T. Walker, and H. Xiong. 1997. Pre-chill spray of chicken carcasses to reduce *Salmonella typhimurium*. Journal of Food Science. 62 (3) 605-607.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – *Salmonella* contamination	Spray chicken carcasses with 5% trisodium phosphate (TSP) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of *S. typhimurium*. When sprayed for 90 seconds there was approximately 1.5 log reduction of *S. typhimurium.*	Li, Y., M.F. Slavik, J.T. Walker, and H. Xiong. 1997. (continued)
		Spray chicken carcasses with 10% trisodium phosphate (TSP) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was 1.5 to 2 log reduction of *S. typhimurium*. When sprayed for 90 seconds there was 1.5 to 4 log reduction of *S. typhimurium.*	
		Spray chicken carcasses with 5% sodium bisulfate (SBS) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of *S. typhimurium*. When sprayed for 90 seconds there was approximately 1.25 log reduction of *S. typhimurium.*	
		Spray chicken carcasses with 10% sodium bisulfate (SBS) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was 1.2 to 1.5 log reduction of *S. typhimurium*. When sprayed for 90 seconds there was 2.3 to 2.6 log reduction of *S. typhimurium.*	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – *Salmonella* contamination	Spray chicken carcasses with 1% cetylpyridinium chloride (CPC) at 207, 345, or 827 kPa water for 30 or 90 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of *S. typhimurium*. When sprayed for 90 seconds there was less than 1.5 log reduction of *S. typhimurium.*	Li, Y., M.F. Slavik, J.T. Walker, and H. Xiong. 1997. (continued)
		Spray chicken carcasses with 1% lactic acids at 207, 345, or 827 kPa water for 30 seconds	When sprayed for 30 seconds (any pressure) there was less than 1 log reduction of *S. typhimurium*.	
		Dip chicken carcasses in 10% solution of trisodium phosphate (TSP), at 50˚F (10˚C), or 122˚F (50˚C) for 15 seconds	Both control (no TSP) and 10% TSP dip (at both temperatures) decreased the incidence of *Salmonella* 1.6-1.8 log units (27-46%). Overall the 122˚F (50˚C) dip showed a greater log reduction by 0.4 units than at 50˚F (10˚C).	Kim, J.W., M.F. Slavik, M.D. Pharr, D.P. Raben, C.M. Lobsinger, and S. Tsai. 1994. Reduction of *Salmonella* on post-chill chicken carcasses by trisodium phosphate (Na_3PO_4) treatment. Journal of Food Safety. 14 (1) 9-17.
		Dip broiler carcasses in 2% lactic acid, 99˚F (37˚C) for 2 minutes	Salmonellae incidence decreased from 100% to 0% positive samples when carcasses were dipped in 2% lactic acid at 99˚F (37˚C). 40˚F (4˚C) dips and less than 2 minutes in the 99˚F (37˚C) dip had little to no effect on the incidence of salmonellae.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – *Salmonella* contamination	Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% acetic acid	There was little to no effect of the acid dips at any concentration on *Salmonella typhimurium.*	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against *Salmonella typhimurium* attached to broiler chicken skin. Journal of Food Protection. 60 (6) 629-633.
		Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% citric acid	There was little to no effect of the acid dips at any concentration on *Salmonella typhimurium.*	
		Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% lactic acid	There was less than 0.5 log reduction with up to 4% acid. 6% acid showed a 0.75 to 1.2 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. (continued)
		Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% malic acid	There was little to no effect of the acid dips at any concentration on *Salmonella typhimurium.*	

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – *Salmonella* contamination	Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% mandelic acid	4% acid or less showed less than 1 log reduction. 6% acid showed a 0.75 to 2 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. (continued)
		Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% propionic acid	There was little to no effect of the acid dips on *Salmonella typhimurium* up to 4%. At 6% there was a 0.5 to 1.65 log reduction.	
		Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% to 6% tartaric acid	There was little to no effect of the acid dips at any concentration on *Salmonella typhimurium.*	

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip/Rinse	B – *Salmonella* contamination	Dipping broiler carcasses for 15 seconds at 73˚F (23˚C), into dip water containing 0.5% or 1% acetic, citric, lactic, malic or tartaric acids plus transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	*Salmonella typhimurium* showed less than 0.5 log reduction with all acid and synergists except 1% acetic acid with 125 ppm sodium lauryl sulfate, which showed between 0.5 and 1 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against *Salmonella typhimurium* attached to broiler skin. Food Microbiology. 14 (5) 477-484.
Dip and Chill		Rinse turkey carcasses in 200 ppm chlorine for 10 seconds then chilled for 4 hours in 0.5% Slow release chlorine dioxide (SRCD)	No positive samples of *Salmonella* (65 to 75% positive pre rinse).	Villarreal, M.E., R.C. Baker, and J.M. Regenstein. 1990. The incidence of *Salmonella* on poultry carcasses following the use of slow release chlorine dioxide (Alcide). Journal of Food Protection. 53 (6) 465-467.
		Dip turkey carcasses in 4.5% SRCD for 20 seconds, pre chill	No positive samples of *Salmonella* (65 to 75% positive pre rinse).	

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Dip and Chill	B – *Salmonella* contamination	Dip turkey carcasses in 4.5% SRCD for 20 seconds and chilled for 4 hours in 0.5% SRCD	No positive samples of *Salmonella* (65 to 75% positive pre rinse).	Villarreal, M.E., R.C. Baker, and J.M. Regenstein. 1990. (continued)
		Dip turkey carcasses in 4.5% SRCD for 20 seconds and chilled for 4 hours in iced water	0 to 10% positive *Salmonella* samples (65 to 75% positive pre rinse).	
Chill carcasses	B – Pathogen growth	Chilling poultry carcasses after slaughter	Poultry carcasses shall be chilled to 40˚F (4˚C) or lower within the following specified times: Time (hours) / Weight of carcass 4 / < 4 pounds 6 / 4-8 pounds 8 / > 8 pounds	MPI Regulations, Sec. 381.66(b)(2) Access on internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html
	B – Growth of *Campylobacter jejuni* in chill water	Treat chill water containing 0.1% NaCl (pH 7) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 2 to 3 log units in 20 minutes.	Li, Y., J.T. Walker, M.F. Slavik, and H. Wang. 1995. Electrical treatment of poultry chiller water to destroy *Campylobacter jejuni*. Journal of Food Protection. 58 (12) 1330-1334.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – Growth of *Campylobacter jejuni* in chill water	Treat chill water containing 0.2% NaCl (pH 7) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 2 to 4 log units in 20 minutes.	Li, Y., J.T. Walker, M.F. Slavik, and H. Wang. 1995. (continued)
		Treat chill water containing 0.3% NaCl (pH 7) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 3 log units in 15 minutes.	
		Treat chill water containing 0.1% trisodium phosphate (pH 11 to 12) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 1 log unit in 20 minutes.	
		Treat chill water containing 0.2% trisodium phosphate (pH 11 to 12) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 2 to 4 log units in 20 minutes.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – Growth of *Campylobacter jejuni* in chill water	Treat chill water containing 0.3% trisodium phosphate (pH 11 to 12) with 10mA/cm^2 and 1 kHz pulsed electrical current	*Campylobacter jejuni* decreased 1 to 3 log units in 3 minutes.	Li, Y., J.T. Walker, M.F. Slavik, and H. Wang. 1995. (continued)
	B – Survival of *Salmonella typhimurium*, and *Campylobacter jejuni*	Chill chicken carcasses in water containing up to 50 ppm chlorine	The amount of chlorine did not change the log count of *S. typhimurium* or *C. jejuni* in chiller water tested fresh to 8 hours.	Yang, H., Y. Li, and M.G. Johnson. 2001. Survival and death of *Salmonella* typhimurium and *Campylobacter jejuni* in processing water and on chicken skin during poultry scalding and chilling. Journal of Food Protection. 64 (6) 770-776.
	B – *Salmonella* growth	Times, meat pH, and temperatures to reach level of food safety concern	Insert poultry temperature, pH and % sodium chloride into model to determine *Salmonella* growth.	ARS *Salmonella* growth model: http://www.arserrc.gov/mfs/PATHOGEN.HTM
	B – *Salmonella* contamination	Chilling broiler carcasses with addition of 0.6% acetic acid to chill water	Use of 0.6% acetic acid, when combined with air or paddle agitation, reduced *Salmonella* incidence by 30%, and reduced Enterobacteriaceae by 1 log or less.	Dickens, J. A. and A. D. Whittemore. 1995. The effects of Extended Chilling Times with Acetic Acid on the Temperature and Microbiological Quality of Processed Poultry Carcasses. Poultry Sci. 74:1044-1048.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – *Salmonella* contamination	Chilling broiler carcasses for 1 hour at 34 to 35˚F (1.1 to 1.7˚C), in chill water containing 0.5% to 1% H_2O_2, 1% lactic acid, or 100 ppm Chlorine	Salmonellae incidence is reduced 50 to 66% with the addition of any one of these additives to the chill water.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% acetic acid	*Salmonella typhimurium* was reduced less than 0.7 log units with up to 6% acetic acid.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids against *Salmonella typhimurium* attached to broiler chicken skin. Journal of Food Protection. 60 (6) 629-633.
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% citric acid	*Salmonella typhimurium* was reduced less than 0.5 log reduction at 0.5% to 2% citric acid. At 4% citric acid the reduction was 1 to 2 log units and at 6% the reduction was 1.5 to 2 log units.	
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% lactic acid	*Salmonella typhimurium* was reduced less than 1 log reduction at 0.5% to 2% lactic acid. At 4% lactic acid the reduction was 0.75 to 1.5 log units and at 6% the reduction was 2 to 2.25 log units.	
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% malic acid	*Salmonella typhimurium* was reduced less than 0.5 log reduction at 0.5% and 1% malic acid. At 2% the reduction was 1.5 log units, at 4% and 6% malic acid the reduction was 2 to 2.75 log units.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – *Salmonella* contamination	Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% mandelic acid	*Salmonella typhimurium* was reduced less than 0.5 log reduction at 0.5% to 2% mandelic acid. At 4% and 6% acid the reduction was 2 log units.	Tamblyn, K.C., and D.E. Conner. 1997. (continued)
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% propionic acid	*Salmonella typhimurium* was reduced less than 1 log reduction at 0.5% and 1% propionic acid. At 2% acid the reduction was 1 to 1.5 log units, at 4% acid the reduction was 1 to 2.25 log units and at 6% the reduction was 1.75 to 2.25 log units.	
		Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% to 6% tartaric acid	*Salmonella typhimurium* was reduced less than 0.5 log reduction at 0.5% to 4% tartaric acid. At 6% acid the reduction was 1.5 log units.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill carcasses	B – *Salmonella* contamination	Chilling broiler carcasses for 1 hour at 32˚F (0˚C), in chill water containing 0.5% or 1% acetic, citric, lactic, malic or tartaric acids plus transdermal synergists of 2% ethanol, 125 ppm sodium lauryl sulfate, 15% dimethyl sulfoxide, or 100 ppm sorbitan monolaurate	*Salmonella typhimurium* showed less than 0.5 log reduction with all acid and synergists except 1% lactic or 1% acetic acid with 125 ppm sodium lauryl sulfate, and 1% malic acid showed between 0.5 and 1 log reduction.	Tamblyn, K.C., and D.E. Conner. 1997. Bactericidal activity of organic acids in combination with transdermal compounds against *Salmonella typhimurium* attached to broiler skin. Food Microbiology. 14 (5) 477-484.
		Fresh water input at a rate of 0.25 to 0.5 gallons per carcass with 0 to 50 ppm chlorine	There is no significant effect detected when using a higher rate of fresh water input. There was less cross-contamination detected with the use of 50 ppm chlorine than with no chlorine, but the cross contamination was not eliminated. Chlorine decreases rapidly in the chilling water because of interaction with organic matter.	Thompson, J.E., J.S. Bailey, N.A. Cox, D.A. Posey, and M.O. Carson. 1979. *Salmonella* on broiler carcasses as affected by fresh water input rate and chlorination of chiller water. Journal of Food Protection. 42 (12) 954-955.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill Carcasses	B – *Salmonella* and fecal coliforms	34 ppm Cl introduced into chiller water after birds	Fecal coliforms and *Salmonella* were undetectable in the chiller water with each of these treatments. Fecal coliforms were reduced more than 1 log, and *Salmonella* positive samples decreased 10 to 13% on the carcasses. There is no statistical difference between these 4 treatments.	Lillard, H.S. 1980. Effect of broiler carcasses and water of treating chiller water with chlorine or chlorine dioxide. Poultry Science. 59 (8) 1761-1766.
		5 ppm Chlorine dioxide (ClO_2) introduced into chiller water after birds		
		20 ppm Cl introduced with fresh water		
		3 ppm Chlorine dioxide (ClO_2) introduced with fresh water		
		Chiller water with 34 ppm Cl	Both treatments showed 2 log unit reduction in fecal coliforms and *Salmonella* was undetectable.	Lillard, H.S. 1979. Levels of chlorine dioxide of equivalent bactericidal effect in poultry processing water. Journal of Food Science 44 (6) 1594-1597.
		Chiller water with 5 ppm Chlorine dioxide (ClO_2)		
		Chiller water with 20 ppm Cl	These levels of Cl and ClO_2 showed 1 log unit reduction of fecal coliforms, however, fecal coliforms and *Salmonella* were still detectable.	
		Chiller water with 3 ppm Chlorine dioxide (ClO_2)		

Poultry Slaughter process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chill Carcasses	B – Bacterial contamination	Chiller water with 30 – 40 mg/L chlorine dioxide or 150 – 200 mg/L chlorine.	Either chlorine dioxide or chlorine in chiller water resulted in a 3 log reduction in bacteria.	Tasi, L., R. Wilson, and V. Randall. 1997. Mutagenicity of Poultry Chiller Water Treated with either Chlorine Dioxide or Chlorine. Journal of Agricultural and Food Chemistry. 45 (6) 2267 – 2272.
Post Chill Dip/Spray	B – Salmonellae contamination	Dipping broiler carcasses at 40˚F (4˚C) for 1 to 10 minutes in 1% lactic acid, 0.5% or 1% H_2O_2	Salmonella incidences decreased with these additives in the dips from 100% positive samples to 33 to 17% positive samples.	Izat, A.L., M. Colberg, M.H. Adams, M.A. Reiber, and P.W. Waldroup. 1989. Production and processing studies to reduce the incidence of salmonellae on commercial broilers. Journal of Food Protection. 52 (9) 670-673.
		Dipping broiler carcasses at 40˚F (4˚C) for 30 seconds in 20% Ethanol	This treatment had little to no effect on the incidences of positive salmonellae samples.	
		Spraying chilled broiler carcasses for 2 minutes with 2% or 5% lactic acid		
		Spraying chilled broiler carcasses with water containing up to 50 ppm chlorine	No significant change was detected in log counts of psychrophiles or total aerobes or the number of positive samples of salmonellae between 0 and 50 ppm chlorine.	Kotula, A.W., G.J. Banwart, and J.A. Kinner. 1967. Effect of postchill washing on bacterial counts of broiler chickens. Poultry Science. 45 (5) 1210-1216.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post Chill Dip/Spray	B – *Campylobacter* spp. contamination	Dip chilled carcasses for 15 seconds in 122˚F (50˚C) 10% trisodium phosphate	There was no immediate effect however, after 1 to 6 days there was a 1.2 to 1.5 log decrease (64%) in the positive incidence of *Campylobacter* spp.	Slavik, M.F., J.W. Kim, M.D. Pharr, D.P. Raben, S. Tsai, and C.M. Lobsinger. 1994. Effect of trisodium phosphate on *Campylobacter* attached to post-chill chicken carcasses. Journal of Food Protection. 57 (4) 324-326.
	B – *Campylobacter jejuni* contamintaion	Chicken carcasses chilled for 50 minutes in chiller water (40°F (4°C)) with 50 ppm chlorine sprayed for 12 seconds at 80 psi with water at 68°F (20°C), 131°F (55°C), or 140°F (60°C) with or without 50 ppm chlorine	There was no significant reduction in *C. jejuni* when sprayed with 68°F (20°C) water. When spray water contained 50 ppm chlorine at 68°F (20°C), 131°F (55°C), or 140°F (60°C) or without cholorine at 131°F (55°C), or 140°F (60°C) there was 1 log reduction in *C. jejuni.*	Li, Y., H. Yang, B.L. Swem. 2002. Effect of high-temperature inside-outside spray on survival of *Campylobacter jejuni* attached to prechill chicken carcasses. Poultry Science. 81 (9) 1371-1377.

Raw, Intact Process

Includes: beef, pork, lamb, and poultry

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *Staphylococcus aureus* growth	Storage at 50˚F (10˚C) or lower	Minimum growth temperature is 50˚F (10˚C).	Troller, J.A. 1976. Staphylococcal growth and enterotoxin production factors for control. Journal of Milk and Food Technology. 39: 499-503.
	B – *Staphylococcus aureus* toxin production	Storage at 50˚F (10˚C) or lower	Minimum toxin production temperature is a few degrees above the minimum growth temperature.	Pereira, J.L., S.P. Salsberg, and M.S. Bergdoll. 1982. Effect of temperature, pH and sodium chloride concentrations on production of staphylococcal enterotoxins A and B. Journal of Food Protection. 45: 1306-1309.
	B – *Yersinia enterocolitica* growth	Storage of vacuum packed beef or lamb at 45˚F (7˚C)	*Y. enterocolitica* can increase in numbers at 45˚F (7˚).	Hanna, M.O., D.L. Zink, Z.L. Carpenter, and C. Vanderzant. 1976. *Yersinia enterocolitica*-like organisms from vacuum packaged beef and lamb. Journal of Food Science. 41: 1254-1256.
		Storage of beef or pork (in a jar, but not retorted) at 45˚F (7˚)		Hanna, M.O., J.C. Stewart, D.L. Zink, Z.L. Carpenter, and C. Vanderzant. 1977. Development of *Yersinia enterocolitica* on raw and cooked beef and pork at different temperatures. Journal of Food Science. 42: 1180-1184.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *Yersinia enterocolitica* growth	Storage of raw pork at 44.5˚F (6.9˚C) for 10 days	*Y. enterocolitica* showed a 4 log increase at 44.5˚F (6.9˚C) in 10 days.	Food Safety and Inspection Service. Facts. 1989. Preventable foodborne illness. May. 5-14.
	B – *Listeria monocytogenes* growth	Storage of raw lamb at 38˚F (4˚) to 42˚F (6˚)	*Listeria monocytogenes* is capable of growth at these temperatures.	Palumbo, S.A. 1986. Is refrigeration enough to restrain foodborne pathogens? Journal of Food Protection. 49(12) 1003-1009.
	B – *Salmonella* growth	Storage at 44˚F (6.7˚C) or lower	Lowest growth temp reported in a food was 44˚F (6.7˚C).	Angelotti, R., M.J. Foter, and K.H. Lewis, 1961. Time-temperature effects on *Salmonella* and *Staphylococci* in foods. 1. Behavior in refrigerated foods. American Journal of Public Health. 51: 76-88.
		Storage at 41.5˚F (5.3˚C) or 43.2˚F (6.2˚C) or lower	Lowest temperature for *Salmonella* growth: 41.5˚F (5.3˚C) *S. Heildelberg* 43.2˚F (6.2˚C) *S. typhimurium*	Matches, J.R., and J. Liston. 1968. Low temperature growth of *Salmonella*. Journal of Food Science. 33: 641-645.
		Pork carcass storage at 40˚F (4˚C)	No change in *Salmonella* prevalence after 24 hours at 40˚F (4˚C).	Epling, L.K., J.A. Carpenter, and L.C. Blankenship. 1993. Prevalence of *Campylobacter* spp. and *Salmonella* spp. on pork carcasses and the reduction effected by spraying with lactic acid. Journal of Food Protection. 56 (6) 536-537.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Pathogen growth	Store raw meat at 41˚F (5˚C) or below	FDA Food Code states: Red meat, which is a potentially hazardous food, must be stored at 41˚F (5˚C) or below.	2001 FDA Food Code, 3-501.16 page 63. Access on internet at: http://www.cfsan.fda.gov/~dms/fc01-3.html#3-5
	B – *E. coli* O157:H7, *Listeria* and *Clostridium* contamination	Spray beef carcasses 80 psi, 32°C for 15 seconds with tap water (pH 7.34)	Under vacuum storage *E. coli* O157:H7 rose to initial level of more than 4 logs, *Listeria* rose 3 log units over the original level and *Clostridium* was reduced by 1 log unit.	Dorsa, W.J., C.N. Cutter, and G.R. Siragusa. 1996. Effects of acetic acid, lactic acid and trisodium phosphate on the microflora of refrigerated beef carcass surface tissue inoculated with *Escherichia coli* O157:H7, *Listeria innocua,* and *Clostridium sporogenes.* Journal of Food Protection. 60 (6) 619-624.
		Spray beef carcasses 80 psi, 32°C for 15 seconds with 12% trisodium phosphate (pH 12.31)	*E. coli* O157:H7 and *Clostridium* did not grow nor was destroyed with any of the treatments *Listeria* increased 3 log units in 21 days.	
		Spray beef carcasses 80 psi, 32°C for 15 seconds with 1.5% lactic acid (pH 2.44)	*E. coli* O157:H7 and *Clostridium* did not grow nor was destroyed with any of the treatments *Listeria* did not grow nor was reduced.	
		Spray beef carcasses 80 psi, 32°C for 15 seconds with 3% lactic acid (pH 2.27)	*E. coli* O157:H7 and *Clostridium* did not grow nor was destroyed with any of the treatments *Listeria* did not grow nor was reduced.	

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *E. coli* O157:H7, *Listeria* and *Clostridium* contamination	Spray beef carcasses 80 psi, 32°C for 15 seconds with 1.5% acetic acid (pH 2.82)	*E. coli* O157:H7 and *Clostridium* did not grow nor was destroyed with any of the treatments *Listeria* did not grow nor was reduced.	Dorsa, W.J., C.N. Cutter, and G.R. Siragusa. 1996. (continued)
		Spray beef carcasses 80 psi, 32°C for 15 seconds with 3% acetic acid (pH 2.69)	*E. coli* O157:H7 and *Clostridium* did not grow nor was destroyed with any of the treatments *Listeria* did not grow nor was reduced.	
	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Product Rinse (before Formulation)	B – *E. coli* O157:H7, *Salmonella enteritidis,* and *Listeria monocytogenes* contamination	Electrolyzed oxidizing water with 80+ ppm free chlorine (40+ for *Listeria monocytogenes*) (pH range 2.3 to 2.6) at 39.2°F (4°C) , 73.4°F (23°C), 95°F (35°C) or 113°F (45°C) or water with chlorine added 70 to 80 ppm.	All cultures were negative even by enrichment after 10 minutes at 39.2°F (4°C) and 73.4°F (23°C), 4 minutes at 95°F (35°C), and 3 minutes at 113°F (45°C). Similar results (not published) were found with water and chlorine against *E. coli* O157:H7 and *Listeria monocytogenes.*	Venkitanarayanan, K.S., G.O. Ezeike, Y. Hung, and M.P. Doyle. Efficacy of Electrolyzed Oxidizing Water for Inactivating *Escherichia coli* O157:H7, *Salmonella enteritidis,* and *Listeria monocytogenes.*Applied and Environmental Microbiology. 65 (9) 4276 – 4279.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Product Rinse (before Formulation)	B – Survival and growth of *Salmonella typhimurium*, *Listeria monocytogenes*, and *Campylobacter coli*	Spray pork bellies for 15 seconds with distilled water, chlorinated water (25 ppm), 2% lactic acid, acidic electrolyzed oxidizing water (50 ppm chlorine, pH 2.4 to 2.7), or aged acidic electrolyzed oxidizing water (100 ppm chlorine, pH 2.3) held at 40°F (4°C) 2 days aerobiacally then vacuum sealed and held for 7 days	*S. typhimurium* showed an immediate decrease of at least 1 log unit, and maintained that difference from no treatment at 7 days, but there was no significant difference between treatments *L. monocytogenes* showed an immediate decrease of 1 log unit , and maintained that difference from no treatment at 7 days, but there was no significant difference between treatments. Growth was demonstrated in 7 days *C. coli* showed no significant difference from no treatement in 7 days with all treatment except lactic acid and electrolyzed oxidating (EO) water, though both showed greater than 2 log reduction. When treated with either lactic acid or EO water, *C. coli* was significantly reduced 1.7 log units immediately and maintained that difference at day 2. Once vacuum packaged the level was not significantly different than no treatment.	Fabrizio, K.A., and C.N. Cutter. 2004. Comparison of electrolyzed oxidizing water with other antimicrobial interventions to reduce pathogens on fresh pork. Meat Science. 68 (3) 463-468.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Thawing	B – *Salmonella* growth	Thaw whole chickens at 71.6°F (22°C) for 14 hours or less to internal temperature of 40°F (4.4°C).	When thawed at room temperature, i.e. 71.6°F (22°C), *Salmonella* showed no increases as the internal temperature reached 40°F (4.4°C) in less than 14 hours.	Jiménez, S.M., M.E. Pirovani, M.S. Salsi, M.C. Tiburzi, and O.P. Snyder. 2000. The Effect of Different Thawing Methods on the Growth of Bacteria in Chicken. Dairy, Food, and Environmental Sanitation. 20 (9) 678 – 683.
		Thaw whole chickens at refrigerated temperatures, i.e. 38.3°F to 45°F (3.5°C to 7.2°C), for 33 hours to internal temperature of 40°F (4.4°C).	At refrigerated temperatures , i.e. 38.3°F to 45°F (3.5°C to 7.2°C), *Salmonella* did not increase; however, spoilage bacteria did have time to increase in the 33 hours needed to reach 40°F (4.4°C).	
		Thaw whole chickens in flowing, potable water at 70°F (21°C) for 5 hours to internal temperature of 40°F (4.4°C).	In potable, flowing water at 70°F (21°C), chicken thawed to 40°F (4.4°C) in 5 hours and there was no increase in *Salmonella*.	

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Thawing	B – Growth of *Salmonella, E. coli* O157:H7, and *S. aureus*	1670g chickens or larger thawed at 86°F (30°C) for 9 hours, internal temperature reaching 68°F (20°C)	No pathogen growth was detected.	Ingham, S.C., R.K. Wadhera, M.A. Fanslau, and D.R. Buege. 2005. Growth of *Salmonella* serovars, *Escherichiacoli* O157:H7, and *Staphylococcus aureus* during thawing of whole chicken and retail ground beef protions at 22 and 30°C. Journal of Food Protection. 68(7) 1457-1461.
Cutting	B- *Salmonella typhimurium* contamination from lymph nodes in pork carcasses and primal cuts	Cutting pork carcass cuts which contain lymph nodes such as, ham, shoulder, etc.	The lymph nodes harbor *Salmonella typhimurium*, and could be a potential biological hazard if not removed or if cut into (or incised) during slaughter or processing. Care should be taken not to cut into them. Corrective action should be implemented if they are.	Wood, R.L., and R. Rose. 1989. Distribution of persistent *Salmonella typhimurium* infection in internal organs of swine. American Journal of Veterinary Research. 50 (7) 1015-1021.
	B – *Clostridium*, *Bacilli*, and other pathogenic contamination in abscesses	Cutting into pork carcasses which contain abscesses	Laboratory experience has shown no pathogenic vegetative cells and only Clostridial and Bacillial spores, of which both remained as spores in the anaerobic condition of the abscess.	Correspondence with George Beran, D.V.M, Ph.D., Distinguished Professor; Microbiology, Immunology, Veterinary Preventative Medicine; Iowa State University.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cutting	B – *Salmonella* growth	Times, meat pH, and temperatures to reach level of food safety concern	Insert poultry temperature, pH and % sodium chloride into model to determine *Salmonella* growth.	ARS *Salmonella* growth model: http://www.arserrc.gov/mfs/PATHOGEN.HTM
Process poultry carcasses	B – Pathogen growth during processing	Cutting and trimming poultry meat	If poultry carcasses exceed 55˚F (13˚C) during processing, they must be chilled to <40˚F (4˚C) in 2 hours.	MPI Regulations, Sec. 381.66 (b)(2) Access on internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html
Formulation/ Treatment/ Rinse	B – *L.monocytogenes, S. aureus, S. typhimurium, E. coli* O157:H7, *P. aeruginosa, Y. enterocoliticas* growth	Beef coated with lactoperoxidase (LPS) system chilled slowly from 53.6°F (12°C) on day 1 to 30.2°F (-1°C) by day 7 and held for a total of 42 days	For all bacteria tested log units decreased by about 2 log units during storage on the beef treated with LPS. Only *E. coli* O157:H7 and *P. aeruginosa* decreased when treated only with water. During the 42 day storage *Pseudomonas* and lactic acid bacteria were not retarded by LPS.	Elliot, R.M., J.C. McLay, M.J. Kennedy, R.S. Simmonds. 2004. Inhibition of foodborne bacteria by the lactoperoxidase system in a beef cube system. International Journal of Food Microbiology. 91 (2004) 73-81.
Rinse, dip or spray	B - *S. typhimurium* survival and growth	Lean beef dipped in acetic acid at 20, 45, or 70°C then held at 1°C for 16 hours	*S. typhimurium* was decreased .75 log units at 20°C, 1 log at 45°C and less than 1.5 log units at 70°C.	Anderson, M.E., R.T. Marshall, and J.S. Dickson. 1992. Efficacies of acetic, lactic and two mixed acids in reducing numbers of bacteria on surfaces of lean meat. Journal of Food Safety. 12. 139-147.
		Lean beef dipped in lactic acid at 20, 45, or 70°C then held at 1°C for 16 hours	*S. typhimurium* decreased greater than 1 log unit at 20°C, 1.25 logs at 45°C and greater than 2 log units at 70°C.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Rinse, dip or spray	B - *S. typhimurium* survival and growth	Lean beef dipped in a solution that contained 2% acetic acid, 1% lactic acid, .25% citric acid, and .1% L – ascorbic acids at 20, 45, or 70°C then held at 1°C for 16 hours	*S. typhimurium* decreased 0.75 log units at 20°C and 45°C and greater than 1 log unit at 70°C.	Anderson, M.E., R.T. Marshall, and J.S. Dickson. 1992. (continued)
		Lean beef dipped in a solution that contained 2% lactic acid, 1% acetic acid, .25% citric acid and .1% L – ascorbic acids	*S. typhimurium* decreased 0.75 log units at 20°C and 45°C and greater than 1 log unit at 70°C.	
	Survival and growth of *S. typhimurium* and *E. coli*	Lean beef dipped in 1% lactic acid at 25, 40, 55, and 70°C	*E. coli* and *S. typhimurium* were not reduced by the addition of lactic acid any more than rinse with water.	Anderson, M.E., and R.T. Marshall. 1990. Reducing microbial populations on beef tissues: concentration and temperature of lactic acid. Journal of Food Safety. 10. 181-190.
		Lean beef dipped in 2% lactic acid at 25, 40, 55, and 70°C	*S. typhimurium* was destroyed 1 to 1.5 log units and *E. coli* was destroyed less than 1 log unit at all temperatures.	
		Lean beef dipped in 3% lactic acid at 25, 40, 55, and 70°C	*S. typhimurium* was destroyed 1-2 log units and *E. coli* was destroyed less than 1 log unit at all temperatures.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Rinse, dip or spray	B – *E. coli, L. monocytogenes, Yersinia enterocolitica, Aeromonas hydrophilia,* and other *Enterobacteriaceae* inhibition	Spray beef with 36°F (2°C) 1.2% acetic or lactic acid for 120 seconds	This spray treatment inhibits the growth of bacteria on raw meat up to 9 days when stored at 36°F (2°C) (1.7 log units less than without the treatment).	Kotula, K.L., and R. Thelappurate. 1994. Microbiological and sensory attributes of retail cuts of beef treated with acetic and lactic acid solutions. Journal of food Protection. 57 (8) 665 – 670.
		Dip pork for 2 minutes into a 3% acetic acid with 2% salt or 3% sodium ascorbate solution	A bacterial hazard is reduced by 2.0 log units when the whole muscle product is dipped, vacuum packed and stored at 36 – 40°F (2-4°C).	Mendonca, A.F., R.A. Molins, A.A. Kraft, and H.W. Walker. 1989. Microbiological, chemical and physical changes in fresh, vacuum-packaged pork treated with organic acids and salts. Journal of Food Science. 54 (1) 18-21.
		Dip pork for 15 seconds into a 3% lactic acid solution at 131˚F (55˚C) and store at 40˚F (4˚C) for at least 4 days	After 4 days up to 15 days of storage at 40˚F (4˚C) the level of *Yersinia enterocolitica,* and *Aeromonas hydrophilia* was reduced 2-3.5 log units to undetectable levels. *L. monocytogenes* was reduced about 2 log units and remained at about 4 log units for the duration.	Greer, G.G., and B.D. Dilts, 1995. Lactic-acid inhibition of the growth of spoilage bacteria and cold tolerant pathogens on pork. International Journal of Food Microbiology. 25 (2) 141 – 151.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Rinse, dip or spray	B – *E. coli* O157:H7 survival and growth	Dipped beef rounds in 2% low molecular weight polylactic acid, or 2% lactic acid with or without 400 IU/ml nisin then vacuum packaged and stored at 40˚F (4˚C) for 28 days	All treatments lowered *E. coli* O157:H7 less than 1.5 log units. There was no significant difference between treatments and nisin made no contribution to the antimicrobial effect of the treatments.	Mustapha, A., T. Ariyapitipun, and A.D. Clarke. 2002. Survival of Escherichia Coli O157:H7 on vacuum-packaged raw beef treated with polylactic acid, lactic acid and nisin. Journal of Food Science. 67 (1) 262-267.
	B – Survival of *E. coli* O157:H7, or *S. aureus*	Spray beef brisket at 77°F to 79°F (25°C to 26°C) at 60 psi for 10, 15, 30 or 60 seconds with water	*E. coli* O157:H7 was reduced 0.7 log units when sprayed 10 to 60 seconds *S. aureus* was not significantly reduced even after spraying for 60 seconds	Hajmeer, M.N., J.L. Marsden,, D.Y.C. Fung, and G.K. Kemp. 2004. Water, sodium chloride and acidified sodium chlorite effects on *Escherichia coli* O157:H7 and *Staphylococcus aureus* on beef briskets. Meat Science. 68 (2) 277-283.
		Spray beef brisket at 77°F to 79°F (25°C to 26°C) at 60 psi for 10, 15, 30 or 60 seconds with 25% salt solution	*E. coli* O157:H7 was reduced 0.7 log units when sprayed 10 to 60 seconds *S. aureus* was not significantly reduced up to 30 seconds sprayed but was reduced 0.4 log units when sprayed for 60 seconds	
		Spray beef brisket at 77°F to 79°F (25°C to 26°C) at 60 psi for 10, 15, 30 or 60 seconds with 0.1% acidified sodium chlorite solution	*E. coli* O157:H7 was reduced 1.5 log units when sprayed for 30 seconds, only 1 log reduction when sprayed for 10, 15 or 60 seconds *S. aureus* was reduced 0.8 log units when sprayed for 10 to 60 seconds	

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging	B – Fecal contamination pathogen survival including but not limited to *Campylobacter*, and *L. monocytogenes*	Fresh pork loins, hot boned and vacuum packaged, stored at 34˚F (1˚C)	Hot processed and packaged meat supported survival and growth of pathogenic fecal bacteria despite immediate storage at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	Van Laack, R.L.J.M., J.L Johnson, C.J.N.M. van der Palen, F.J.M. Smulders, and J.M.A. Snijders. 1993. Survival of pathogenic bacteria on pork loins as influenced by hot processing and packaging. Journal of Food Protection. 56 (10) 847-851.
		Fresh pork loins, chilled and vacuum packaged, stored at 34˚F (1˚C)	There was no appreciable effect of packaging on the growth or survival of pathogenic bacteria with vacuum packaging. A hazard is likely to occur if fecal contamination is not removed prior to storage.	
		Fresh pork loins, chilled and left unpackaged, stored at 34˚F (1˚C)	*Campylobacter*, *L. monocytogenes* and other pathogens will continue to survive and grow even at refrigerated temperatures. A hazard is likely to occur if fecal contamination is not removed prior to storage.	
	B – Growth of *Listeria monocytogenes*	Vacuum packaged beef strip loin pH 5.5-5.7 stored at 32˚F (5.3˚C)	*L. monocytogenes* showed no log change on lean meat and showed a 2 log increase on fat after 76 days.	Grau, F.H., and P.B. Vanderlinde. 1990. Growth of *Listeria monocytogenes* on vacuum-packaged beef. Journal of Food Protection. 53 (9) 739-741.
		Vacuum packaged beef strip loin pH 5.5-5.7 stored at 41.5˚F (0˚C)	*L. monocytogenes* showed a 2.5 log growth on lean meat and showed a 4 log increase on fat after 30 days.	

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging	B- *Salmonella* growth	Pork loins vacuum packaged and stored at 36˚F (2˚C)	*Salmonella* prevalence reduced from 0.7% to zero after 36 days of storage at 36˚F (2˚C).	Saide, J.J., C.L. Knipe, E.A. Murano, and G.E. Beran. 1995. Contamination of pork carcasses during slaughter, fabrication and chilled storage. Journal of Food Protection. 58 (9) 993-997.
	B – Pathogen growth	Poultry internal temperature maintained at 40˚F (4˚C) during storage and at 55˚F (12.8˚C) during processing.	… Eviscerated poultry to be shipped from the establishment in packaged form shall be maintained at 40˚F (4˚C) or less, except that during further processing and packaging operations, the internal temperature may rise to a maximum of 55˚F (12.8˚C). Provided that immediately after packaging, the poultry is placed under refrigeration at a temperature that will promptly lower the internal temperature of the product to 40˚F (4˚C) or less, or the poultry is placed in a freezer…	FSIS poultry processing regulation: 381.66(b) Access on the internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html
Storage	B – Survival of *E. coli* O157:H7	Storage of lean beef trimmings quickly frozen (initially -31°F (-35°C)) or slowly frozen (0°F (-18°C)) for 12 weeks	There was no significant decrease in *E. coli* O157:H7 when held frozen at 0°F (-18°C) for up to 12 weeks. Slow freezing of some strains demonstrated at least 1 log reduction, however this was not consistent across all tested strains	Dykes, G.A. 2000. The effect of freezing on the survival of *Escherichia coli* O157:H7 on beef trimmings. Food Research International. 33(5) 387-392.

Raw not-ground process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth of *E. coli* and *Salmonella typhimurium*	Mutton carcasses and meat held at 50°F (10°C) or lower	Lag time for *E. coli* and *Salmonella typhimurium* was 23.25 hours and generation time was 6.7 hours at 50°F (10°C) and increased infinitely as temperature decreased	Smith, M.G. 1985. The generation time, lag time, and minimum temperature o growth of coliform organisms on meat, and the implications for codes of practice in abattoirs. Journal of Hygiene Cambridge. 94 (1) 289-300.
	B – Survival of *E. coli* O157:H7 and *Listeria monocytogenes*	Broth held at -18°F (-28°C), 0°F (-18°C) or 23°F (-5°C) for up to 21 days	*E. coli* O157:H7 decreased 0.5 log units at -18°F (-28°C), and 1.5 log units at 0°F (-18°C) in 7 days and remained constant for 21 days. There was no decrease in 21 days at or 23°F (-5°C) *L. monocytogenes* showed less than 0.5 log reduction in 21 days at all three temperatures.	Chou, C.C., S.J. Cheng, Y.C. Wang, and K.T. Chung. 1999. Behavior of Escherichia coli O157:H7 and Listeria monocytogenes in tryptic soy broth subjected to various low temperature treatments. Food Research International. 32 (1) 1-6.
	B-growth of *Staphylococcus aureus*, *Clostridium botulinum*, and *Clostridium perfringens*	pH, water activity, temperature and time limits	Unless product is shelf stable, other methods must be used to prevent growth (e.g., low pH, freezing, low water activity, refrigeration temperature and time limits)	FSIS. 2005. Meat and Poultry Hazards and Controls Guide. Pg. 24 http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/5100.2/Meat_and_Poultry_Hazards_Controls_Guide_10042005.pdf

Raw, Non-Intact Process

Includes: beef, pork, lamb and poultry, which have been ground, injected, tenderized, etc.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Carcass rinse	B – Coliforms and *S. aureus* growth	Beef fore quarter sprayed with hypochlorus acid, 200 mg/L, pH 6-6.5 at 100 lbs/in^2 for 12 seconds at 16°C ground, packaged in low oxygen permeable film at 2°C	There was no significant difference in numbers of coliform and *S. aureus* from day 0 to day 13 between beef with hypochlorus acid and without, however, the beef trim started with higher levels of contamination.	Johnson, M.G., T.C. Titus, L.H. McCaskill, and J.C. Acton. 1979. Bacterial counts on surfaces of carcasses and in ground beef from carcasses sprayed or not sprayed with hypochlorous acid. Journal of Food Science. 44 (1) 169-173.
		Frozen boneless lean beef, ground, packaged in low oxygen permeable film stored at 2°C		
		Beef fore quarters; ground, packaged in low oxygen permeable film stored at 2°C		

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Product Rinse (before Formulation)	B – *E. coli* O157:H7, *Salmonella enteritidis,* and *Listeria monocytogenes* contamination	Electrolyzed oxidizing water with 80+ ppm free chlorine (40+ for *Listeria monocytogenes*) (pH range 2.3 to 2.6) at 39.2°F (4°C) , 73.4°F (23°C), 95°F (35°C) or 113°F (45°C) or water with chlorine added 70 to 80 ppm.	All cultures were negative even by enrichment after 10 minutes at 39.2°F (4°C) and 73.4°F (23°C), 4 minutes at 95°F (35°C), and 3 minutes at 113°F (45°C). Similar results (not published) were found with water and chlorine against *E. coli* O157:H7 and *Listeria monocytogenes.*	Venkitanarayanan, K.S., G.O. Ezeike, Y. Hung, and M.P. Doyle. 1999. Efficacy of Electrolyzed Oxidizing Water for Inactivating *Escherichia coli* O157:H7, *Salmonella enteritidis,* and *Listeria monocytogenes.* Applied and Environmental Microbiology. 65 (9) 4276 – 4279.
Cutting	B- *Salmonella typhimurium* contamination from lymph nodes in pork carcasses and primal cuts	Cutting, trimming and grinding pork carcass cuts which contain lymph nodes such as, ham, shoulder, etc.	The lymph nodes harbor *Salmonella typhimurium*, and could be a potential biological hazard if not removed or if cut into (or incised) during slaughter or processing. Care should be taken not to cut into them. Corrective action should be implemented if they are.	Wood, R.L., and R. Rose. 1989. Distribution of persistent *Salmonella typhimurium* infection in internal organs of swine. American Journal of Veterinary Research. 50 (7) 1015-1021.

Raw, Ground Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cutting	B – *Clostridium, Bacilli*, and other pathogenic contamination in abscesses	Cutting into pork carcasses which contain abscesses	Laboratory experience has shown no pathogenic vegetative cells and only Clostridial and Bacillial spores, of which both remained as spores in the anaerobic condition of the abscess.	Correspondence with George Beran, D.V.M, Ph.D., Distinguished Professor; Microbiology, Immunology, Veterinary Preventative Medicine; Iowa State University.
	B – *Salmonella* growth	Times, meat pH, and temperatures to reach level of food safety concern	Insert poultry temperature, pH and % sodium chloride into model to determine *Salmonella* growth.	ARS *Salmonella* growth model: http://www.arserrc.gov/mfs/PATHOGEN.HTM
Thawing	B – Growth of *Salmonella, E. coli* O157:H7, and *S. aureus*	453g ground beef thawed at 86°F (30°C) or 81.5°F (22°C) for 9 hours, internal temperature reaching 80.6°F (27°C) and 62.6°F (17°C) respectively	There were less than 0.5 log growth for these pathogens.	Ingham, S.C., R.K. Wadhera, M.A. Fanslau, and D.R. Buege. 2005. Growth of *Salmonella* serovars, *Escherichiacoli* O157:H7, and *Staphylococcus aureus* during thawing of whole chicken and retail ground beef protions at 22 and 30°C. Journal of Food Protection. 68(7) 1457-1461.
		1359g ground beef thawed at 86°F (30°C) for 9 hours, internal temperature reaching 52°F (11°C)	There was no growth for these pathogens.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Nitrite addition	C and B – Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. For internet access, go to: file:///C:/Users/knipe.1/Documents/HACCPTraining/HACCPPhase2/BorchertandCassensNitriteChemHazard1998.html
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
	C and B – Excessive nitrite level in product	Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7I To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
Phosphate addition	B – Growth of *L. monocytogenes, S. typhimurium,* and *E. coli* O157:H7	Addition of 0.5% phosphate blend to ground beef or pork	There is minimal or no effect of the phosphate addition on the growth of *L. monocytogenes, S. typhimurium,* and *E. coli* O157:H7.	Flores, L.M., S.S. Sumner, D.L. Peters, and R. Mandigo. 1996. Evaluation of a phosphate to control pathogen growth in fresh and processed meat products. Journal of Food Protection. 59 (4) 356-359.

Raw, Ground Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival of *E.coli* O157:H7	Ground beef with Sodium Lactate (0.9% or 1.8%), Sodium Diacetate (0.1%, or 0.2%), Sodium Citrate (1% or 2%) or a combination of Sodium Lactate and Diacetate (0.9% and 0.1%, or 1.8% and 0.2%) then stored at 36°F (2°C) or 50°F (10°C)	*E. coli*O157:H7 significantly decreased by the time the meat appeared spoiled when store at 36°F (2°C) but not when stored at 50°F (10°C).	Ajjarapu, S., and L.A. Shelef. 1999. Fate of pGFP-bearing *Escherichia coli* O157:H7 in ground beef a t 2 and 10°C and effects of lactate, diacetate and citrate. Applied and Environmental Microbiology. 65(12) 5394-5397.
	B- *E. coli* O157:H7 growth	Storage of *E. coli* O157:H7 at various temperatures, NaCl levels and pH levels	There was no growth of *E. coli* O157:H7 below 46.4°F (8°C), and slow to no growth when salt levels were above 20g/L. pH ranging from 4.5 to 8.5 did not greatly effect growth. All combinations of salt, ranging from 5 g/L to 35 g/L, pH (4.5 to 8.5) and temperature 82.4°F (28°C) and higher grew *E. coli* O157:H7.	Buchanan, R.L., and L.A. Klawitter. 1992. The effect of incubation temperature, initial pH, and sodium chloride on the growth kinetics of *Escherichia coli* O157:H7. Food Microbiology. 9 (3) 185-196.
	B – *Salmonella, L. monocytogenes* and *E.coli* O157:H7 contamination	Lean beef trimmings pH enhanced with ammonia gas to 9.6	*Salmonella*, *L.monocytogenes*, and *E.coli* O157:H7 were reduced by 4, 3, and 1 log unit, respectively, by the change in pH.	Niebuhr, Steven E. and J.S. Dickson. 2002. Impact of pH Enhancement on Populations of *Salmonella, Listeria monocytogenes*, and *Escherichia coli* O157:H7 in Boneless Lean Beef

Raw, Ground Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – *Salmonella, L. monocytogenes* and *E.coli* O157:H7 contamination	Lean beef trimmings pH enhanced with ammonia gas to 9.6, then frozen, chipped and compressed into blocks	After freezing, no *Salmonella* or *E.coli* O157:H7 were detectable and *L. monocytogenes* was reduced 3 log units total.	Trimmings. Journal of Food Protection. 66 (5) 874-877.
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.
Process poultry carcasses	B – Pathogen growth during processing	Cutting, trimming and grinding poultry meat	If poultry carcasses exceed 55˚F (13˚C) during processing, they must be chilled to <40˚F (4˚C) in 2 hours.	MPI Regulations, Sec. 381.66 (b)(2) Access on internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html
Storage	B – *S. typhimirum* growth	Times and temperatures to reach level of food safety concern	You enter the time and temperatures between 46˚F (8˚C) and 118˚F (48˚C). This spreadsheet will provide you with lag time growth rate and overall log growth for the parameters set.	Poultry Food Access Risk Model (FARM), on ARS Website: http://www.arserrc.gov/mfs/Pfarmrsk.htm#pre

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *Listeria monocytogenes* contamination and growth	pH of uncooked bratwurst 5.35-6.45 stored at 40˚F (4.4˚C)	A hazard is likely if contaminated ($6.1x10^2$ inoculation) with *Listeria monocytogenes*. It will continue to grow (4 log increase over 6 weeks) and create a biological risk.	Glass, K.A., and M.P. Doyle. 1989. Fate of *Listeria monocytogenes* in processed meat products during refrigerated storage. Applied and Environmental Microbiology. 55 (6) 1565-1569.
	B – *Staphylococcus aureus* growth	Storage at 50˚F (10˚C) or lower	Minimum *Staphylococcus aureus* growth temperature is 50˚F (10˚C).	Troller, J.A. 1976. Staphylococcal growth and enterotoxin production factors for control. Journal of Milk and Food Technology. 39: 499-503.
	B – *Staphylococcus aureus* toxin production	Storage at 50˚F (10˚C) or lower	Minimum toxin production temperature is a few degrees above the minimum growth temperature.	Pereira, J.L., S.P. Salsberg, and M.S. Bergdoll. 1982. Effect of temperature, pH and sodium chloride concentrations on production of staphylococcal enterotoxins A and B. Journal of Food Protection. 45: 1306-1309.
	B – *Yersinia enterocolitica* growth	Storage of raw pork at 44.5˚F (6.9˚C) for 10 days	*Y. enterocolitica* showed a 4 log increase at 44.5˚F (6.9˚C) in 10 days.	Food Safety and Inspection Service. Facts. 1989. Preventable foodborne illness. May. 5-14.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *Salmonella* growth	Storage at 44˚F (6.7˚C) or lower	Lowest *Salmonella* growth temperature reported in a food was 44˚F (6.7˚C).	Angelotti, R., M.J. Foter, and K.H. Lewis, 1961. Time-temperature effects on *Salmonella* and *Staphylococci* in foods. 1. Behavior in refrigerated foods. American Journal of Public Health. 51: 76-88.
		Storage at 41.5˚F (5.3˚C) or 43.2˚F (6.2˚C) or lower	Lowest temperature for growth: 41.5˚F (5.3˚C) *S. Heildelberg* 43.2˚F (6.2˚C) *S. typhimurium*	Matches, J.R., and J. Liston. 1968. Low temperature growth of *Salmonella*. Journal of Food Science. 33: 641-645.
		Vacuum packaged ground beef storage	Lowest temperature for growth of *Salmonella* on vacuum packaged ground beef is 50˚F (10˚C).	Ayres, J.C. 1978. *Salmonella* in meat products. In proceedings from the 31st annual Reciprocal Meats Conference. 148-155.
	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival of *E. coli* O157:H7	Storage of ground beef at –4˚F (-20˚C)	There was no log change in *E. coli* O157:H7 when stored at –4˚F (-20˚C) for 0 to 9 months.	Doyle, M.P., J.L. Schoeni. 1984. Survival and growth characteristics of *Eschrichia coli* associated with hemorrhagic colitis. Applied and Environmental Microbiology. 10, 855-856.
	B – Growth of *E. coli* and *Salmonella typhimurium*	Mutton carcasses and meat held at 50°F (10°C) or lower	Lag time for *E. coli* and *Salmonella typhimurium* was 23.25 hours and generation time was 6.7 hours at 50°F (10°C) and increased infinitely as temperature decreased	Smith, M.G. 1985. The generation time, lag time, and minimum temperature o growth of coliform organisms on meat, and the implications for codes of practice in abattoirs. Journal of Hygiene Cambridge. 94 (1) 289-300.
	B – Survival and growth of *E. coli* O157:H7	Vacuum packaged ground beef, and fresh pork sausage stored at 40˚F (4˚C) for 7 days	At 40˚F (4˚C) there was approximately 0.7 log reduction in the number of *E. coli* O157:H7 organisms.	Flores, L.M., S.S. Sumner, D.L. Peters, and R. Mandigo. 1996. Evaluation of a phosphate to control pathogen growth in fresh and processed meat products. Journal of Food Protection. 59 (4) 356-359.
		Vacuum packaged ground beef, and fresh pork sausage stored at 54˚F (12˚C) for 7 days	At 54˚F (12˚C) *E. coli* O157:H7 grew 1.5-2 log units in pork and 5-6 log units in beef in 7 days.	
		Vacuum packaged ground beef, and fresh pork sausage stored at 68˚F (20˚C) for 24 hours	At 68˚F (20˚C) *E. coli* O157:H7 grew 1.5-2 log units in pork and 3.5-4 log units in beef in 24 hours.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth of *L. monocytogenes* and *S. typhimurium*	Vacuum packaged ground beef, and fresh pork sausage stored at 40˚F (4˚C) for 7 days	At 40˚F (4˚C) there was little (less than 0.5 log reduction) or no growth of *L. monocytogenes* and *S. typhimurium.*	Flores, L.M., S.S. Sumner, D.L. Peters, and R. Mandigo. 1996. (Continued)
	B – Growth of *L. monocytogenes* during refrigeration	Storage of ground beef (pH 6.2, and 15 or 38% fat) at 40˚F (4˚C)	*L. monocytogenes* showed a generation time of 1.2 days for 15% fat and 1.45 days for 38% fat.	Rosso, L., S. Bajard, J.P. Flandrois, C. Lahellec, J. Fournaud, and P. Veit. 1996. Differential growth of *Listeria monocytogenes* at 4 and 8˚C: Consequences for the shelf life of chilled products. Journal of Food Protection. 59 (9) 944-949.
		Storage of minced beef (pH 6.2, and 15 or 38% fat) at 42˚F (6˚C)	*L. monocytogenes* showed a generation time of 0.4 days for 15% fat and 38% fat.	
		Storage of minced beef (pH 6.2, and 15 or 38% fat) at 46˚F (8˚C)	*L. monocytogenes* showed a generation time of 0.3 days for 15% fat and 0.35 days for 38% fat.	
		Storage of minced beef (pH 6.2, and 15 or 38% fat) at 54˚F (12˚C)	*L. monocytogenes* showed a generation time of 0.2 days for 15% fat and 0.1 days for 38% fat.	
	B-growth of *Staphylococcus aureus*, *Clostridium botulinum*, and *Clostridium perfringens*	pH, water activity, temperature and time limits	Unless product is shelf stable, other methods must be used to prevent growth (e.g., low pH, freezing, low water activity, refrigeration temperature and time limits)	FSIS. 2005. Meat and Poultry Hazards and Controls Guide. Pg. 24 http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/5100.2/Meat_and_Poultry_Hazards_Controls_Guide_10042005.pdf

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Frozen storage times and temperatures	B – Survival of *E. coli* O157:H7	Storage of lean beef trimmings quickly frozen (initially -31°F (-35°C)) or slowly frozen (0°F (-18°C)) for 12 weeks	There was no significant decrease in *E. coli* O157:H7 when held frozen at 0°F (-18°C) for up to 12 weeks. Slow freezing of some strains demonstrated at least 1 log reduction, however this was not consistent across all tested strains	Dykes, G.A. 2000. The effect of freezing on the survival of *Escherichia coli* O157:H7 on beef trimmings. Food Research International. 33(5) 387-392.
		Ground beef held at 0°F (-18°C) for up to 240 hours	*E. coli* O157:H7 survived the first 72 hours at 0°F (-18°C), after 120 hours the survivors decreased by 10 to 30% and 40 to 65% after 240 hours. The was not a difference between cells that had been cold shocked (50°F (10°C) for 6 hours) or not (68°F (20°C) constantly).	Grzadkowska, D., and M.W. Griffiths. 2001. Cryotolerance of *Escherichia coli* O157:H7 in laboratory media and food. Journal of Food Science. 66(8). 1169-1173.
Frozen storage times and temperatures	B – Survival of *E. coli* O157:H7 and *Listeria monocytogenes*	Broth held at -18°F (-28°C), 0°F (-18°C) or 23°F (-5°C) for up to 21 days	*E. coli* O157:H7 decreased 0.5 log units at -18°F (-28°C), and 1.5 log units at 0°F (-18°C) in 7 days and remained constant for 21 days. There was no decrease in 21 days at or 23°F (-5°C) *L. monocytogenes* showed less than 0.5 log reduction in 21 days at all three temperatures.	Chou, C.C., S.J. Cheng, Y.C. Wang, and K.T. Chung. 1999. Behavior of Escherichia coli O157:H7 and Listeria monocytogenes in tryptic soy broth subjected to various low temperature treatments. Food Research International. 32 (1) 1-6.
	B – Survival of *Trichinella spiralis*	Freezing ground pork for a given time-temperature interval	Trichina are non-infectious when frozen to the time-temperature relationship found with the equation: log (time in hours) = 5.98 + 0.40 (temperature ˚C).	Kotula, A.W., A.K. Sharar, E. Paroczay, H.R. Gamble, K.D. Murrell, and L. Douglass. 1990. Infectivity of *Trichinella spiralis* from frozen pork. Journal of Food Protection. 53 (7) 571-573.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Frozen storage times and temperatures	B – Survival of *Trichinella spiralis*	Freezing ground pork for a given time-temperature interval	*Trichinella spiralis* will be destroyed at these specific time-temperature intervals: 0˚F (-18˚C) for 106 hours -5˚F (-21˚C) for 82 hours -10˚F (-23˚C) for 63 hours -15˚F (-26˚C) for 48 hours -20˚F (-29˚C) for 35 hours -25˚F (-32˚C) for 22 hours -30˚F (-35˚C) for 8 hours -35˚F (-37˚C) for 1/2 hour	CFR 318.10 I (iv) Table 2. To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
Thawing	B – *Salmonella* growth	Thaw whole chickens at 71.6°F (22°C) for 14 hours or less to internal temperature of 40°F (4.4°C).	When thawed at room temperature, i.e. 71.6°F (22°C), *salmonella* showed no increases as the internal temperature reached 40°F (4.4°C) in less than 14 hours.	Jiménez, S.M., M.E. Pirovani, M.S. Salsi, M.C. Tiburzi, and O.P. Snyder. 2000. The Effect of Different Thawing Methods on the Growth of Bacteria in Chicken. Dairy, Food, and Environmental Sanitation. 20 (9) 678 – 683.
		Thaw whole chickens at refrigerated temperatures, i.e. 38.3°F to 45°F (3.5°C to 7.2°C), for 33 hours to internal temperature of 40°F (4.4°C).	At refrigerated temperatures , i.e. 38.3°F to 45°F (3.5°C to 7.2°C), *Salmonella* did not increase; however, spoilage bacteria did have time to increase in the 33 hours needed to reach 40°F (4.4°C).	

Raw, Ground Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Thawing	B – *Salmonella* growth	Thaw whole chickens in flowing, potable water at 70°F (21°C) for 5 hours to internal temperature of 40°F (4.4°C).	In potable, flowing water at 70°F (21°C), chicken thawed to 40°F (4.4°C) in 5 hours and there was no increase in *salmonella*.	Jiménez, S.M., M.E. Pirovani, M.S. Salsi, M.C. Tiburzi, and O.P. Snyder. 2000. (Continued)

Fully-Cooked, Not Shelf Stable Process

Includes: Fully cooked hams, wieners, bologna, luncheon meats, summer sausage, etc.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C – Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://meatsci.osu.edu/sites/meatsci/files/imce/BorchertCassensNitriteHazard1998.pdf
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite).	CFR 318.7I To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
	B – Pathogen competition and growth against *Lactobacillus* and *Leuconostoc* growth	Adding 3-4% sodium lactate to cooked beef	If product contains 3-4% sodium lactate, the micro flora shift to primarily *Lactobacillus* during the 84 day shelf life at 32°F (0°C) indicating that a hazard is not likely to occur.	Papadopoulos, L.S., R.K. Miller, G.R. Acuff, C. Vanderzant, and H.R. Cross. 1991. Effect of sodium lactate on microbial and chemical composition of cooked beef during storage. Journal of Food Science. 56 (2) 341-347.
		Not adding 3-4% sodium lactate	*Leuconostoc* spp., organisms that are not a likely hazard, are the dominant bacteria after 56 days of storage at 32°F (0°C) when little or no sodium lactate is added to product.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Pathogen survival	Addition of smoke (liquid or solid) to products	At the manufacturers' recommended levels, most bacteria were not inhibited by the addition of smoke to growth medium.	Suñen, E. 1998. Minimum inhibitory concentration of smoke wood extracts against spoilage and pathogenic micro-organisms associated with foods. Letters in Applied Microbiology. 27 (1) 45 – 48.
	B – Growth of pathogenic bacteria and mold	Addition of liquid smoke to products	All smokes tested showed some additional anti-microbial activity. The most effective have low pH and high carbonyl content, while phenols do not seem to effect microbial inhibition.	Milly, P.J., R.T. Toledo, S. Ramakrishnan. 2005. Determination of Minimum Inhibitory Concentrations of Liquid Smoke Fractions. Journal of Food Science. 70 (1) M12 – M17.
	B – *C. botulinum* growth and toxin formation	Pork liver sausage with pork trim, calcium reduced dry milk, salts, spices, and nitrite. Cooked at 76.5°C (170°F) for 60 minutes then stored at 27°C (80.6°F) for 4 weeks	When no nitrite was added all sausages were toxic by week 2. At 50 ppm sausages were toxic by week 3, and at 100 ppm toxins were found at week 4. At 150 ppm. No sausages were found to have toxins at week 4.	Hauschild, A.H.W., R. Hilsheimer, G. Jarvis, and D.P. Raymond. 1982. Contribution of Nitrite to the Control of *Clostridum botulinum* in Liver Sausage. Journal of Food Protection. 45 (6) 500-506.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – *C. botulinum* growth and toxin formation	Vacuum packaged spaghetti and meat sauce (pH 4.5 - 6) processed at 75°C (167°F) for 36 minutes then stored at 15°C (59°F) for 42 days	Toxin was detected in samples with pH >5.5 after 14 days. When pH was 5.25. toxin was found after 35 days and no toxin was found when pH was <5.25. When salt concentration was >1.5%, there was no toxin production in the 42 days. Microwave heating 5-10 minutes at full or half power (880 watt microwave) inactivated the toxin.	Simpson, M.V., J.P. Smith, K.Dodds, H.S. Ramaswamy, B. Blanchfield and B.K. Simpson. 1994. Challenge Studies with *Clostridium botulinum* in a Sous-Vide Spaghetti and Meat-Sauce Product. Journal of Food Protection. 58 (3) 229-234.
	B – *L. monocytogenes, Staphylococcus aureus, S. typhimurium, E. coli,* and *Clostridium perfringens* growth	Addition of 2% sodium lactate (NaL) to cooked beef round stored for 28 days at 50°F (10°C)	There is no appreciable difference between the control (no lactate) and adding 2% NaL. *L. monocytogenes, S. typhimurium,* and *E. coli*, increased by at least 3 log units *S. aureus* grew 1.5 log units and *C. perfringens* was not detected after 7 days.	Miller, R.K. and G.R. Acuff. 1994. Sodium lactate affects pathogens in cooked beef. Journal of Food Science. 59 (1) 15-19.
		Addition of 3% sodium lactate to cooked beef round stored for 28 days at 50°F (10°C)	There was 2.5 log units of growth of *L. monocytogenes* with 3% lactate (no lactate, 4.5 log growth); 1 log decrease of *S. typhimurium* with 3% lactate (no lactate, 4 log growth); 1 log growth of *E. coli* (no lactate, 3 log growth); no change in count of *S. aureus* with no lactate or 3% lactate, and *C. perfringens* was not detected in any of the samples after 14 days.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – *L. monocytogenes,* et all, growth (continued)	Addition of 4% sodium lactate to cooked beef round stored for 28 days at 50°F (10°C)	There was less than 0.5 log change in *L. monocytogenes, S. aureus, S. typhimurium, E. coli* O157:H7, and no *C. perfringens* were detected after 14 days with 4% lactate. Those samples with no lactate *L. monocytogenes, S. typhimurium,* and *E. coli* O157:H7, increased by at least 3 log units *S. aureus* grew 1.5 log units and *C. perfringens* was not detected after 7 days.	Miller, R.K. and G.R. Acuff. 1994. (continued)
	B- growth of *Listeria*	Bologna type sausages containing 120 ppm nitrite, 2% salt and 0-4% sodium lactate syrup (60%) predicted *L. innocua* growth at 45-68°F (7-20°C)	*L. innocua* growth was predicted, though somewhat low, by the equation: Growth rate/ hour $= 0.0361^2 x(^oC + 0.927)^2 x$ $\frac{1335x[(606\,pH - 3066) - p]}{(606\,pH - 3066)(1335 - p)}$ where *p* is the millimolar concentration of sodium lactate	Houtsma, P.C., M.L. Kant-Mutermans, F.M. Rombouts, and M.H. Zwietering. 1996. Model for the Combined Effects of Temperature, pH, and Sodium Lactate on Growth Rates of *Listeria innocua* in Broth and Bologna-Type Sausages. Applied and Environmental Microbiology. 62 (5) 1616-1622.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes, A. hydrophila,* and *Y. enterocolitica*	Addition of smoke (liquid or solid), at the manufacturers' recommended level, to products and held at 41°F (5°C) for up to 21 days.	Some smoke products can inhibit *L. monocytogenes*, , *A. hydrophila,* and *Y. enterocolitica* for up to 21 days, but *L. monocytogenes* and *Y. enterocolitica* show no log reduction in that time.	Suñan, E. B. Fernandez-Galian, and C. Aristimuño. 2001. Antibacterial activity of smoke wood condensates against *Aeromonas hydrophila, Yersinia enterocolitica* and *Listeria monocytogenes* at low temperature. Food Microbiology. 18 (4) 387 – 393.
	B – Growth of *L. monocytogenes* and *Salmonella*	Beef bologna with 2.5% sodium lactate, 0.2% sodium diacetate or both stored at 5°C (41°F) or 10°C (50°F)	After 45 days at 5°C there was no to slight growth (less than 1 log) of *L. monocytogenes* with either or both of the salts. At 10°C, there was 2 to 5 log growth. In all cases, including without salts, *Salmonella* was undetectable after 30 days at both 5°C and 10°C	Mbandi, E. and L.A. Shelef. 2002. Enhanced antimicrobial effects of combination of lactate and diacetate on *Listeria monocytogenes* and *Salmonella* spp. in beef bologna. International Journal of Food Microbiology. 76 (2002) 191-198.
	B – Growth of *L. monocytogenes*	Ground beef (55% moisture) with 2%NaCl, and 2-3% Sodium lactate stored at 68°F (20°C)	*L. monocytogenes* showed less than 0.5 log growth over 7 days.	Chen, N., and L.A. Shelef, 1992. Relationship between water activity, salts of lactic acid and growth of *Listeria monocytogenes* in a meat model system. Journal of Food Protection. 55 (8) 574-578.
		Ground beef (55% moisture) with 2-3% Sodium lactate stored at 68°F (20°C).	*L. monocytogenes* showed a 5 log growth in 5 days with 2% NaL.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L monocytogenes*	Rainbow trout with 21g/kg salt, cold smoked then injected with 36g/kg sodium lactate, 240 IU/g Nisinora combination of 18g/kg sodium lactate and 120 IU/g Nisin and stored 17 days at 46.4°F (8°C).	The addition of Nisin only allowed 2 log units of growth however, this was 1.7 log less than no treatment. Lactate alone decreased *L.monocytogenes* by less than 0.5 log units. The combination of Nisin and lactate decreased *L.monocytogenes* 1.5 log units	Nykanen, A., K. Weckman, and A. Lapvetelainen. 2000. Synergisitc inhibition of *Listeria monocytogenes* on cold smoked rainbow trout by nisin and sodium lactate. International Journal of Food Microbiology. 61 (2000) 63-72.
		Rainbow trout with 15g/kg salt injected with 36g/kg sodium lactate, 240 IU/g Nisinora combination of 18g/kg sodium lactate and 120 IU/g Nisin, cold smoked then held 30 days at 37.4°F (3°C).	In all treatments *L. monocytogenes* grew. The combination of lactate and Nisin only allowed 0.1 log growth in the 30 days, Nisin alone allowed 1.2 log growth and lactate allowed 1.3 log growth as compared to no treatment which showed 1.8 log units of growth.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO_2) 4% Potassium or Sodium Lactate, stored at 95°F (35°C)	4% lactate inhibited growth by1- 2 log units, however overall growth was 4-5 log units in 68 hours.	Shelef, L.A., and Q. Yang. 1991. Growth suppression of *Listeria monocytogenes* by lactates in broth, chicken and beef. Journal of Food Protection. 54 (4) 283-287.
		Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO_2) 4% Potassium or Sodium Lactate, stored at 68°F (20°C)	4% lactate inhibited growth by 1-2 log units, however overall growth was 4-6 log units in 8 days.	
		Ground beef or chicken with added broth (2 – 3% NaCl, 140 ppm KNO_2) 4% Potassium or Sodium Lactate, stored at 68°F (20°C)	4% lactate inhibited growth by 2-4 log units in beef and no inhibition in chicken was found. Overall growth was 2-6 log units in 21 days.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	Bologna type sausage with 2% sodium lactate	No *L. monocytogenes* growth was detected when held at 41°F (5°C) for 28 days.	Qvist, S., K. Sehested, and P. Zeuthen. 1994. Growth suppression of Listeria monocytogenes in a meat product. International Journal of Food Microbiology. 24 (1/2) 283-293.
		Bologna type sausage with 2% sodium lactate and 0.25% glucono-delta-lactone	No *L. monocytogenes* growth was detected when held at 50°F (10°C) or less for 35 days.	
		Bologna type sausage with 2% sodium lactate and 0.50% glucono-delta-lactone		
	B – Growth of *L. monocytogenes*	Cervelat (pork and beef sausage) with 2.5% NaCl, 2.5% sodium lactate and 0.25% sodium acetate, vacuum packaged and stored at 40°F (4°C)	With the addition of sodium lactate and sodium acetate there was no *L. monocytogenes* log change detected in 35 days at 40°F (4°C).	Blom, H., E. Nerbrink, R. Dainty, T. Hagtvedt, E. Borch, H. Nissen, and T. Nesbakken. 1997. Addition of 2.5% lactate and 0.25% acetate controls growth of *Listeria monocytogenes* in vacuum-packed, sensory acceptable cervelat sausage and cooked ham stored at 4°C. International Journal of Food Microbiology. 38(1) 71-76.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	Cervelat (pork and beef sausage) with 2.5% NaCl, 2.5% sodium lactate and 0.25% sodium acetate, vacuum packaged and stored at 48°F (9°C)	With the addition of sodium lactate and sodium acetate there was no *L. monocytogenes* log change detected in 35 days at 48°F (9°C).	B lom, H., E. Nerbrink, R. Dainty, T. Hagtvedt, E. Borch, H. Nissen, and T. Nesbakken. 1997. (continued)
		Cooked ham sliced and vacuum packaged, stored at 40°F (4°C)	There was no log growth of *L. monocytogenes* in 35 days at 40°F (4°C).	
		Cooked ham sliced and vacuum packaged, stored at 48°F (9°C)	There was a 2.5 log growth of *L. monocytogenes* in 35 days at 48°F (9°C).	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – *L. monocytogenes* survival and growth	Use of various liquid smoke products at 0.25% and 0.5%	0.25% Char-Sol and Arro-Smoke P50 resulted in a 5 log reduction of *L. monocytogenes* in 4 hours. 0.25% Chardex Hickory resulted in a 5 log reduction of *L. monocytogenes* in 24 hours. 0.25% CharSol PN-9 resulted in a 5 log reduction of *L. monocytogenes* in 48 hours. 0.25% Charoil Hickory resulted in a 5 log reduction of L. *monocytogenes* in 96 hours. 0.5% Chardex Hickory, Arro-Smoke P50, and CharSol-10, resulted in a 5 log reduction of *L. monocytogenes* in 4 hours. 0.5% CharSol PN-9 and Charoil Hickory resulted in a 5 log reduction of *L. monocytogenes* in 24 hours.	Messina, M.C., H.A. Ahmad, J.A. Marchello, C.P. Gerba, and M.W. Paquette. 1988. The effect of liquid smoke on *Listeria monocytogenes*. Journal of Food Protection. 51 (8) 629-631.
	B – Growth of *L. monocytogenes*	pH of product is near or below 5.0, stored at 40˚F (4.4˚C) Roast Beef (<1% NaCl, 4.61-5.31pH after week 2)	*Listeria monocytogenes* is not likely to grow; however if contaminated prior to storage it will not be destroyed. Roast beef – *L. monocytogenes* changed in log units decline 1 unit to increase 2 units in 6 weeks.	Glass, K.A., and M.P. Doyle. 1989. Fate of *Listeria monocytogenes* in processed meat products during refrigerated storage. Applied and Environmental Microbiology. 55 (6) 1565-1569.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	PH of product is near or above 6.0 Cooked ham (2.5-3% NaCl, 6.52-5.13 pH) Bologna (2.3-2.6% NaCl, 6.46-5.06 pH) Wieners (2.4-2.6% NaCl, 6.18-5.44 pH)	A hazard is likely if contaminated with *Listeria monocytogenes*. It will continue to grow and create a risk. Cooked ham – 3 to 4 log increase Bologna – 3 to 4 log increase Wieners – 0.5 to 3 log increase	Glass, K.A., and M.P. Doyle. 1989. (continued)
		Cooked cured ham (2.2% NaCl) vacuum packaged and stored at 40˚F (4˚C) for 20 days	Storage at 40˚F (4˚C) resulted in a 1 log growth of *L. monocytogenes* in 20 days.	Kant-Muermans, M.L.T., and F.K. Stekelenburg, 1998. The influence of different additives on the quality of cooked ham products. TNO Nutrition and Food Research Institute. Project number 847655.
		Cooked cured ham (2.2% NaCl) with 1.5% Sodium Lactate, vacuum packaged and stored at 40˚F (4˚C) for 40 days	Treatment with 1.5% sodium lactate resulted in no log growth of *L. monocytogenes* over 40 days.	
		Cooked cured ham (2.2% NaCl) with 2% Sodium Lactate, vacuum packaged and stored at 40˚F (4˚C) for 40 days	Treatment with 2% sodium lactate resulted in no log growth of *L. monocytogenes* over 40 days.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	Cooked cured ham (2.2% NaCl) with 0.1% di-acetate, vacuum packaged and stored at 40˚F (4˚C) for 15 days	Treatment with 0.1% di-acetate resulted in 1 log growth of *L. monocytogenes* over 15 days.	Kant-Muermans, M.L.T., and F.K. Stekelenburg, 1998. (continued)
		Cooked cured ham (2.2% NaCl) with 0.2% di-acetate, vacuum packaged and stored at 40˚F (4˚C) for 40 days	Treatment with 0.2% di-acetate resulted in no log growth of *L. monocytogenes* over 40 days.	
		Cooked cured ham (2.2% NaCl) with 0.9% Sodium Lactate and 0.1% di-acetate, vacuum packaged and stored at 40˚F (4˚C) for 40 days	Treatment with 0.9% sodium lactate and 0.1% di-acetate resulted in no log growth of *L. monocytogenes* over 40 days.	
		Cooked cured ham (2.2% NaCl) with 1.5% Sodium Lactate and 0.1% di-acetate, vacuum packaged and stored at 40˚F (4˚C) for 40 days	Treatment with 1.5% sodium lactate and 0.1% di-acetate resulted in no log growth of *L. monocytogenes* over 40 days.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *L. monocytogenes*	Beef gravy with pH 4 to 8, salt content 0 to 6%, sodium pyrophosphate 0 to 0.3%, cooked to temperatures of 131 to 149°F (55 to 65°C)	As pH decreased sensitivity to temperature increased. Salt content protected *L.monocytogenes* against deactivation at all temperatures, however at high pH, 3% salt was the most protective. As sodium pyrophosphate concentration increased to 0.2% deactivation time decreased, however 0.3% sodium pyrophosphate showed protection against deactivation	Juneja, Vijay K. and Brian S. Eblen. 1999. Predictive Thermal Inactivation Model for *Listeria monocytogenes* with Temperature, pH, NaCl, and Sodium Pyrophosphate as Controlling Factors. Journal of Food Protection. 62 (9) 986-993.
		Cooked cured ham (2.2% NaCl) with 1% sodium citrate (Ional), vacuum packaged and stored at 40˚F (4˚C) for 15 days	Treatment with 1% sodium citrate (Ional) resulted in greater than 5 log growth of *L. monocytogenes* over 15 days.	Kant-Muermans, M.L.T., and F.K. Stekelenburg, 1998. (continued)
	B – Growth of *C. perfringens*	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 3% NaCl and held at 40˚F (4˚C), 59˚F (15˚C), or 82˚F (28˚C)	There was no *C. perfringens* growth at 40˚F (4˚C) or 59˚F (15˚C) for 28 days. At 28˚F (82˚C) there was no growth in 12 hours.	Juneja, V.K., and B.S. Marmer. 1996. Growth of *Clostridium perfringens* from spore inocula in *sous-vide* turkey products. International Journal of Food Microbiology. 32 (1-2) 115-123.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of *C. perfringens*	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 2% or less NaCl and held at 40˚F (4˚C), 59˚F (15˚C), or 82˚F (28˚C)	There was no *C. perfringens* growth at 40˚F (4˚C) for 28 days and at 59˚F (15˚C) and 82˚F (28˚C) there was no growth for 8 hours.	Juneja, V.K., and B.S. Marmer. 1996. Growth of *Clostridium perfringens* from spore inocula in *sous-vide* turkey products. International Journal of Food Microbiology. 32 (1-2) 115-123.
	B – *E. coli* O157:H7 survival	Additional malic acid to pH 3.9	The addition of malic acid and citric acid to the growth medium reduced *E. coli* O157:H7 4 log units at pH 4.2 or lower however still detectable at pH 3.9.	Ryu, J.H., Y. Deng, L.R. Beuchat. 1999. Behavior of acid-adapted and unadapted *Escherichia coli* O157:H7 when exposed to reduced pH achieved with various organic acids. Journal of Food Protection. 62(5) 451-455.
		Additional citric acid to pH 3.9		
		Additional lactic acid to pH 3.9	The addition of lactic acid to the growth medium reduced *E. coli* O157:H7 by 4 log units at pH 3.9 however it was still detectable at pH 3.9.	
		Additional acetic acid to pH 3.9	The addition of acetic acid to the growth medium reduced *E. coli* O157:H7 by 3 log units at pH 5.1 and 4.8, 4 log units at pH 4.5, and 6 log units at pH 4.2. *E. coli* O157:H7 was undetected at pH 3.9 (more than 7 log unit reduction).	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B- *E. coli* O157:H7 growth	Storage of *E. coli* O157:H7 at various temperatures, NaCl levels and pH levels	There was no growth of *E. coli* O157:H7 below 46.4°F (8°C), and slow to no growth when salt levels were above 20g/L. pH ranging from 4.5 to 8.5 did not greatly effect growth. All combinations of salt, ranging from 5 g/L to 35 g/L, pH (4.5 to 8.5) and temperature 82.4°F (28°C) and higher grew *E. coli* O157:H7.	Buchanan, R.L., and L.A. Klawitter. 1992. The effect of incubation temperature, initial pH, and sodium chloride on the growth kinetics of *Escherichia coli* O157:H7. Food Microbiology. 9 (3) 185-196.
	B – Survival and growth of *E. coli* O157:H7	Ground roasted beef mixed with up to 40% mayonnaise and held at 5°C for 72 hours	There was no log change in *E. coli* O157:H7 in 72 hours.	Abdul-Raouf, U.M., L.R. Beuchat, and M.S. Ammar. 1993. Survival and growth of *Escherichia coli* O157:H7 in ground, roasted beef as affected by pH, acidulants, and temperature. Applied and Environmental Microbiology. 2364-2368.
		Ground roasted beef mixed with up to 40% mayonnaise and held at 21°C for 24 hours	32% to 40% mayonnaise resulted in less than .5 log growth of *E. coli* O157:H7, 24% and less resulted in greater than 1 log to greater than 4 log growth.	
		Ground roasted beef mixed with up to 40% mayonnaise and held at 30°C for 24 hours	40% mayonnaise resulted in no growth of *E. coli* O157:H7, 32% and less resulted in a 2.5-4.5 log growth of *E. coli* O157:H7.	
		Ground roasted beef acidified with acetic acid to pH 5.4, 5.0, and 4.7 and stored at 5, 21, and 30°C for 24 hours	There was no growth or destruction of *E. coli* O157:H7 at pH 5.4 or 5.0. At pH 4.7 there was 1.5 to 2 log reduction at each of the temperatures.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival and growth of *E. coli* O157:H7	Ground roasted beef acidified with citric acid to pH 5.4, 5.0, and 4.7 and stored at 5, 21, and 30°C for 24 hours	There was no growth or destruction at any pH level when stored at 5°C. At 21°C *E. coli* O157:H7 increased 3 log units at pH 5.4 and 5.0, but no change at pH 4.7. At 30°C there was 2-5 log units of growth for all pH.	Abdul-Raouf, U.M., L.R. Beuchat, and M.S. Ammar. 1993. Survival and growth of *Escherichia coli* O157:H7 in ground, roasted beef as affected by pH, acidulants, and temperature. Applied and Environmental Microbiology. 2364-2368.
		Ground roasted beef acidified with lactic acid to pH 5.4, 5.0, and 4.7 and stored at 5, 21, and 30°C for 24 hours	There was no growth or destruction at any pH level when stored at 5°C. At 21°C *E. coli* O157:H7 increased 3 log units at pH 5.4 and 5.0, but no change at pH 4.7. At 30°C there was 2-5 log units of growth for all pH.	
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.
Thawing	B – pathogen growth	Thawing ready-to-cook poultry	Thawing media (water, air, etc.) shall not exceed 70°F.	MPI Regulations, Section 381.65(h)(1) Access on the internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfr381_99.html

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage Products, American Meat Institute Foundation, 1997.
	B – Potential Staphylococcus growth	Fermentation to pH 5.3 or less	(Fermentation Temperature (˚F)–60) X hours = degree hours Process acceptable if: Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90˚F (32°C). Fewer than 1000 degree hours when the highest fermentation temperature is between 90˚F (32°C) and 100˚F (38°C). Fewer than 900 degree hours when the highest fermentation temperature is greater than 100˚F (38°C).	
	B – Survival of *L. monocytogenes*	Cooking fermented sausage at temperatures ranging from 120°F (48.9°C) to 140°F (60°C)	*Listeria monocytogenes* has a D-value of 98.6 minutes at 120°F (48.9°C), and 9.13 minutes at 140°F (60°C).	Schoeni, J.L., K. Brunner, and M.P. Doyle. 1991. Rates of thermal inactivation of *Listeria monocytogenes* in beef and fermented beaker sausage. Journal of Food Protection. 54 (5) 334-337.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B - Survival of *Salmmonella seftenberg, C. perfringens,* and *E. coli* O128:B12	Dried fermented turkey sausage step-wise heat treated at 81˚F (27˚C) for 3 hours, 90˚F (32˚C) for 4 hours, 115˚F (46˚C) for 5 hours, spray cooled to 61 to 64˚F (16 to 18˚C) and dried at 50˚F (10˚C) 72% RH for 8 days	*S. seftenberg* decreased 1.5 to 20 log units. *C. perfringens* decreased 2 to 3.6 log units. *E. coli* O128:B12 decreased 1.4 to 2.1 log units.	Baran, W.L., and K.E. Stevenson. 1975. Survival of selected pathogens during processing of a fermented turkey sausage. Journal of Food Science. 40 (3) 618-620.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – Survival of *E. coli* O157:H7	Lebanon-style bologna: 92% lean beef (90/10) 3.3% salt, 2.9% sugar, 0.8% dextrose, 0.7% spices, 0.14% potassium nitrate, 0.01% sodium nitrite, 0.15% lactic acid starter culture stuffed into 115 mm or 90 mm diameter casings, fermented 8 hours at internal temperature 80°F (26.7°C), with 90%RH, 24 hours at internal temperature 100°F (37.8°C), with 80% RH then 24 hours at internal temperature 110°F (43.3°C) with smoke the final 2 hours, 80%RH, 0, 1, 2, or 5 hours of heating at internal temperature 115°F (46.1°C) . 90% RH was used throughout for 90mm	All counts were below detection level after heating processes (greater than 6 log reduction of *E. coli* O157:H7) for 115 mm diameter After all heating processes there was 2.4 to 2.7 log reduction of *E. coli* O157:H7 for 90 mm diameter	Gety, K.J.K., R.K. Phebus, J.L. Marsden, J.R. Schwenke, and C.L. Kastner. 1999. Control of *Escherichia coli* O157:H7 in large (115 mm) and intermediate (90 mm) diameter Lebanon-style bologona. Journal of Food Science. 64 (6) 1100-1107.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cook-in-bag packaging	B – *Clostridium perfringens* and *Salmonella* survival in roast beef	Beef roasts cooked in plastic bags, in a water bath to 140°F (60°C) internal temperature for 12 minutes	*Salmonella* was eliminated and *C. perfringens* was reduced 3 log units.	Smith, A.M., D.A. Evans, and B.M. Buck. 1981. Growth and survival of *Clostridium perfringens* in rare roast beef prepared in a water bath. Journal of Food Protection. 44: 9-14.
	B – *Clostridium perfringens* growth during storage of cooked ground beef	After cooking ground beef product (3% salt, and pH 5.5) to 160˚F (71.1˚C), cooled to 32˚F (0˚C) then stored at 82˚F (28˚C), in vacuumized, cook-in-bag	No hazard is likely to occur from *Clostridium perfringens* within 24 hours at 82˚F (28˚C), as no growth occurred. 36 hours were required for 1 log growth.	Juneja, V.K., and W.M. Majka. 1995. Outgrowth of *Clostridium perfringens* spores in cook-in-bag beef products. Journal of Food Safety. 15 (1) 21-34.
		After cooking ground beef product (0% salt, pH 7.0) to 160˚F (71.1˚C), cooled to 32˚F (0˚C) then stored at 59˚F (15˚C), in vacuumized, cook-in-bag	Growth of *Clostridium perfringens* was delayed (less than 1 log increase) 5 days, and posed no hazard in that time.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cook-in-bag packaging	B – *Clostridium perfringens* growth during storage of cooked ground beef	After cooking ground beef product (3% salt, and pH 7.0) to 160˚F (71.1˚C), cooled to 32˚F (0˚C) then stored at 59˚F (15˚C), in vacuumized, cook-in-bag	Growth of *Clostridium perfringens* was delayed (less than 1 log increase) 7 days, and posed no hazard in that time.	Juneja, V.K., and W.M. Majka. 1995. (continued)
		After cooking ground beef product (3% salt, and pH 5.5) to 160˚F (71.1˚C), cooled to 32˚F (0˚C) then stored at 59˚F (15˚C), in vacuumized, cook-in-bag	Growth of *Clostridium perfringens* was delayed (less than 1 log increase) 21 days, and posed no hazard in that time.	
		After cooking ground beef to an internal temperature of 160˚F (71.1˚C), cooled to 32˚F (0˚C) then stored at 40˚F (4˚C) in vacuum packaged, cook-in bag, regardless of salt content or pH.	Less than 1 log of growth of *Clostridium perfringens* was detected, even after 28 days, no hazard is posed.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cook-in-bag packaging	B – Growth of *C. perfringens*	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 3% NaCl and held at 40˚F (4˚C), 59˚F (15˚C), or 82˚F (28˚C)	There was no *C. perfringens* growth at 40˚F (4˚C) or 59˚F (15˚C) for 28 days. At 28˚F (82˚C) there was no growth in 12 hours.	Juneja, V.K., and B.S. Marmer. 1996. Growth of *Clostridium perfringens* from spore inocula in *sous-vide* turkey products. International Journal of Food Microbiology. 32 (1-2) 115-123.
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 2% or less NaCl and held at 40˚F (4˚C), 59˚F (15˚C), or 82˚F (28˚C)	There was no *C. perfringens* growth at 40˚F (4˚C) for 28 days and at 59˚F (15˚C) and 82˚F (28˚C) there was no growth for 8 hours.	
Cooking	B – *L. monocytogenes*, survival	Cooking ham to minimum internal temperature of 150°F (65°C) and maintaining that internal temperature for at least 40 minutes	*Listeria monocytogenes* is destroyed (no detection after 50 days) provided that product is cooked to an internal temperature of 150°F (65°C) and maintained at that temperature for 40 minutes.	Carlier, V., J.C. Augustin, and J. Rozier. 1996. Destruction of *Listeria monocytogenes* during a ham cooking process. Journal of Food Protection. 59 (6) 592-595.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking Ground Beef to 125°F (52°C), 135°F (57°C) and 145°F (63°C) (internal)	*Listeria monocytogenes* showed a 4 log reduction in ground beef at these temperatures, in these time-internal temperature limits. 125°F (52°C) internal for 325 min. 135°F (57°C) internal for 25 min. 145°F (63°C) internal for 2 min.	Fain, A.R., J.E. Line, A. B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of heat to *Listeria monocytogenes* Scott A: D-value and z-value determinations in ground beef and turkey. Journal of Food Protection. 54 (10) 756-761.
		Cooking Ground Turkey to 160°F (71.1°C) internal	After cooking for 2 minutes at 160°F (71.1°C) internal, *L. monocytogenes* was reduced by a 5 to 6 log reduction.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking raw ground beef (10% fat) on a 365°F (185°C) griddle for 6 to 10 minutes then held at room temperature for 1 minute	After 6 minutes (internal temperature 168°F (75.5°C)) *L. monocytogenes* was reduced 2.8 log units when held at room temperature for 1 minute after cooking, 2 log units reduction when immediately chilled. After 8 minutes (internal temperature 192°F (88.9°C)) *L. monocytogenes* was reduced 3 log units when held at room temperature for 1 minute after cooking, 2.7 log units reduction when immediately chilled. After 10 minutes (internal temperature 198°F (92.4°C)) *L. monocytogenes* was reduced 6.75 log units when held at room temperature for 1 minute after cooking, 5.25 log units reduction when immediately chilled.	Passos, M.H.C.R., A.Y. Kuaye. 2002. Influence of the formulation, cooking time and final internal temperature of beef hamburgers on the destruction of *Listeria monocytogenes*. Food Control. 13(1) 33-40.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking raw ground beef (20% fat) on a 365°F (185°C) griddle for 6 to 10 minutes then held at room temperature for 1 minute	After 6 minutes (internal temperature 182.5°F (83.6°C)) *L. monocytogenes* was reduced 3 log units when held at room temperature for 1 minute after cooking, 2.7 log units reduction when immediately chilled. After 8 minutes (internal temperature 194°F (89.8°C)) *L. monocytogenes* was reduced 4 log units when held at room temperature for 1 minute after cooking, 3.7 log units reduction when immediately chilled. After 10 minutes (internal temperature 195°F (90.8°C)) *L. monocytogenes* was reduced 5.4 log units when held at room temperature for 1 minute after cooking, 4.5 log units reduction when immediately chilled.	Passos, M.H.C.R., A.Y. Kuaye. 2002. (continued)

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking raw ground beef (10% fat) with 1.5% salt on a 365°F (185°C) griddle for 6 to 10 minutes then held at room temperature for 1 minute	After 6 minutes (internal temperature 177°F (80.8°C)) *L. monocytogenes* was reduced 2.85 log units when held at room temperature for 1 minute after cooking, 1.9 log units reduction when immediately chilled. After 8 minutes (internal temperature 173°F (78.5°C)) *L. monocytogenes* was reduced 3.6 log units when held at room temperature for 1 minute after cooking, 3 log units reduction when immediately chilled. After 10 minutes (internal temperature 190°F (87.7°C)) *L. monocytogenes* was reduced 4.2 log units when held at room temperature for 1 minute after cooking, 3.75 log units reduction when immediately chilled.	Passos, M.H.C.R., A.Y. Kuaye. 2002. (continued)

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking raw ground beef (10% fat) with 10.5% hydrated (2:1) textured soy protein (51%dry basis protein) on a 365°F (185°C) griddle for 6 to 10 minutes then held at room temperature for 1 minute	After 6 minutes (internal temperature 202°F (94.6°C)) *L. monocytogenes* was reduced 2.85 log units when held at room temperature for 1 minute after cooking, 2.25 log units reduction when immediately chilled. After 8 minutes (internal temperature 185°F (85.2°C)) *L. monocytogenes* was reduced 4.5 log units when held at room temperature for 1 minute after cooking, 3.8 log units reduction when immediately chilled. After 10 minutes (internal temperature 188°F (86.5°C)) *L. monocytogenes* was reduced 6.5 log units when held at room temperature for 1 minute after cooking, 5.95 log units reduction when immediately chilled.	Passos, M.H.C.R., A.Y. Kuaye. 2002. (continued)
		Cooking ground beef roast at temperatures ranging from 130°F (54.4°C) to 154°F (62.8°C)	*Listeria monocytogenes* has a D-value of 22.4 minutes at 130°F (54.4°C), and 2.56 minutes at 154°F (62.8°C).	Schoeni, J.L., K. Brunner, and M.P. Doyle. 1991. Rates of thermal inactivation of *Listeria monocytogenes* in beef and fermented beaker sausage. Journal of Food Protection. 54 (5) 334-337.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes*, survival	Cooking pork and turkey tumbled and pork emulsion type sausages to 158°F (70°C)	When product is cooked to an internal temperature of at least 158°F (70°C) *L. monocytogenes* is destroyed.	Samelis, J., and J. Metaxopoulos, 1999. Incidence and principal sources of *Listeria* spp. and *Listeria monocytogenes* contamination in processed meats and a meat processing plant. Food Microbiology. 16 (5) 465-477.
		Cooking chicken breast to specific internal temperatures	The following log reductions were reached when cooking chicken breast to these specific instantaneous internal temperatures. 150˚F (65.6˚C): 2.8 log reduction 160˚F (71.1˚C): 1.8 log reduction 165˚F (73.9˚C): 4.4 log reduction 170˚F (76.7˚C): 5.3 log reduction 180˚F (82.2˚C): 4.85 log reduction	Carpenter, S.L., and M.A. Harrison. 1989. Survival of *Listeria monocytogenes* on processed poultry. Journal of Food Science. 54 (3) 556-557.
		Ground Turkey (5.4%±0.3% fat) or Ground Beef (34.4±1.1% fat) heated to 131° F (55° C) to 158°F(70°C)	*Listeria monocytogenes* decreased by 1 log unit in: 37 minutes at 131°F (55°C). 18 minutes at 135.5° F (57.5°C). 8.5 minutes at 140°F (60°C). 3 minutes at 144.5° F (62.5°C). 2 minutes at 149°F (65°C). 24 seconds at 153.5°F (67.5°C). and 7 seconds at 158°F (70°C).	Murphy, R.Y., E.M. Martin, L.K. Duncan, B.L. Beard, and J.A. Marcy. 2004. Thermal Process Validation for *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* in Ground Turkey and Beef Products. Journal of Food Protection. 67 (7) 1394-1402.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *L. monocytogenes* heat resistance	Addition of partially cooked ham rework	When cooking ham to 140°F (60°C), rework, previously heated at 108°F (42°C) for 1 hr (heat shocked), resulted in *L. monocytogenes* with more heat resistance than *L. monocytogenes* in rework, which was previously heated at 108°F (42°C) for 20 minutes.	Carlier V., J.C. Augustin, and J. Rozier. 1996. Heat resistance of *Listeria monocytogenes*: D- and z-values in ham. Journal of Food Protection. 59 (6) 588-591.
		Holding product between 104˚F (40˚C) and 118˚F (48˚C) for 3 to 20 minutes	D-value for *L. monocytogenes* increases up to 2.3 fold when cooked at 131˚F (55˚C). The time allotted to destroy *L. monocytogenes* must increase correspondingly.	Linton, R.H., M.D. Pierson, and J.R. Bishop. 1990. Increase in heat resistance of *Listeria monocytogenes* Scott A by sublethal heat shock. Journal of Food Protection. 53 (11) 924-927.
	B – *E.coli* O157:H7 and *L. monocytogenes* survival	Ground beef patties cooked on a double sided grilling –broiling system to final internal temperature of 71.2°C (160°F) or 75.8°C (168°F)	*E.coli* O157:H7 decreased 5.7 log units when cooked to 71.2°C and 6.1 log units when cooked to 75.8°C. *L. monocytogenes* decreased 5.4 log units at 71.2°C and 5.6 log units at 75.8°C	D'sa, Elaine M., Mark A. Harrison, Scott E. Williams, and Marc H. Broccoli. 1999. Effectiveness of Two Cooking Systems in Destroying *Escherichia coli* O157:H7 and *Listeria monocytogenes* in Ground Beef patties. Journal of Food Protection. 63 (7) 894-899.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *E.coli* O157:H7 and *L. monocytogenes* survival	Ground beef patties cooked on a single sided broiling system to final internal temperatures of 62.7°C (145°F) and 69.3°C (157°F)	*E.coli* O157:H7 decreased 1.3 log units at 62.7°C and 2.9 log units at 69.3°C. *L. monocytogenes* decreased 1.8 log units at 62.7°C and 3.6 log units at 69.3°C	D'sa, Elaine M., Mark A. Harrison, Scott E. Williams, and Marc H. Broccoli. 1999. Effectiveness of Two Cooking Systems in Destroying *Escherichia coli* O157:H7 and *Listeria monocytogenes* in Ground Beef patties. Journal of Food Protection. 63 (7) 894-899.
	B – Survival of *L. monocytogenes*, *Salmonella*, and *E. coli* O157:H7	Ground pork with 45% moisture, 40% fat and 15% protein heated to 131°F (55°C) to 158°F (70°C)	The D value for *E coli* O157:H7 decreases from 33.5 minutes at 131°F (55°C) to 0.05 minutes (3 seconds) at 158°F (70°C). The D values for *Salmonella* and *L. monocytogenes* decreases from 47 minutes at 131°F (55°C) to 0.09 minutes (5.4 seconds) at 158°F (70°C).	Murphy, R.Y., B.S. Beard, E.M. Martin, L.K. Duncan, and J.A. Marcy. 2004. Comparative study of thermal inactivation of *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* in ground pork. Journal of Food Science 69(4) 97-101.
	B – *Clostridium perfringens* survival during cooking process	Cooking Ground Beef to 140°F (60°C)	Cooking beef to an internal temperature of 140°F (60°C) destroys *Clostridium perfringens* and the risk of spore germination is eliminated if the temperature is constantly raised by at least 13°C/hour. Research showed same results with fluid thioglycollate medium (FTM).	Shigehisa, T., T. Nakagami, and S. Taji. 1985. Influence of heating and cooling rates on spore germination and growth of *Clostridium perfringens* in media and roast beef. Japanese Journal of Veterinary Science. 47 (2) 259-267.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *Clostridium perfringens* survival during cooking process	Cooking ground beef to 135°F (57°C) internal temperature	*C. perfringens* showed a 5 log reduction of vegetative cells within 50 minutes at 135°F (57°C) in ground beef.	Roy, R.J., F.F. Busta, and D.R. Thompson. 1981. Thermal inactivation of *Clostridium perfringens* after growth at several constant and linearly rising temperatures. Journal of Food Science. 46: 1586-1591.
	B – Stability of *C. perfringens* enterotoxin through cooking	Cooking chicken gravy to 142°F (61°C) for 23.8 minutes	*C. perfringens* enterotoxin is destroyed after cooking chicken gravy at 142°F (61°C) for at least 23.8 minutes.	Bradshaw, J.G. G.N. Stelma, and V.I. Jones, et al. 1982. Thermal inactivation of *Clostridium perfringens* enterotoxin in buffer and chicken gravy. Journal of Food Science. 47: 914-916.
	B – *E. coli* O157:H7 survival during cooking process	Ground beef acidified to pH 5.0 with lactic acid, acetic acid, or citric acid heated to 52°C	All formulations showed less than 1 log reduction when heated for 70 minutes.	Abdul-Raour, U.M., L.R. Beuchat, and M.S. Ammar. 1993. Survival and growth of *Escherichia coli* O157:H7 in ground, roasted beef as affected by pH, acidulants, and temperature. Applied and Environmental Microbiology. 2364-2368.
		Ground beef acidified to pH 5.0 with lactic acid, acetic acid, or citric acid heated to 54°C	Using acetic acid *E. coli* O157:H7 was reduced 7 log units in 42 minutes, citric and lactic acids showed 5-6 log reduction in 70 minutes.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *E. coli* O157:H7 survival during cooking process	Ground beef acidified to pH 5.0 with lactic acid, acetic acid, or citric acid heated to 56°C	*E. coli* O157:H7 was reduced 6 log units in 14 minutes.	Abdul-Raour, U.M., L.R. Beuchat, and M.S. Ammar. 1993. (Continued)
		Cooking ground beef to specific internal temperatures: 130˚F (54.4˚C) 135˚F (57.2˚C) 138˚F (58.9˚C) 140˚F (60˚C) 145˚F (62.8˚C) 148˚F (64.3˚C)	D-values for *E. coli* O157:H7 in ground beef for these specific internal temperatures are: 130˚F (54.4˚C): 2,390 min. 135˚F (57.2˚C): 270 min. 138˚F (58.9˚C): 70 min. 140˚F (60˚C): 45 min. 145˚F (62.8˚C): 24 min. 148˚F (64.3˚C): 9.6 min.	Doyle, M.P., J.L. Schoeni. 1984. Survival and growth characteristics of *Eschrichia coli* associated with hemorrhagic colitis. Applied and Environmental Microbiology. 10: 855-856.
		Cooking Ground Beef to 155°F (68°C)	By heating the ground beef to 155°F (68°C) a hazard posed by *E. coli* O157:H7 is not likely to occur.	Mermelstein, N.H. 1993. Controlling *E. coli* O157:H7 in meat. Food Technology. 47 (4) 90-91.
		Cooking ground beef to 135°F (57°C) internal temperature	*E. coli* showed a 7 log reduction in 30 minutes at 135°F (57°C) in ground beef.	Line, J.E., A.R. Fain Jr., A.B. Moran, L.M. Martin, R.V. Lechowich, J.M. Carosella, and W.L. Brown. 1991. Lethality of Heat to *Escherichia coli* O157:H7: D-value and Z-value determinations in ground beef. Journal of Food Protection. 54 (10) 762-766.
		Cooking ground beef to 145°F (63°C) internal temperature	*E. coli* showed a 7 log reduction in 1 minute at 145°F (63°C) internal in ground beef.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *E. coli* O157:H7 survival during cooking process	Cooking Ground Turkey, Pork and Lamb:	*E. coli* O157:H7 is reduced by 1 log unit in ground turkey, pork and lamb at these time and temperature levels. 131°F (55°C) internal for 11.9 min. 135.5°F (57.5°C) internal for 3.7 min. 140°F (60°C) internal for 2.0 min. 144.5°F (62.5°C) internal for 0.9 min. 149°F (65°C) internal for 0.4 min.	Juneja, V.K., and B.S. Marmer. 1999. Lethality of heat to *Escherichia coli* O157:H7: D- and z- value determinations in turkey, lamb, and pork. Food Research International. 32 (1) 23-28.
	B – Survival of *E. coli* O157:H7	Ground Turkey (5.4%±0.3% fat) or Ground Beef (34.4±1.1% fat) heated to 131° F (55° C) to 158°F(70°C)	*E. Coli* O157:H7 decreased by 1 log unit in: 22 minutes at 131°F (55°C). 9 minutes at 135.5° F (57.5°C). 2 minutes at 140°F (60°C). 1 minute at 144.5° F (62.5°C). 20 seconds at 149°F (65°C). 7 seconds at 153.5°F (67.5°C). and 3 seconds at 158°F (70°C).	Murphy, R.Y., E.M. Martin, L.K. Duncan, B.L. Beard, and J.A. Marcy. 2004. Thermal Process Validation for *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* in Ground Turkey and Beef Products. Journal of Food Protection. 67 (7) 1394-1402.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – Survival of *E. coli* O157:H7	Morcillia sausages with 17.59 – 34% fat and 57 – 68% moisture content held at 129°F (54°C).	*E. coli* O157:H7 was reduced by 1 log unit in 6.5 minutes.	Oteiza, J.M., L. Giannuzzi, and A.N. Califano. 2003. Thermal inactivation of *Escherichia coli* O157:H7 and *Escherichia coli* isolated from morcilla as affected by composition of the product. Food Research International. 36 (7) 703 – 712.
		Morcillia sausages with 17.59 – 34% fat and 57 – 68% moisture content held at 136.4°F (58°C).	*E. coli* O157:H7 was reduced by 1 log unit in 3.6 minutes.	
		Morcillia sausages with 17.59 – 34% fat and 57 – 68% moisture content held at 143.6°F (62°C).	*E. coli* O157:H7 was reduced by 1 log unit in 1.3 minutes.	
	B – *E. coli* O128, *Salmonella, Staphylococcus aureus* survival during cooking process	Dry-roasting beef to 140°F (60°C) in oven temperatures at 230°F (110°C) to 266°F (130°C)	When dry-oven-roasting roast beef the internal temperature must reach 140°F (60°C) to ensure the destruction of *E. coli* O128, *Staphylococcus aureus*, and *Salmonella*. Oven temperature did not effect results as long as internal temperature reached 140°F (60°C).	Shigehisa, T., T. Nakagami, S. Taji, and G. Sakaguchi. 1985. Destruction of salmonellae, *Escherichia coli*, and *Staphylococcus aureus* inoculated into and onto beef during dry-oven roasting. Japanese Journal of Veterinary Sciences. 47 (2) 251-257.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *Salmonella* survival during cooking process	Dry roasting of large beef roasts at oven temperatures of 250°F (121°C) or 275°F (135°C)	*Salmonella* will be destroyed (7 log reduction) if roasts (16-18 pounds) are dry roasted to these specifications: 250°F (121°C) oven, internal temperature of at least 130°F (54.4°C). 275°F (135°C) oven, internal temperature of at least 125°F (51.6°C).	Goodfellow, S.J., and W.L. Brown. 1978. Fate of *Salmonella* inoculated into beef for cooking. Journal of Food Protection. 41 (8) 598-605.
		Dry Roasting small (less than 10 pounds) beef roasts in oven temperatures of 275°F (135°C) or less	*Salmonella* are not fully destroyed when dry roasting beef roasts of less than 10 pounds in an oven at 275°F (135°C), or less, when heated to an internal temperature of 135°F (57.2°C), however there was a 5 log reduction.	
		Including steam cooking for at least 30 minutes in total cooking time	*Salmonella* will be destroyed if large beef roasts (16-18 pounds) are cooked to an internal temperature of at least 130°F (54.4°C) using at least 30 minutes of steam in the cooking process where the oven temperature is 175°F (79.4°C).	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *Salmonella* survival during cooking process	Water cooking in 165°F (73.8°C) water	*Salmonella* will be destroyed (7 log reduction) at these time-internal temperature levels in 165°F (73.8°C) water. 125°F (51.6°C) internal for more than 7 hours. 130°F (54.4°C) internal for 60 minutes. 135°F (57.2°C) internal for 3 minutes. Above 135°F (57.2°C) internal instantaneous.	Goodfellow, S.J., and W.L. Brown. 1978. (continued)
	B –Survival of *Salmonella*	Ground Turkey (5.4%±0.3% fat) or Ground Beef (34.4±1.1% fat) heated to 131° F (55° C) to 158°F(70°C)	*Salmonella* decreased by 1 log unit in: 44 minutes at 131°F (55°C). 20 minutes at 135.5° F (57.5°C). 7 minutes at 140°F (60°C). 3 minute at 144.5° F (62.5°C). 1.5 minutes at 149°F (65°C). 20 seconds at 153.5°F (67.5°C). and 6 seconds at 158°F (70°C).	Murphy, R.Y., E.M. Martin, L.K. Duncan, B.L. Beard, and J.A. Marcy. 2004. Thermal Process Validation for *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* in Ground Turkey and Beef Products. Journal of Food Protection. 67 (7) 1394-1402.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B –Survival of *Salmonella*	Chicken leg quarters cooked in an impingement oven at 450°F (232°C) with air velocity of 1.4 m/s 43% humidity for 5 to 35 minutes	*Salmonella* survivors can be predicited by the model: 1.0031- 0.6589(time)+0.008 (time x mass) = ln (survivor CFU/initial CFU) Where time is in minutes and mass is in grams	Murphy, R.Y., K.H. Driscoll, L.K. Duncan, T. Osaili, and J.A. Marcy. 2004. Thermal lethality of *Salmonella* in chicken leg quarters processed via an air/stream impingement oven. Journal of Food Protection. 67 (3) 493-498.
	B – *Salmonella* and *L. monocytogenes* survival during cooking process	Cooking times and internal temperatures of meat products to achieve lethality	AMI Process Lethality Equation calculates f-values for individual processes based upon cooking and cooling times and temperatures.	Access AMI Process Lethality Equation at: meatpoultryfoundation.org/content/process-lethality-spreadsheet
	B – Survival of *L. monocytogenes* and *Salmonella*	Ground chicken thigh and leg meat cooked in bag (10.3% fat)	1 log of *Salmonella* destroyed at these times and temperatures:	Murphy, R.Y., T. Osaili, L.K. Duncan, and J.A.Marcy. 2004. Thermal inactivation of *Salmonella* and*Listeria monocytogenes* in ground chicken thigh/leg meat and skin. Poultry Science. 83. 1218-1225.
			°C / *Salmonella* / *Listeria* 55 / 43.76 / 38.94 57.5 / 13.66 / 9.67 60 / 5.72 / 2.04 62.5 / 1.62 / 1.01 65 / .55 / .30 67.5 / .19 / .10 70 / .07 / .04	
		Ground chicken skin and fat (47%) cooked in bag	55 / 43.3 / 34.05 57.5 / 14.09 / 10.19 60 / 7.31 / 3.95 62.5 / 2.21 / 1.37 65 / .79 / .41 67.5 / .23 / .13 70 / .09 / .05	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – *Salmonella* and *L. monocytogenes* survival during cooking process	Cooking cooked beef, roast beef, and cooked corned beef products	Time and temperature combinations to meet either a 6.5 or a 7.0 log reduction in *Salmonella*.	MPI Regulations, Section 381.17(a) Appendix A to FSIS Compliance Guidelines Access Appendix A, on internet at: www.fsis.usda.gov/oa/fr/95033f%2Da.htm
	B – *Salmonella* and *L. monocytogenes* survival during cooking process	Fully cooking ground beef patties	USDA FSIS regulations state that fully cooked patties should reach an instantaneous internal temperature of 160˚F (71˚C).	MPI Regulations, Section 318.23(b)(1)(i) Access on internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
		Cooking cured and non-cured poultry products	Poultry products should be cooked to specific time and temperature combinations based upon fat content of the product.	FSIS. March 2005 Compliance Guides. Time-temperature tables for cooking ready-to-eat poultry products Access on internet at: http://www.fsis.usda.gov/OPPDE/rdad/FSISNotices/RTE_Poultry_Tables.pdf

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Cooking	B – Contamination with *Trichinella spiralis*	Cooking pork chops in a conventional or convection oven or flat grill to an internal temperature of 151°F (66°C)	Pork cooked to an internal temperature of at least 151°F (66°C) using a conventional or convection oven or flat grill rendered the trichina non-infectious.	Kotula, A.W., K.D. Murrell, L. Acosta-Stein, L. Lamb, and L. Douglas. 1983. Destruction of *Trichinella spiralis* during cooking. Journal of Food Science. 48 (3) 765-768.
	B – Contamination with *Trichinella spiralis*	Cooking pork chops with microwave ovens up to an internal temperature of 180˚F (82˚C)	When using microwaves to cook meat, a consistent temperature cannot be guaranteed and therefore does not necessarily render trichina non-infectious. At the maximum final temperature 180˚F (82˚C) there will still be cold spots where the trichina can survive.	
Reheating	B – Survival of *C. perfringerns* vegetative cells	Reheating vacuumized, cooked beef to internal temperature of 149°F (65°C)	Reheating product to an internal temperature of 149˚F (65˚C) before consumption will kill vegetative cells preventing a hazard.	Juneja, V.K., B.S. Marmer, and A.J. Miller. 1994. Growth and sporulation potential of *Clostridium perfringens* in aerobic and vacuum-packaged cooked beef. Journal of Food Protection. 57 (5) 393-398.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Reheating	B – Survival of *C. perfringerns* vegetative cells	Heating previously cooked ground beef containing 0.15% to 0.3% sodium pyrophosphate to 149˚F (65˚C)	When ground beef containing 0.15% to 0.3% sodium pyrophosphate is heated to 149˚F (65˚C) for 30 seconds 8 log units of *C. perfringens* are destroyed.	Juneja, V.K., B.S. Marmer. 1998. Thermal inactivation of *Clostridium perfringens* vegetative cells in ground beef and turkey as affected by sodium pyrophosphate. Food Microbiology. 15 (3) 281-287.
		Heating previously cooked turkey containing 0.15% to 0.3% sodium pyrophosphate to 140˚F (60˚C)	When turkey containing 0.15% to 0.3% sodium pyrophosphate is heated to 140˚F (60C) for 30 seconds 8 log units of *C. perfringens* are destroyed.	
Post-cooking Intervention	B – Growth of *Clostridium sporogenes*	Cooked beef treated with a 75 ppm solution of nisin vacuum packaged and stored up to 70 days at 39.2°F (4°C) or 50°F (10°C)	In all treatments, *C. sporogenes* decreased 1 to 2 log units with in the first 21 days of storage and remained unchanged to 70 days. Only no treatment at 50°F (10°C) showed increased cell counts with a growth of 2 log units.	Hague, M.A., C.L. Kastner, D.Y.C. Fung, K. Kone, and J.R. Schwenke. Use of Nisin and Microwave Treatment Reduces *Clostridium sporogenes* outgrowth in Precooked Vacuum-Packaged Beef. 1997. Journal of Food Protection. 60(9) 1072 – 1074.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post-cooking Intervention	B – Growth of *Clostridium sporogenes*	Cooked beef microwaved to raise the surface temperature to 95°F(35°C) to 131°F (55° C) vacuum-packaged and stored up to 70 days at 39.2°F (4°C) or 50°F (10°C)	In all treatments, *C. sporogenes* decreased 1 to 2 log units with in the first 21 days of storage and remained unchanged to 70 days. Only no treatment at 50°F (10°C) showed increased cell counts with a growth of 2 log units.	Hague, M.A., C.L. Kastner, D.Y.C. Fung, K. Kone, and J.R. Schwenke. (continued)
		Cooked beef both treated with a 75 ppm solution of nisin and microwaved to a surface temperature at 95°F(35°C) to 131°F (55° C) vacuum-packaged and stored up to 70 days at 39.2°F (4°C) or 50°F (10°C).	In all treatments, *C. sporogenes* decreased 1 to 2 log units with in the first 21 days of storage and remained unchanged to 70 days. Only no treatment at 50°F (10°C) showed increased cell counts with a growth of 2 log units.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post-cooking Intervention	B – Growth of *L. monocytogenes*	Frankfurters and cooked ham innoculated with *Pediococcus acidilactici* and *Lactobacillus casei,* and *Lactobacillus paracasei* then vacuum packaged and stored at 5°C (45°F) for 28 days	The lactic acid bacteria inhibited *L. monocytogenes* growth for the 28 days. In the frankfurters approxamity 1 log decrease of *L. monocytogenes* was found. Overall, pH dropped from about 6.5 to 4.6 in the frankfurters and 5.7 in the ham.	Amezquita, A. and M.M Brashears. 2002. Competitive Inhibition of *Listeria monocytogenes* in Ready-to-Eat Meat Product by Lactic Acid Bacteria. Journal of Food Protection. 65 (2) 316-325.
Post cook holding, pre chilling	B – *Salmonella* spp. lag times	Cooked ground chicken breast meat, held at 77˚F (25˚C)	11 strains of *Salmonella* spp. showed lag times of 2.2 hours to 3.09 hours when held at 77˚F (25˚C).	Oscar, T.P. 2000. Variation of lag time and specific growth rate among 11 strands of *Salmonella* inoculated onto sterile ground chicken breast burgers and incubated at 25C. Journal of Food Safety. 20 (4) 225-236.
	B – Growth of *C. perfringens*	Chili cooked to 167˚F (75˚C) quickly cooled to 90˚F (32.2˚C) and held for up to 6 hours	There was 0.5 log growth of *C. perfringens* in 6 hours at 90˚F (32.2˚C).	Blankenship, L.C., S.E. Craven, R.G. Leffler, and C. Custer. 1988. Growth of *Clostridiun perfringens* in cooked chili during cooling. Applied and Environmental Microbiology. 54 (5) 1104-1108.
		Chili cooked to 167˚F (75˚C) quickly cooled to 95˚F (35˚C) to 110˚F (43.3˚C) and held for up to 6 hours	There was no log growth of *C. perfringens* in 2 hours in this temperature range, however in 6 hours there was 2 to 3 log growth when kept at 95˚F (35˚C) to 110˚F (43.3˚C).	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post cook holding, pre chilling	B – Growth of *C. perfringens*	Chili cooked to 167˚F (75˚C) quickly cooled to 80˚F (26.7˚C) or 70˚F (21.1˚C) and held for up to 6 hours	There was no log growth of *C. perfringens* in 6 hours at either 80˚F (26.7˚C) or 70˚F (21.1˚C).	Blankenship, L.C., S.E. Craven, R.G. Leffler, and C. Custer. 1988. (Continued)
Post packaging heat treatment	B – *L. monocytogenes* survival	Fully cooked RTE turkey breasts packaged in .08 mm film heated in 96°C water	*L. monocytogenes* was reduced by 1 log unit in 2 minutes, 2 log units in 5 minutes, 3.5 log units in 10 minutes, 5 log units in 20 minutes, 6 log units in 40 minutes, and 7 log units in 50 minutes.	Murphy, R.Y., L.K. Duncan, K.H. Driscoll, J.A. Marcy, and B.L. Beard. 2003. Thermal inactivation of *Listeria monocytogenes* on ready-to-eat turkey breast meat products during postcook in-package pasteurization with hot water. Journal of Food Protection. 66 (9) 1618-1622.
Chilling process after cooking	B- *C. perfringens* growth during chilling process	Cooked, cured meat products	Determine log changes in *C. perfringens* at various chilling times and temperatures.	To use prediction model, based upon research by V.K. Juneja, go to: http://www.arserrc.gov/mfs/pathogen.htm
		Ready-to-eat turkey cooled from 120˚F (48.9˚C) to 55˚F (12.8˚C) in 6 hours	There was no log growth of *C. perfringens.*	Steel, F.M., and K.H. Wright. 2001. Cooling rate effect on outgrowth of *Clostridium perfringens* in cooked ready-to-eat turkey breast roast. Poultry Science. 80 (6) 813-816.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling process after cooking	B- *C. perfringens* growth during chilling process	Ready-to-eat turkey cooled from 120˚F (48.9˚C) to 55˚F (12.8˚C) in 6 hours	There was 0.75 log growth of *C. perfringens.*	Steel, F.M., and K.H. Wright. 2001. (Continued)
		Ready-to-eat turkey cooled from 120˚F (48.9˚C) to 55˚F (12.8˚C) in 6 hours	There was 1.25 log growth of *C. perfringens.*	
		Cooked, uncured ground turkey chilled from 120°F (48.9°C) to 55°F (12.8°C) in 6 hours.	There was 2.25 to 2.44 log units growth of *C. perfringens* in the 6 hours of chilling.	Kalinowski, R.M., R.B. Tompkin, P.W. Bodnaruk, W.P. Pruett, Jr. 2003. Impact of cooking, cooling, and subsequent refrigeration on the growth or survival of *Clostridium perfringens* in cooked meat and poultry products. Journal of Food Protection. 66(7) 1227-1232.
		Cooked, uncured ground turkey with no salt or with 1 to 3% salt held at 80°F (26.7°C) to 120°F (48.9°C) for up to 6 hours	There was log growth of 1.4 to 5.2 units of *C. perfringens* in 6 hours. 1 to 3% salt increased the lag time 2 hours	
		Cooked, cured ground turkey chilled from 120°F (48.9°C) to 80°F (26.7°C) in 6 hours.	There was no log growth of *C. perfringens* in the 6 hours of chilling.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling process after cooking	B- *C. perfringens* growth during chilling process	Cooked, cured ground turkey chilled from 130°F (54.4°C) to 45°F (7.2°C) in 24 hours.	There was 3.7 log growth of *C. perfringens* in 24 hours. 2.66 log growth of *C. perfringens* occurred between 95°F (35°C) to 52°F (11.1°C) durring the second 12 hours.	Kalinowski, R.M., R.B. Tompkin, P.W. Bodnaruk, W.P. Pruett, Jr. 2003. Impact of cooking, cooling, and subsequent refrigeration on the growth or survival of *Clostridium perfringens* in cooked meat and poultry products. Journal of Food Protection. 66(7) 1227-1232.
		Cooked, cured ground turkey with no salt or with 1 to 3% salt held at 100°F (37.8°C) to 120°F (48.9°C) or below 90°F (32.2°C) for up to 6 hours	There was log growth of 2.6 to 4.1 units of *C. perfringens* in 6 hours. There was no log growth below 90°F (32.2°C) in 6 hours. 1 to 3% salt increased the lag time 3 hours With 3% salt, inoculation dropped below detection level after 1 hour	
		Cooked ground beef cooled from 130˚F (54.4˚C) to 45˚F (7.2˚C) in 12 hours	There was no log growth of *C. perfringens.*	Juneja, V.K., O.P. Snyder Jr, and M. Cygnarowicz-Provost. 1994. Influence of cooling rate on outgrowth of *Clostridium perfringens* spores in cooked ground beef. Journal of Food Protection. 57 (12) 1063-1067.
		Cooked ground beef cooled from 130˚F (54.4˚C) to 45˚F (7.2˚C) in 15 hours	There was 1 log growth of *C. perfringens.*	
		Cooked ground beef cooled from 130˚F (54.4˚C) to 45˚F (7.2˚C) in 18 hours	There was 5 log growth of *C. perfringens.*	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling process after cooking	B – Growth of *Bacillus cerus, Clostridium botulinum, Listeria monocytogenes, Staphylococcus aureus,* and *Salmonella* spp.	Chilling cooked ground beef from 126˚F (52.4˚C) to 45˚F (7.2˚C) within 21 hours	Product cooled from 126˚F (52.4˚C) to 45˚F (7.2˚C) with in 21 hours showed no log increase of *Clostridium botulinum, Listeria monocytogenes, Staphylococcus aureus,* and *Salmonella* spp.	Juneja, V.K., O.P. Snyder, and B.S. Marmer Jr. 1997. Potential for growth from spores of *Bacillus cerus* and *Clostridium botulinum* and vegetative cells of S*taphylococcus aureus, Listeria monocytogenes,* and *Salmonella* serotypes in cooked ground beef during cooling. Journal of Food Protection. 60 (3) 272-275.
	B – *Clostridium perfringens* growth of heat resistant spores before fully chilled	Cooling from 140°F (60°C) to 50°F (10°C) at a constant rate	Temperature must constantly decrease at a rate of 10°C/hour from 140°F (60°C) to 50°F (10°C) to prevent growth of heat resistant spores.	Shigehisa, T., T. Nakagami, and S. Taji. 1985. Influence of heating and cooling rates on spore germination and growth of *Clostridium perfringens* in media and roast beef. Japanese Journal of Veterinary Science. 47 (2) 259-267.
		Holding meat products below 59°F (15°C)	*C. perfringens* does not grow in meat products at temperatures below 59°F (15°C).	Labbe, R.G., and C.L. Duncan. 1974. Sporulation and enterotoxin production by *Clostridium perfringens* type A under conditions of controlled pH and temperature. Canadian Journal of Microbiology. 20: 1493-1501.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling process after cooking	B – *Clostridium perfringens* growth of heat resistant spores before fully chilled	Holding meat products below 68˚F (20˚C)	Lowest temperature of growth for *C. perfringens* is 68˚F (20˚C).	Rey C.R., H.W. Walker, and P.L. Rohrbaugh. 1975. The influence of temperature on growth, sporulation, and heat resistance of spores of six strains of *Clostridium perfringens*. Journal of Milk and Food Technology. 38:461-465.
	B – Growth and toxin production of *C. botulinum*	Holding meat products below 36˚F (2.2˚C) and a_w is 0.94 or less.	*C. botulinum* does not grow at 36˚F (2.2˚C) or lower, and the minimum a_w is 0.94.	Sperber, W.H., 1982. Requirements of *Clostridium botulinum* for growth and toxin production. Food Technology. 36 (12) 89-94.
	B – *Clostridium perfringens* growth in temperature abused product	Temperature abuse (82˚F(28˚C)) of cooked beef product	Temperature abuse of refrigerated products for 6 hours did not permit *C. perfringens* growth.	Juneja, V.K., B.S. Marmer, and A.J. Miller. 1994. Growth and sporulation potential of *Clostridium perfringens* in aerobic and vacuum-packaged cooked beef. Journal of Food Protection. 57 (5) 393-398.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chilling process after cooking	B – *Clostridium perfringens* growth and toxin formation	Ready-to-eat roast beef, cooked beef and corned beef products, fully cooked, partially cooked, and char-marked meat patties, and certain partially cooked and ready-to-eat poultry products	Establishments are required by FSIS to meet the stabilization performance standards for preventing the growth of spore-forming bacteria.	Appendix B, to FSIS Compliance Guidelines Access on internet at: www.fsis.usda.gov/oa/fr/95033F-b.htm Meat and Poultry Regulations, Sections 9 CFR §§ 318.17(a)(2) http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301 FSIS Directive 7370.2, on the internet: http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/FSISDir7370.2.pdf

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Brine Chill	B – *Yersinia enterocolita, L. monocytogenes*, and *Staphylococcus aureus* survival and growth in recycled chiller brines.	Using brine solutions from 0.5% to 20% sodium chloride, and temperatures from 10.4˚F (-12˚C) to 82.4˚F (28˚C)	For *Y. enterocolitica*: At 9% NaCl, growth was prevented at any temperature. At 19˚F (-7˚C), growth prevention was more likely than pathogen death, suggesting a protective effect at lower temperatures. For *L. monocytogenes*: Lethal or static conditions were observed at >9% NaCl. Lowering temperature appeared to enhance survival. For *S. aureus*, death was observed at 9% NaCl or higher, and at 41˚F (5˚C) or lower. The times, temperatures, and salt concentrations specified in Meat & Poultry Inspection Bulletin 83-16 are sufficient to prevent these three pathogens from growing, but may not cause death of pathogens.	Miller, A. J., J. E. Call, and B. S. Eblen. 1997. Growth, injury and survival potential of *Yersinia enterocolitica, L. monocytogenes*, and *Staphylococcus aureus* in brine chiller conditions. Journal of Food Protection. 60 (11) 1334-1340. MPI Bulletin 83-16
Post cooking handling	B – *S. aureus, Salmonella* spp. and *L. monocytogenes* contamination	Exposing product (opening packages) after product is cooked; surface rubbed with spices	*S. aureus* increased in some cases but were not consistent. There were no positive *Listeria* spp. or *Salmonella* spp.	Michel, M.E., J.T. Keeton, and G.R. Acuff. 1991. Pathogen survival in precooked beef products in processing. Journal of Food Protection. 54 (10) 767-772.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Temperature control and storage after cooking	B – Survival and growth of *C. perfringens*	Holding beef gravy at various temperatures ranging from 40°F (4.44°C) to 125°F (51.3°C)	40°F (4.44°C) to 60°F (15.6°C) – stabilization or slow death over 5 days.	Hall, H.E., and R. Angelotti. 1965. *Clostridium perfringens* in meat and meat products. Applied Microbiology. 13 (3) 352-357.
			65°F (18.3°C) – 2 log growth in 4 days.	
			70°F (21.1°C) – 2 log growth in 3 days.	
			75°F (23.9°C) – 2 log growth in 2 days.	
			80°F (26.7°C) – 2 log growth in 1 day.	
			85°F (29.4°C) to 95°F (35°C) – 2 log growth in less than 24 hours.	
			115°F (46°C) – 2 log growth in less than 4 hours.	
			120°F (49°C) – while vegetative cells are destroyed, spores are shocked and will germinate leading to a 2 log increase in 4 days.	
			125°F (51.6°C) – there were no log changes in 5 days.	
	B – Survival and growth of *C. perfringens*	Cooked, uncured ground turkey held at 33°F (0.6°C) to 50°F (10°C) for up to 7 days	*C. perfringens* was reduced 1.25 to 1.9 log units when stored for 24 hours and 2.3 to 2.75 log units when stored for 7 days.	Kalinowski, R.M., R.B. Tompkin, P.W. Bodnaruk, W.P. Pruett, Jr. 2003. Impact of cooking, cooling, and subsequent refrigeration on the growth or survival of *Clostridium perfringens* in cooked meat and poultry products. Journal of Food Protection. 66(7) 1227-1232.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Temperature control and storage after cooking	B- *Staphylococci aureus, Salmonella typhimurium,* and *Clostridium perfringens* growth during hot holding of roast beef	Fully cooked roast beef – holding temperature at 120°F (48.8°C) or warmer	When holding meat at 120°F (48.8°C) *Staphylococci aureus* was reduced approximately 3 log units in 6 hours and *Salmonella typhimurium* was reduced < 3 log units in 24 hours.	Brown, D.F., and R.M. Twedt. 1972. Assessment of the sanitary effectiveness of holding temperature of beef cooked at low temperature. Applied Microbiology. 24 (4) 599-603.
		Fully cooked roast beef – holding temperature at 122°F (50°C)	When holding meat at 122°F (50°C) *Salmonella typhimurium* was reduced 1 log unit in 12 hours, and 3 log units in 18 hours.	
		Fully cooked roast beef – holding temperature at 124°F (51.1°C)	When holding meat at 124°F (51.1°C) *Salmonella typhimurium* was reduced 2 log units in 6 hours, and 4 log units in 12 hours. *Clostridium perfringens* was reduced > 1 log unit in 18 hours.	
		Fully cooked roast beef – holding temperature at 128°F (53.3°C)	When holding meat at 128°F (53.3°C) *Salmonella typhimurium* was reduced > 4 log units in 6 hours. *Clostridium perfringens* was reduced 2-3 log units, below detection limits in 6 hours.	
	B – *Yersinia enterocolitica growth*	Storage of cooked beef, or pork roasts at 45˚F (7˚C)	*Y. enterocolitica* can increase 7 log units in 10 days at 45˚F (7˚C).	Hanna, M.O., J.C. Stewart, Z.L. Carpenter, D.L. Zink, and C. Vanderzant. 1977. Development of *Yersinia enterocolitica* on raw and cooked beef and pork at different temperatures. Journal of Food Science. 42: 1180-1184.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Temperature control and storage after cooking	B – *C. botulinum* toxin production	Beef stew held at 34°F (1°C), 36°F (2°C), or 38°F (3°C) for up to 104 days	*C. botulinum* toxin was detected between 14 and 31 days when the stew was held at 38°F (3°C). No toxin was detected at 104 days when held at 34°F (1°C) or 36°F (2°C).	Schmidt, C.F., R.V. Lechowich, and J.F. Folinazzo. 1961. Growth and toxin production by type E clostridium botulinum below 40°F. Journal of Food Science. 26(6) 626-630.
	B – *C. botulinum* toxin production, *L. monocytogenes*, and enterotoxigenic *E. coli* growth	Storage of products at less than 41°F (5°C)	*C. botulinum* type E grew and produced toxin in beef stew at 38°F(3.3°C) within 31 days. *L. monocytogenes* is capable of growth at 40°F (4°C) and 43°F (6°C) in milk and lamb. Enterotoxigenic *E. coli* were able to grow and produce toxin at 40°F (4°C) in broth and broth with cream.	Palumbo, S.A. 1986. Is refrigeration enough to restrain foodborne pathogens? Journal of Food Protection. 49(12) 1003-1009.
	B – Survival of *E. coli* O157:H7 and *Listeria monocytogenes*	Broth held at -18°F (-28°C), 0°F (-18°C) or 23°F (-5°C) for up to 21 days	*E. coli* O157:H7 decreased 0.5 log units at -18°F (-28°C), and 1.5 log units at 0°F (-18°C) in 7 days and remained constant for 21 days. There was no decrease in 21 days at or 23°F (-5°C) *L. monocytogenes* showed less than 0.5 log reduction in 21 days at all three temperatures.	Chou, C.C., S.J. Cheng, Y.C. Wang, and K.T. Chung. 1999. Behavior of Escherichia coli O157:H7 and Listeria monocytogenes in tryptic soy broth subjected to various low temperature treatments. Food Research International. 32 (1) 1-6.

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Temperature control and storage after cooking	B – Survival of *E. coli*, *Staphylococcus aureus* and *Salmonella*	Slurries made from commercially available chicken, beef and turkey pot pies held for 18 hours at 95°F (35°C)	*Salmonella* grew when the pH of the slurry was greater than 4.0 *E. coli* and *Staphylococcus aureus* grew when the pH was greater than 4.5.	Dack, G.M., and G. Lippitz. 1962. Fate of Staphylococci and enteric microorganisms introduced into slurry of frozen pot pies. Applied Microbiology. 10 (5) 472-479.
	B – *Campylobacter jejuni* growth and survival	Store cooked ground chicken at 40°F (4°C)	*Campylobacter jejuni* decreased 1 to 2 log units over 17 days.	Blankenship, L.C., and S.E. Craven. 1982. *Campylobacter jejuni* survival in chicken meat as a function of temperature. Applied and Environmental Microbiology. 44 (1) 88-92.
		Store cooked ground chicken at 73°F (23°C)	*Campylobacter jejuni* decreased 2.5 to 5 log units over 17 days.	
		Store cooked ground chicken at 99°F (37°C)	*Campylobacter jejuni* increased 1 to 2 log units over the first 4 days then decreased 1 log unit by day 17 for an over all 1 log unit change or no change.	
		Store cooked ground chicken at 109°F (43°C)	*Campylobacter jejuni* decreased 5 to 6 log units in 10 to 17 days.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of *Bacillus cereus, C. perfringens, E. coli, S. typhimurium,* and *S. aureus*	Chopped ham, sliced and vacuum packed, stored at 40˚F (4˚C) for 24 hours	There was no log change in *C. perfringens, E. coli, S. typhimurium,* and *S. aureus*, however, *B. cereus* decreases 1.5 log units.	Stiles, M.E., and L.-K. Ng. 1979. Fate of pathogens inoculated onto vacuum-packaged sliced hams to simulate contamination during packaging. Journal of Food Protection. 42 (6) 464-469.
		Chopped ham, sliced and vacuum packed, stored at 70˚F (21˚C) for 24 hours	*C. perfringens* decreased by 1 log units, the other pathogens tested all increased 0.5 to 3 log units.	
		Chopped ham, sliced and vacuum packed, stored at 86˚F (30˚C) for 24 hours	All pathogens tested increased 3.5 to 6.5 log units.	
		Chopped ham, sliced and vacuum packed, stored at 40˚F (4˚C) for 30 days	There was no log change in the pathogens tested except there was a 2 log unit decrease in *B. cereus,* and *C. perfringens.*	
		Chopped ham, sliced and vacuum packed, stored at 50˚F (10˚C) for 30 days	There was 1 to 2.5 log unit decreases in all pathogens tested except *E. coli*, which showed a 2.5 log growth.	

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Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of *E. coli, S. typhimurium,* and *S. aureus*	Chopped ham, sliced and vacuum packed, stored at 40˚F (4˚C) for 24 hours	There was a 0.5 log decrease in *E. coli,* and *S. typhimurium.* There was no log change in *S. aureus*.	Stiles, M.E., and L.-K. Ng. 1979. Fate of enteropathogens inoculated onto chopped ham. Journal of Food Protection. 42 (8) 624-630.
		Chopped ham, sliced and vacuum packed, stored at 70˚F (21˚C) for 24 hours	There was a 2.5 log increase in *E. coli,* there was a 1 log increase in *S. typhimurium,* and a 1.5 to 3 log increase in *S. aureus.*	
		Chopped ham, sliced and vacuum packed, stored at 86˚F (30˚C) for 24 hours	There was a 2.5 log increase in *E. coli,* and *S. typhimurium.* There was greater than 6 log growth in *S. aureus*.	
	B – Growth of *S. typhimurium, S. aureus,* and *C. perfringens*	Cooked roast beef stored in air at 40˚F (4.4˚C) for 42 days	There was no log growth for *S. typhimurium, S. aureus, or C. perfringens* at 40˚F (4.4˚C) for up to 42 days.	Hintlian, C.B., and J.H. Hotchkiss. 1987. Comparative growth of spoilage and pathogenic organisms on modified atmosphere-packaged cooked beef. Journal of Food Protection. 50 (3) 218-223.
		Cooked roast beef stored in air at 40˚F (4.4˚C) for 0 to 35 days then at 55˚F (12.8˚C) for 7 days	There was >5 log increase for *S. typhimurium, S. aureus, and C. perfringens* after the 7 days at 55˚F (12.8˚C).	
		Cooked roast beef stored in 75% CO_2, 10% O_2, 15% N_2 at 40˚F (4.4˚C) for 42 days	There was no log growth for *S. typhimurium, S. aureus, or C. perfringens* at 40˚F (4.4˚C) for up to 42 days.	
		Cooked roast beef stored in 75% CO_2, 10% O_2, 15% N_2 at 40˚F (4.4˚C) for 0 to 35 days then at 55˚F (12.8˚C) for 7 days	There was >5 log increase for *S. typhimurium,* and 1 to 2 log increase of *S. aureus and C. perfringens* after the 7 days at 55˚F (12.8˚C).	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of *Escherichia, Shigella,Proteus Klebsiella, Bacillus,*and *Clostridium perfringens,*	Water activity (a_w) level at or below 0.95 such as some fresh meat, and cooked sausages, also foods containing approximately 40% sucrose or 7%NaCl	These pathogens will be inhibited at or below these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.
	B – Growth of *Salmonella, Vibrio, C. botulinum,* some molds and yeasts	Water activity (a_w) level at or below 0.91 such as some cured meat, like hams,and foods containing 55% sucrose or 12% NaCl		
	B – *Listeria monocytogenes, Aeromonas hydrophilia*, and *Yersinia enterocolitica* growth	Packaging sliced roast beef with controlled CO_2 atmosphere (saturated)	When packaged with a controlled CO_2 atmosphere there is less than 1 log unit of growth when stored at 29°F (-1.5°C) for 1,000 hours (>41 days).	Hudson J.A., S.J. Mott, and N. Penney. 1996. Growth of *Listeria monocytogenes, Aeromonas hydrophila*, and *Yersinia enterocolitica* on vacuum and saturated carbon dioxide controlled atmosphere-packaged sliced roast beef. Journal of Food Protection. 57 (3) 204-208.
		Vacuum packaging sliced roast beef	When vacuum packaged there is a 4 log growth when stored at 29°F (-1.5°C) for 1,000 hours (>41 days).	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of mesophiles and psychrotrophs	Packaging roast beef with controlled CO_2 atmosphere (saturated)	Mesophiles and psychrotrophs grew 1.5 log units over 21 days.	McDaniel, M.C., J.A. Marchello, and A.M. Tinsley. 1984. Effect of different packaging treatments on microbiological and sensory evaluation of precooked beef roasts. Journal of Food Protection. 47 (81) 23-26.
		Packaging roast beef with controlled (15%) CO_2 and (30%) O_2, (55%) N_2 atmosphere	Mesophiles grew 2.5 log units and psychrotrophs grew 4.5 log units over 21 days.	
		Vacuum packaging sliced roast beef	Mesophiles grew 4 log units and psychrotrophs grew 4.5 log units over 21 days.	
	B – *C. perfringens, S. aureus, E. coli, S. typhimurium,* and *L. monocytogenes* survival and growth on vacuum packaged roast beef	Cooked roast beef slices, vacuum packaged and stored at 37°F (3°C) for 70 days	Despite some decreases in counts (as much as 2 log units in some cases) *C. perfringens, S. aureus, E. coli, S. typhimurium,* and *L. monocytogenes* were detectable for the entire 70 days and a hazard is likely to occur if product is contaminated after cooking.	Michel, M.E., J.T. Keeton, and G.R. Acuff. 1991. Pathogen survival in precooked beef products in processing. Journal of Food Protection. 54 (10) 767-772.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – Growth of *S. aureus, Y. enterocolitica, B. cereus, S. typhimurium* and *S. enteritidis*	Sliced, vacuum-packaged bologna	*S. aureus* showed a 6 log growth over 28 days when stored at 54°F (12°C).	Nielsen, H.-J.S., and P. Zeuthen, 1984. Influence of lactic acid bacteria and the overall flora on development of pathogenic bacteria in vacuum-packed, cooked emulsion-style sausage. Journal of Food Protection. 48 (1) 28-34.
			S. aureus showed a 1.5 log growth over 28 days when stored at 46°F (8°C).	
			Y. enterocolitica showed less than 2 log growth at 46°F (8°C) and less than 1 log growth at 41°F (5°C) over 28 days.	
			S. typhimurium showed a 4 log growth in 9 days when stored at 59°F (15°C).	
			B. cereus and *S. enteritidis* does not grow at 50°F (10°C) or less.	
	B – Growth of *C. perfringens*	Cured hot dogs vacuum packaged	*C. perfringens* showed no growth over 28 days at 54°F (12°C), or 50°F (10°C).	
	B – *Listeria monocytogenes* survival and growth	Vacuum-packaged frankfurters stored 20 days at 40°F (4°C)	*L. monocytogenes* multiplied > 1 log unit the first 10 days and another 1 log unit in the second 10 days. A hazard is likely due to the favorable environment the vacuum packaging creates.	Buncic, S., L. Paunovic, and D. Radisic. 1991. The fate of *Listeria monocytogenes* in fermented sausages and in vacuum-packaged frankfurters. Journal of Food Protection. 54 (6) 413-417.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – *Listeria monocytogenes* survival and growth	All-beef wiener exudate inoculated with 100 AU pediocin AcH, or 4 log units of *Pediococcus acidilactici* H stored at 40°F (4°C) for 29 days	*L. monocytogenes* decreased 1 to 2 log units with either of these treatments.	Yousef, A.E., J.B. Luchansky, A.J. Degnan, and M.P. Doyle. 1991. Behavior of *Listeria monocytogenes* in wiener exudates in the presence of *Pediococcus acidilactici* H or Pediocin AcH during storage at 4 or 25°C. Applied and Environmental Microbiology. 57 (5) 1461-1467.
		All-beef wiener exudate stored at 40°F (4°C) for 29 days	*L. monocytogenes* decreased 0.61 to 3.8 log units in 29 days.	
		All-beef wiener exudate inoculated with 100 AU pediocin AcH, or 4 log units of *Pediococcus acidilactici* H stored at 77°F (25°C) for 5.8 days	*L. monocytogenes* decreased 3 to 4 log units with either of these treatments.	
		All-beef wiener exudate stored at 77°F (25°C) for 5.8 days	There was great variation in *L. monocytogenes* activity. pH < 4.4 = 2 to 4.2 log reduction. pH > 4.5 = 1.7 to 3.6 log increase.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B - *Listeria monocytogenes* survival and growth	Cooked ham, chicken breast and luncheon meats packaged in 30% CO_2/ 70% N_2 or vacuum packaged and held 35 days at 44.6°F (7°C)	*L.monocytogenes* grew 7 log units in 35 days	Beumer, R.R., M.C. te Giffel, E. de Boer and F.M. Rombouts. 1996. Growth of *Listeria monocytogenes* on sliced cooked meat products. Food Microbiology. 13 (4) 333-340.
		Saveloy (fermented sausage) and Coburger ham (raw) packaged in 30% CO_2/ 70% N_2 or vacuum packaged and held at 32°F (0°C) for 6 weeks	*L.monocytogenes* did not grow and fell below detection level during the storage time.	
	B – *Listeria monocytogenes* survival	Storage at 16°F (-9°C) to 12°F (-11°C) up to 14 days	*L. monocytogenes* culture sustained 44-46% injury in the first 24 hours, however all of the injury was reversible upon thawing.	Flanders, K.J., C. W. Donnelly. 1994. Injury, resuscitation and detection of *Listeria* spp. from frozen environments. Food Microbiology. 11 (6) 473-480.
		Storage in phosphate buffer for 1 month at -18°C (-0.4°F) or -198°C (-324.4°F) (liquid nitrogen)	Storage at -18°C resulted in 87 % death and 79% injury. Stroage at -198°C for 1 month resulted in little or no injury or death. Freezing at -198°C then storage at -18°C resulted in 60% death and 36% injury	El-Kest, Souzan E., Ahmed E. Yousef, and Elmer H. Marth. 1991. Fate of *Listeria monocytogenes* During Freezing and Frozen Storage. Journal of Food Science. 56 (4) 1068-1071

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – *Listeria monocytogenes* growth	Pork white pudding or Roulade slices (both ph 6.2, a_w = 0.975 and 0.98 respectively) held at temperatures between 23°F (-5°C) and 114°F (45.5°C)	If temperature is below 48°F (9°C) growth rate is predicted by: $\frac{Temperature(°C)+5}{745446.24}\left(\frac{\log CFU/g}{hr}\right)$ If temperature is greater than 48°F (9°C) growth rate is predicted by: $\frac{T^3-46.1(T^2)+28.2(T)-40.95}{1124.65(T)-53654.832}\left(\frac{\log CFU/g}{hr}\right)$ These equations cannot be extrapolated to other pH or a_w values.	Membré, J., M. Kubaczka, J. Dubois, and C. Chèné. 2004. Temperature effect on *Listeria monocytogenes* growth in the event of contamination of cooked pork products. Journal of Food Protection. 67 (3) 463-469.
	B – *C. perfringens* and *S. aureus* growth	Vacuum packaged cooked roast beef stored at 37°F (3°C) for 70 days	*C. perfringens* showed a 2 log decrease and *S. aureus* showed no log change in 70 days of storage.	Michel, M.E., J.T. Keeton, and G.R. Acuff. 1991. Pathogen survival in precooked beef products in processing. Journal of Food Protection. 54 (10) 767-772.
	B – *C. perfringens* growth	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 40˚F (4˚C)	There was no *C. perfringens* log increase at 40˚F (4˚C).	Juneja, V.K., and B.S. Marmer. 1996. Growth of *Clostridium perfringens* from spore inocula in *sous-vide* turkey products. Journal of International Food Microbiology. 32 (1-2) 115-123.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B – *C. perfringens* growth	Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 59˚F (15˚C)	There was no *C. perfringens* log increase at 59˚F (15˚C) with 3% NaCl for 28 days. However, 1 and 2 % NaCl showed 2 to 4 log increase over 28 days after the first 3 days when there was no growth.	J uneja, V.K., and B.S. Marmer. 1996. (continued)
		Vacuum-packaged, cook-in-bag turkey pH 6, 0.3% sodium pyrophosphate and 1, 2, or 3% NaCl stored at 82˚F (28˚C)	There was no *C. perfringens* log increase at 82˚F (28˚C) for 8 hours, however in 28 days there was >5 log increase in all three formulations.	
		Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 68˚F (20˚C)	*C. perfringens* grew >3 log units at 68˚F (20˚C) with sodium lactate, there was no log increase with calcium lactate.	Aran, N. 2001. The effect of calcium and sodium lacatates on growth from spores fo *Bacillus cereus* and *Clostridium perfringens* in a ‘sous-vide’ beef goulash under temperature abuse. International Journals of Food Microbiology. 63 (1-2) 117-123.
	B - *C. perfringens* and *B. cereus* growth	Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 68˚F (20˚C)	There was no log increase of *B. cereus* in 28 days with 3% sodium lactate or 1.5% or 3% calcium lactate. There was a 1 log increase of *B. cereus* with 1.5% sodium lactate in 28 days. There was no log increase of *C. perfringens* with calcium lactate in 28 days however there was a 3 log increase when sodium lactate was used.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and/or Storage	B - *C. perfringens* and *B. cereus* growth	Vacuum-packaged beef goulash 1.6% NaCl, 5.5 pH, 1.5% or 3.0% sodium lactate or calcium lactate stored at 59˚F (15˚C)	There was no log increase of *B. cereus* in 28 days at 59˚F (15˚C). There was no log increase of *C. perfringens* when calcium lactate or 3% sodium lactate was used, however there was a 3 log increase when 1.5% sodium lactate was used.	Aran, N. 2001. (continued)
Storage	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.
	B – *Salmonella* growth	Cooked chicken patties stored at 25°C (77°F)	The shortest lag time for all *Salmonella* strains tested was 2.2 hours, followed by log growth of 0.4 log/ hour	Oscar, Thomas P. 2000. Variation of Lag Time and Specific Growth Rate Among 11 Strains of *Salmonella* Inoculated onto Sterile Ground Chicken Breast Burgers and Incubated at 25°C. Journal of Food Safety. 20 (2000) 225-236.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B-growth of *Staphylococcus aureus*, *Clostridium botulinum*, and *Clostridium perfringens* and *Listeria monocytogenes*	pH, water activity, temperature and time limits	Unless product is shelf stable, other methods must be used to prevent growth (e.g., low pH, freezing, low water activity, refrigeration temperature and time limits)	FSIS. 2005. Meat and Poultry Hazards and Controls Guide. Pg. 24 http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/5100.2/Meat_and_Poultry_Hazards_Controls_Guide_10042005.pdf
Storage after cooking	B-growth of *Listeria monocytogenes*	Product temperature, pH and water activity	*Listeria monocytogenes* can grow between the minimum and maximum Minimum Temp. 31.3ºF (-0.4ºC) pH 4.39 Water activity .92 Optimum Temp. 98.6ºF (37ºC) pH 7.0 Maximum Temp. 113ºF (45ºC) pH 9.4	FSIS. 2006. *Listeria monocytogenes* Rule Compliance Guidelines. Pg. 12 http://www.fsis.usda.gov/oppde/rdad/FRPubs/97-013F/LM_Rule_Compliance_Guidelines_May_2006.pdf
Post package pasteurization	B – Survival of *L. monocytogenes*	Vacuum packaged smoked ham reheated in 195°F (90.6° C) water	*L. monocytogenes* was reduced 3 log after 4 minutes, 3.5 log after 6 minutes, less than 4 log units after 8 minutes.	Cooksey, D.K., B.P. Klein, F.K. McKeith, and H.P. Blaschek. 1993. Reduction of *Listeria monocytogenes* in Precooked Vacuum-Packaged Beef Using Postpackaging Pasteurization. Journal of Food Protection. 56(12) 1034-1038.
		Vacuum packaged smoked ham reheated in 200°F (93.3° C) water	*L. monocytogenes* was reduced less than 3.5 log after 4 minutes, 3.5 log after 6 minutes, and more than 4 log units after 8 minutes.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post package pasteurization	B – Survival of *L. monocytogenes*	Vacuum packaged precooked beef loins reheated in 180° F (82° C) water for 16 minutes	*L. monocytogenes* was reduced more than 2 log units on meat surface and in broth inside package. This reduction in *L. monocytogenes* was maintained for 85 days after the reheating treatment.	Cooksey, D.K., B.P. Klein, F.K. McKeith, and H.P. Blaschek. 1993. (continued)
		Fully cooked chicken breast (approximately 13 mm thick), individually vacuum-packaged, steam or hot water heated at 194°F (90°C).	Surface *L. monocytogenes* was reduced 7 log units in 5 minutes.	Murphy, R.Y., L.K. Duncan, K.H. Driscoll, B.L. Beard, M.B. Berrang, and J.A. Marcy. 2003. Determination of Lethality of *Listeria monocytogenes* in Fully Cooked Chicken Breast Fillets and Strips during Postcook In-Package Pasteurization. Journal of Food Protection. 66 (4) 578 – 583.
		Fully cooked chicken breast strips in 0.5 pound (227 grams) package (approximately 35 mm thick), vacuum-packaged, steam or hot water heated at 194°F (90°C).	Surface *L. monocytogenes* was reduced 7 log units in 25 minutes.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post package pasteurization	B – Survival of *L. monocytogenes*	Fully cooked chicken breast strips in 1 pound (454 grams) package (approximately 44 mm thick), vacuum-packaged, steam or hot water heated at 194°F (90°C).	Surface *L. monocytogenes* was reduced 7 log units in 35 minutes.	Murphy, R.Y., L.K. Duncan, K.H. Driscoll, B.L. Beard, M.B. Berrang, and J.A. Marcy. 2003 (continued)
		Vacuum packaged smoked ham reheated in 205°F (96.1°C) water	*L. monocytogenes* was reduced 2.5 to 3 log units in 4 to 6 minutes. *L. monocytogenes* was reduced 3.5log units in 8 and 10 minutes.	Muriana, P.M., W. Quimby, C.A. Davidson, and J. Grooms. 2002. Postpackage pasteurization of ready-to-eat deli meats by submersion heating for reduction of *Listeria monocytogenes.* Journal of Food Protection. 65(6) 963-969.
		Vacuum packaged roast beef reheated in 195°F (90.6°C) water.	*L. monocytogenes* was reduced 2 to 2.5 log units in 4 to 6 minutes. *L. monocytogenes* was reduced 2.5 to 3 log units in 8 to 10 minutes.	
		Vacuum packaged roast beef reheated in 200°F (93.3°C) water.	*L. monocytogenes* was reduced 2.5 to 3 log units in 4 to 6 minutes. *L. monocytogenes* was reduced 3 to 3.5 log units in 8 to 10 minutes.	
		Vacuum packaged roast beef reheated in 205°F (96.1°C) water.	*L. monocytogenes* was reduced 2 to 2.5 log units in 4 to 10 minutes.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post package pasteurization	B – Survival of *L. monocytogenes*	Vacuum packaged skin-on turkey reheated in 195°F (90.6°C) or 200°F (93.3°C) water.	*L. monocytogenes* was reduced 2 to 3 log units in 4 to 10 minutes.	Muriana, P.M., W. Quimby, C.A. Davidson, and J. Grooms. 2002 (continued)
		Vacuum packaged skin-on turkey breasts reheated in 205°F (96.1°C) water.	*L. monocytogenes* was reduced more than 1.5 log units in 4 to 10 minutes.	
		Vacuum packaged, smoked turkey reheated in 205 °F (96.1°C) water.	*L. monocytogenes* was reduced more than 2 log units after 4 minutes. *L. monocytogenes* was reduced greater than 3 log units after 6 minutes. *L. monocytogenes* was reduced 3 log units after 8 minutes.	
		Vacuum packaged formed turkey or whole muscle turkey reheated in 205 °F (96.1°C) water.	*L. monocytogenes* was reduced 2.5 to 3 log units in 4 to 8 minutes.	
		Vacuum packaged turkey ham or netted turkey reheated in 200°F (93.3°C) or 205 °F (96.1°C) water	*L. monocytogenes* was reduced 3.5 log units after 3 minutes. *L. monocytogenes* was reduced 3 to 3.5 log units after 4 minutes.	

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post package pasteurization	B – Survival of *L. monocytogenes*	Vacuum packaged netted turkey breasts, containing sodium lactate, reheated in 200°F (93.3°C) water or 205 °F (96.1°C) water	*L. monocytogenes* was reduced 2 to 2.5 log units after 3 minutes. *L. monocytogenes* was reduced more than 2.5 log units after 4 minutes.	Muriana, P.M., W. Quimby, C.A. Davidson, and J. Grooms. 2002 (continued)
		Vacuum packaged cracked pepper, mesquite and lemon dill turkey, reheated in 200°F (93.3°C) water or 205 °F (96.1°C) water	*L. monocytogenes* was reduced 1.5 to 2.5 log units after 3 minutes.	
	B – Survival of *Listeria* or *Salmonella*	Fully cooked ground chicken breast products 12.7 to 63.5 mm thickness, heated at 131°F (55°C) to 203°F (95°C) for 5 seconds to 90 minutes	Time to a 7 log reduction for *Salmonella* can be predicted by: Heating time (seconds) = 0.7986 x (product thickness mm)^2 +9.9031 x (product thickness mm) + 94.428 Time to a 7 log reduction for *L.isteria innocua* can be predicted by: Heating time (seconds) = 0.8598 x (product thickness mm)^2 +7.4653 x (product thickness mm) + 152.59	Murphy, R.Y., L.K. Duncan, K.H. Driscoll, and J.A. Marcy. 2003. Lethality of *Salmonella* and *Listeria innocua* in fully cooked chicken breast meat products during postcook in-package pasteurization. Journal of Food Protection. 66 (2) 242-248.

Fully cooked, not shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Post package pasteurization	B – Survival of *Listeria*	Fully cooked chicken breast strips vacuum packaged exposed to steam or hot water at 190°F (88°C) for 10 to 35 minutes	After 25 minutes there was a 2 log reduction of *L. innocua* and after 35 minutes a 7 log reduction. No significant difference was found in water activity or shear force. There was significantly less expressable and total moisture in the water treated products and those treated for 35 minutes.	Murphy, R.Y., M.E. Berrang. 2002. Effect of steam- and hot-water post-process pasteurization on microbial and physical property measures of fully cooked vacuum-packaged chicken breast strips. Journal of Food Science. 67 (6) 2325-2329.

Heat Treated, Not Fully Cooked

Includes: Char-marked patties, flash-fried products, bacon

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C – Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://meatsci.osu.edu/sites/meatsci/files/imce/BorchertCassensNitriteHazard1998.pdf
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c) To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
	B – Pathogen survival	Addition of smoke (liquid or solid) to products	At the manufacturers' recommended levels, most bacteria were not inhibited by the addition of smoke to growth medium.	Suñen, E. 1998. Minimum inhibitory concentration of smoke wood extracts against spoilage and pathogenic mico-organisms associated with foods. Letters in Applied Microbiology. 27 (1) 45 – 48.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of pathogenic bacteria and mold	Addition of liquid smoke to products	All smokes tested showed some additional anti-microbial activity. The most effective have low pH and high carbonyl content, while phenols do not seem to effect microbial inhibition.	Milly, P.J., R.T. Toledo, S. Ramakrishnan. 2005. Determination of Minimum Inhibitory Concentrations of Liquid Smoke Fractions. Journal of Food Science. 70 (1) M12 – M17.
	B- *E. coli* O157:H7 growth	Storage of *E. coli* O157:H7 at various temperatures, NaCl levels and pH levels	There was no growth of *E. coli* O157:H7 below 46.4°F (8°C), and slow to no growth when salt levels were above 20g/L. pH ranging from 4.5 to 8.5 did not greatly effect growth. All combinations of salt, ranging from 5 g/L to 35 g/L, pH (4.5 to 8.5) and temperature 82.4°F (28°C) and higher grew *E. coli* O157:H7.	Buchanan, R.L., and L.A. Klawitter. 1992. The effect of incubation temperature, initial pH, and sodium chloride on the growth kinetics of *Escherichia coli* O157:H7. Food Microbiology. 9 (3) 185-196.
	B – Growth of *L. monocytogenes, A. hydrophila,* and *Y. enterocolitica*	Addition of smoke (liquid or solid), at the manufacturers' recommended level, to products and held at 41°F (5°C) for up to 21 days.	Some smoke products can inhibit *L. monocytogenes*, , *A. hydrophila,* and *Y. enterocolitica* for up to 21 days, but *L. monocytogenes* and *Y. enterocolitica* show no log reduction in that time.	Suñan, E. B. Fernandez-Galian, and C. Aristimuño. 2001. Antibacterial activity of smoke wood condensates against *Aeromonas hydrophila, Yersinia enterocolitica* and *Listeria monocytogenes* at low temperature. Food Microbiology. 18 (4) 387 – 393.
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.

Not Heat Treated, Shelf Stable Process

Includes: dry-cured products (Traditional Italian Salami)

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://www.ag.ohio-state.edu/~meatsci/borca2.htm
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c) To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
	B – Pathogen survival	Addition of smoke (liquid or solid) to products	At the manufacturers' recommended levels, most bacteria were not inhibited by the addition of smoke to growth medium.	Suñen, E. 1998. Minimum inhibitory concentration of smoke wood extracts against spoilage and pathogenic micro-organisms associated with foods. Letters in Applied Microbiology. 27 (1) 45 – 48.

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Growth of pathogenic bacteria and mold	Addition of liquid smoke to products	All smokes tested showed some additional anti-microbial activity. The most effective have low pH and high carbonyl content, while phenols do not seem to effect microbial inhibition.	Milly, P.J., R.T. Toledo, S. Ramakrishnan. 2005. Determination of Minimum Inhibitory Concentrations of Liquid Smoke Fractions. Journal of Food Science. 70 (1) M12 – M17.
	B – Growth of *L. monocytogenes, A. hydrophila,* and *Y. enterocolitica*	Addition of smoke (liquid or solid), at the manufacturers' recommended level, to products and held at 41°F (5°C) for up to 21 days.	Some smoke products can inhibit *L. monocytogenes*, , *A. hydrophila,* and *Y. enterocolitica* for up to 21 days, but *L. monocytogenes* and *Y. enterocolitica* show no log reduction in that time.	Suñan, E. B. Fernandez-Galian, and C. Aristimuño. 2001. Antibacterial activity of smoke wood condensates against *Aeromonas hydrophila, Yersinia enterocolitica* and *Listeria monocytogenes* at low temperature. Food Microbiology. 18 (4) 387 – 393.
	B – Survival and growth of *Salmonella*	Addition of $NaNO_2$ and KNO_3 and use of starter culture or glucono-delta-lactone to lower pH to 4.8 to 5.3	100 ppm $NaNO_2$ and 150 ppm KNO_3 or 50 ppm $NaNO_2$ and 75 ppm KNO_3 is adequate to produce a safe dry sausage as long as a starter culture or glucono-delta-lactone is used to lower pH to 4.8 to 5.3.	Puolanne, E. 1977. Effects of reduced addition of nitrate and nitrite on the properties of dry sausage. Journal of the Scientific Agricultural Society of Finland. 49 (1) 1-106.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B - *E. coli* O157:H7 survival	Addition of malic acid to pH 3.9	The addition of malic acid and citric acid to the growth medium reduced *E. coli* O157:H7 4.0 log units at pH 4.2 or lower however it was still detectable at pH 3.9.	Ryu, J.H., Y. Deng, L.R. Beuchat. 1999. Behavior of acid-adapted and unadapted *Escherichia coli* O157:H7 when exposed to reduced pH achieved with various organic acids. Journal of Food Protection. 62(5) 451-455.
		Addition of citric acid to pH 3.9		
		Addition of lactic acid to pH 3.9	The addition of lactic acid to the growth medium reduced *E. coli* O157:H7 by 4 log units at pH 4.2, and 6 log units at pH 3.9 however it was still detectable at pH 3.9.	
		Addition of acetic acid to pH 3.9	The addition of acetic acid to the growth medium reduced *E. coli* O157:H7 by 3 log units at pH 5.1, and 4.8, 4 log units at pH 4.5, 6 log units at pH 4.2 and *E. coli* O157:H7 was undetected at pH 3.9 (reduction of more than 7 log units).	
	B- *E. coli* O157:H7 growth	Storage of *E. coli* O157:H7 at various temperatures, NaCl levels and pH levels	There was no growth of *E. coli* O157:H7 below 46.4°F (8°C), and slow to no growth when salt levels were above 20g/L. pH ranging from 4.5 to 8.5 did not greatly effect growth. All combinations of salt, ranging from 5 g/L to 35 g/L, pH (4.5 to 8.5) and temperature 82.4°F (28°C) and higher grew *E. coli* O157:H7.	Buchanan, R.L., and L.A. Klawitter. 1992. The effect of incubation temperature, initial pH, and sodium chloride on the growth kinetics of *Escherichia coli* O157:H7. Food Microbiology. 9 (3) 185-196.

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.
Fermentation	B - *E. coli* O157:H7 survival through fermentation and drying	Product is fermented, using starter culture, at 68-86°F (20-30°C), for 1-3 days, at about 90% RH, followed by drying for up to 60 days at about 85% RH.	Seven commercial processes were evaluated and it was found that fermentation can result in 0.3 to 1.3 log reduction of *E. coli* O157:H7; not sufficient to meet the required 2 log reduction. Three models have been developed to assist estimating the time required to achieve a 2 log reduction when parameters such as water activity, pH and drying time are used.	Pond, T.J., D.S. Wood, I.M. Mumin, S. Barbut and M.W. Griffith. 2001. Modeling the survival of *E. coli* O157:H7 in uncooked, semidry, fermented sausage. Journal of Food Protection. 64 (6) 759-766.
	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH.	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – Potential Staphylococcus growth	Fermentation to pH 5.3 or less	(Fermentation Temperature (˚F)–60) X hours = degree hours Process acceptable if: Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90˚F (32°C). Fewer than 1000 degree hours when the highest fermentation temperature is between 90˚F (32°C) and 100˚F (38°C). Fewer than 900 degree hours when the highest fermentation temperature is greater than 100˚F (38°C).	Products, American Meat Institute Foundation, 1997.
Drying	B – Growth of many yeasts	Water activity (a_w) level at or below 0.87 such as fermented sausage, and foods containing approximately 65% sucrose or 15%NaCl	These pathogens are inhibited at these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – growth of most molds (mycotogenic penicillia), *Staphyloccoccus aureus, most Saccharomyces (bailii) spp. Debaromyces*	Water activity (a_w) level at or below 0.80	These pathogens are inhibited at these water activity levels.	Beuchat, L.R. 1981. (continued)
	B – growth of halophilic bacteria, *mycotoxigenic aspergilli*	Water activity (a_w) level at or below 0.75		
Storage	B – *Staphylococcus* growth	Storage of dry-cured hams at 36°F (2°C) in vacuum packaging.	A hazard by *Staphylococcus* is less likely if stored just above freezing.	Kemp, J.D., B.E. Langlois, K. Akers, and D.K. Aaron. 1989. Effect of storage temperature, time and method of slicing on microbial population and white film development in vacuum packaged, dry-cured ham slices. Journal of Food Science. 54 (4) 871-873.
		Storage of dry-cured hams at 75°F (24°C) in vacuum packaging.	A bacterial hazard is likely to occur because there are no retardant conditions to slow bacteria growth. There is a 3 to 4 log increase in growth from storage at 36°F (2°C).	
	B – *E. coli* O157:H7 growth in ground beef product	Ground beef dried at 72˚F (22˚C) to near 30% moisture when stored at 40˚F (4˚C) 55% relative humidity for 2 months, **NOT** vacuum packaged	No hazard is posed after 2 months, in these conditions as all traces of *E. coli* were destroyed.	Cosanu, S., and K. Ayhan. 2000. Survival of enterohaemorrahagic *Escherichia coli* O157:H7 strand in Turkish soudjouck during fermentation, drying and storage periods. Meat Science. 54 (4) 407-411.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – *E. coli* O157:H7 growth in ground beef product	Ground beef dried at 72˚F (22˚C) to near 30% moisture when stored at 40˚F (4˚C) 55% relative humidity for 3 months, vacuum packaged	No hazard is posed after 3 months of storage in these conditions as all traces of *E. coli* were destroyed.	Cosanu, S., and K. Ayhan. 2000. (continued)
	B- Survival of *E. coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. and *Staphylococcus aureus*.	Sliced, vacuum-packaged dry-cured ham stored at 77°F (25°C) for 28 days	Survival of these pathogens in vacuum-packaged dry-cured ham may pose a hazard if consumed without adequate cooking.	Ng, W.F., BE. Langlois, and W.G. Moody. 1997. Fate of selected pathogens in vacuum-packaged dry-cured (country style) ham slices stored at 2 and 25°C. Journal of Food Protection. 60 (12) 1541-1547.
		Sliced, vacuum-packaged dry-cured ham stored at 35.6°F (2°C) for 28 days	Survival of these pathogens in vacuum-packaged dry-cured ham may pose a hazard if consumed without adequate cooking.	
	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B - *E. coli* O157:H7 survival, and growth	After fermentation at 76˚F (24˚C), 90% RH to pH <4.8, then dried at 55˚F (13˚C) 65% RH to pH approx. 4.6, a_w approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 40˚F (4˚C)	After 90 days of storage at 40˚F (4˚C), *E. coli* O157:H7 was still detectable.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of *Escherichia coli* O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.
		After fermentation at 76˚F (24˚C), 90% RH to pH <4.8, then dried at 55˚F (13˚C) 65% RH to pH approx. 4.6, a_w approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 70˚F (21˚C)	After 90 days of storage at 70˚F (21˚C) no *E. coli* O157:H7 was detectable by direct plating but was found after enrichment.	

Not heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Aging time and packaging	B – Growth of bacteria and mold	Curing hams for 2 days per pound covered with stockinettes	Bacteria and molds are equally likely to grow with either type of packaging, which could potentially cause a hazard.	Draughon, F.A., C.C. Melton, and D. Maxedon. 1981. Microbial profiles of country-curd hams aged in stockinettes, barrier bags and paraffin wax. Applied and Environmental Microbiology. 41 (4) 1078-1080.
		Curing hams for 2 days per pound covered with barrier bags		
		Curing hams for 2 days per pound covered with a coating of paraffin wax	The use of paraffin wax coating did not seem to affect the growth of bacteria, however molds were less likely to grow, reducing the risk of mycotoxins.	
	B – Survival of *Trichina spiralis*	Curing dry-cured ham at 50°F (10°C) for at least 90 days	Trichina are rendered non infective when ham is cured at the given time temperature intervals.	Lin, K.W., J.T. Keeton, T.M. Craig, R.H. Huey, M.T. Longnecker, H.R. Gamble, C.S. Custer, and H.R. Cross. 1990. Bioassay of dry-cured ham processed to affect *Trichina spiralis*. Journal of Food Science. 55 (2) 289-292, 297.
		Curing dry-cured ham at 75°F (23.9°C) for at least 35 days		
		Curing dry-cured ham at 90°F (32.2°C) for at least 11 days		

Heat Treated, Shelf Stable Process

Includes: dry sausage products

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration)	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://meatsci.osu.edu/sites/meatsci/files/imce/BorchertCassensNitriteHazard1998.pdf
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR318.7(c) To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
	B – Pathogen survival	Addition of smoke (liquid or solid) to products	At the manufacturers' recommended levels, most bacteria were not inhibited by the addition of smoke to growth medium.	Suñen, E. 1998. Minimum inhibitory concentration of smoke wood extracts against spoilage and pathogenic mico-organisms associated with foods. Letters in Applied Microbiology. 27 (1) 45 – 48.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B –Growth of pathogenic bacteria and mold	Addition of liquid smoke to products	All smokes tested showed some additional anti-microbial activity. The most effective have low pH and high carbonyl content, while phenols do not seem to effect microbial inhibition.	Milly, P.J., R.T. Toledo, and S. Ramakrishnan. 2005. Determination of Minimum Inhibitory Concentrations of Liquid Smoke Fractions. Journal of Food Science. 70 (1) M12 – M17.
	B – Growth of *L. monocytogenes, A. hydrophila,* and *Y. enterocolitica*	Addition of smoke (liquid or solid), at the manufacturers' recommended level, to products and held at 41°F (5°C) for up to 21 days.	Some smoke products can inhibit *L. monocytogenes, , A. hydrophila,* and *Y. enterocolitica* for up to 21 days, but *L. monocytogenes* and *Y. enterocolitica* show no log reduction in that time.	Suñan, E. B. Fernandez-Galian, and C. Aristimuño. 2001. Antibacterial activity of smoke wood condensates against *Aeromonas hydrophila, Yersinia enterocolitica* and *Listeria monocytogenes* at low temperature. Food Microbiology. 18 (4) 387 – 393.
	B – *Listeria monocytogenes,* survival with potassium nitrate and/or sodium nitrite addition	Addition of sodium nitrite at 50 ppm (3-3.5% NaCl) to dried sausage	*Listeria monocytogenes* can be reduced by 1 log unit over a period of 21 days of storage.	Junttila, J., J. Hirn, P. Hill, and E. Nurmi. 1989. Effect of different levels of nitrite and nitrate on the survival of *Listeria monocytogenes* during the manufacture of fermented sausage. Journal of Food Protection. 52 (3) 158-161.
	B – *Listeria monocytogenes,* survival with potassium nitrate and/or sodium nitrite addition	Addition of sodium nitrite at 120 ppm (3-3.5% NaCl) to dried sausage	*Listeria monocytogenes* can be reduced by 1 log unit over a period of 21 days of storage.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – *Listeria monocytogenes*, survival with potassium nitrate and/or sodium nitrite addition	Addition of sodium nitrite at 200 ppm (3-3.5% NaCl) to dried sausage	*Listeria monocytogenes* can be reduced by 1 log unit over a period of 21 days of storage. However this is over the limit of allowable nitrite.	Junttila, J., J. Hirn, P. Hill, and E. Nurmi. 1989. (continued)
		Addition of sodium nitrite at 200 ppm and potassium nitrate at 300 ppm (3% NaCl) to dried sausage	*Listeria monocytogenes* can be reduced by 2 log units over a period of 21 days of storage. However this is over the limit of allowable nitrite.	
		Addition of potassium nitrate at 1000 ppm (3.5% NaCl) to dried sausage	*Listeria monocytogenes* can be reduced by 3 log units over a period of 21 days of storage. However this is over the limit of allowable nitrite.	
	B – Survival and growth of *Salmonella*	Addition of $NaNO_2$ and KNO_3 and use of starter culture or glucono-delta-lactone to lower pH to 4.8 to 5.3	100 ppm $NaNO_2$ and 150 ppm KNO_3 or 50 ppm $NaNO_2$ and 75 ppm KNO_3 is adequate to produce a safe dry sausage as long as a starter culture or glucono-delta-lactone is used to lower pH to 4.8 to 5.3.	Puolanne, E. 1977. Effects of reduced addition of nitrate and nitrite on the properties of dry sausage. Journal of the Scientific Agricultural Society of Finland. 49 (1) 1-106.
	B –*S. aureus*, *Salmonella* and *Clostridium sporogenes* survival with nitrite addition	Addition of up to 150 ppm of nitrite	Nitrite at these levels has little or no effect controlling *Staphylococcus aureus* (1-2 log growth), *Salmonella* (0.5 – 1 log reduction), *or Clostridium sporogenes* (no log change).	Collins-Thompson, D.L., B. Krusky, W.R. Usborne, and A.H.W. Hauschild. 1984. The effect of nitrite on the growth of pathogens during manufacture of dry and semi-dry sausage. Canadian Institute of Food Science and Technology Journal. 17 (2) 102-106.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formuation	B – *L. monocytogenes* heat resistance	Holding product between 104˚F (40˚C) and 118˚F (48˚C) for 3 to 20 minutes	D-value for *L. monocytogenes* increases up to 2.3 fold when cooked at 131˚F (55˚C). The time allotted to destroy *L. monocytogenes* must increase correspondingly.	Linton, R.H., M.D. Pierson, and J.R. Bishop. 1990. Increase in heat resistance of *Listeria monocytogenes* Scott A by sublethal heat shock. Journal of Food Protection. 53 (11) 924-927.
	B – Survival of *Listeria monocytogenes*	Beef Jerky no marinade dried 10 hours. 140ºF (60ºC)	There was no significant reduction of *Listeria monocytogenes* due to pre-drying treatment.	Calicioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall, and G.C. Smith, 2002. Destruction of acid- and non-adapted *Listeria monocytogenes* during drying and storage of beef jerky. Food Microbiology. 19 (6) 545-559.
		Beef Jerky marinade 10 minutes in traditional marinade (pH 3) dried 10 hours 140ºF (60ºC) then stored 42 days at 77ºF (25ºC)	There was no significant reduction of *Listeria monocytogenes* due to pre-drying treatment.	

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival of *Listeria monocytogenes*	Marinated Beef Jerky in a traditional sauce that includes 4.7% ethanol, (pH 3.0) for 24 hours at 40ºF (4ºC) then dried 10 hours at 140ºF (60ºC) and stored at 77ºF (25ºC) for 14 days	There was no significant reduction of *Listeria monocytogenes* due to pre-drying treatment.	C alicioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall, and G.C. Smith. 2002. (continued)
		Beef jerky marinated with 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 39.2ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC) then stored at 77ºF (25ºC) for 14 days (aw <.70)	Treatment with acetic acid and Tween showed a 1 log reduction in *Listeria monocytogenes*.	

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival of *Listeria monocytogenes*	Beef jerky marinated with 1% Tween 20 for 15 minutes then 5% acetic acid. 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 40ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC) then stored at 77ºF (25ºC) for 14 days (aw <.70)	Treatment with acetic acid and Tween showed a 1 log reduction in *Listeria monocytogenes*.	C alicioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall, and G.C. Smith. 2002. (continued)
	B – Survival of *E.coli O157:H7*	Beef Jerky rapidly dipped into batter at 200ºF (94ºC), then marinated (pH 4.3) for 24 hours at 40ºF (4ºC)	*E.coli O157:H7* was reduced 1.3 log units after hot water and marinade.	Albright, S.N., P.A. Kendall, J.S. Avens, J.N. Sofos. 2003. Pretreatment effect on inactivation of Escherichia coli O157:H7 inoculated beef jerky. Lebensmittel Wissenschaft Technologie. 36 (4) 381-389.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival of *E.coli O157:H7*	Beef jerky seasoned with salt, sugar and pepper and held for 24 hours at 40ºF (4ºC) then immersed for 90 seconds in brine of the same seasoning at 172.4ºF (78ºC)	*E.coli O157:H7* was reduced 3 log units after seasoning and hot brine.	A lbright, S.N., P.A. Kendall, J.S. Avens, J.N. Sofos. 2003. (continued)
		Beef jerky immersed for 20 seconds in 50/50 vinegar (5% acetic acid) water mixture at 135.5ºF (57.5ºC) then marinate (pH 4.3) for 24 hours at 40ºF (4ºC)	*E.coli O157:H7* was reduced .5 log units after treatment with vinegar and marinade.	
		Beef jerky marinated (pH 4.3) for 24 hours at 39.2ºF (4ºC) then immersed for 20 seconds in 50/50 vinegar (5% acetic acid) water mixture at 135.5ºF (57.5ºC)		

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	B – Survival of *E.coli* O157:H7	Addition of malic acid to pH 3.9	The addition of malic and citric acid to the growth medium reduced *E.coli* O157:H7 4 log units at pH 4.2 or lower, however still detectable at pH 3.9.	Ryu, J.H., Y. Deng, L.R. Beuchat. 1999. Behavior of acid-adapted and unadapted *Escherichia coli* O157:H7 when exposed to reduced pH achieved with various organic acids. Journal of Food Protection. 62(5) 451-455.
		Addition of citric acid to pH 3.9		
		Addition of lactic acid to pH 3.9	The addition of lactic acid to the growth medium reduced O157:H7 by 4 log units at pH 4.2 and 6 log units at pH 3.9, however it was still detectable at pH 3.9.	
		Addition of acetic acid to pH 3.9	The addition of acetic acid to the growth medium reduced O157:H7 by 3 log units at pH 5.1 and 4.8, 4 log units at pH 4.5, 6 log units at pH 4.2 and O157:H7 was undetected at pH 3.9 (reduction of more than 7 log units).	
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B - *E. coli* O157:H7 survival, and growth	Tempering meat mixture containing starter culture at 55°F (13°C) for less than 2 hours, then freezing at -4°F (-20°C) for more than 3 days, and thawing at 40°F (4°C) over a period of at least 3 days followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)	Tempering meat or directly freezing then thawing at 40°F (4°C) over 3 days prior to fermentation and drying does not effect *E. coli* O157:H7 survival during storage at either 40°F (4°C) or 70°F (21°C). E. coli O157:H7 was reduced 0.9 to 1.5 log units during fermentation and 0.2 to 0.6 log units during drying.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of *Escherichia coli* O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.
		Freeze meat mixture containing starter culture at -4°F (-20°C) >3 days then thawing at 40°F (4°C) over a period of at least 3 days followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)		

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B - *E. coli* O157:H7 survival, and growth	Refrigerate meat mixture containing starter culture less than 8 hours at 40°F (4°C) followed by fermentation at 76°F (24°C), 90%RH to pH at or less than 4.8, then drying at 55°F (13°C)	Tempering meat or directly freezing then thawing at 40°F (4°C) over 3 days prior to fermentation and drying does not effect *E. coli* O157:H7 survival during storage at either 40°F (4°C) or 70°F (21°C). E. coli O157:H7 was reduced 0.9 to 1.5 log units during fermentation and 0.2 to 0.6 log units during drying.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. (continued)
	B – *E. coli* O157:H7 survival through drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	*E. coli* O157:H7 was reduced 1.2 log units with this process.	Hinkins, J.C., N.G. Faith, T.D. Lorang, P. Bailey, D. Buege, C.W. Kaspar, and J.B. Luchansky. 1996. Validation of pepperoni processes for control of *Escherichia coli* O157:H7. Journal of Food Protection 59 (12) 1260-1266.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Processing	B – *E. coli* O157:H7 survival through drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, heated to 128°F (53°C) for 60 minutes or 145°F (63°C) instantaneous, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of *E. coli* O157:H7, 5 log units or more, and did not visibly affect the texture or appearance of the product.	Hinkins, J.C., N.G. Faith, T.D. Lorang, P. Bailey, D. Buege, C.W. Kaspar, and J.B. Luchansky. 1996. (continued)
Fermentation	B – *L. monocytogenes* survival and growth	Fermented pork and beef sausages, ripened for 4 days at 64-68˚F (18-20˚C) then dried at 64˚F (18˚C) with a pH range of 5.47 to 4.8	*L. monocytogenes* decrease 3 log units in 35 days.	Buncic, S., L. Paunovic, and D. Radisic. 1991. The fate of *Listeria monocytogenes* in fermented sausages and in vacuum-packaged frankfurters. Journal of Food Protection. 54 (6) 413-417.
		Beef and pork sausage fermented at 32˚F (90˚C) without a starter culture	*L. monocytogenes* increased 2 log units during fermentation.	Glass, K.A., and M.P. Doyle. 1989. Fate and thermal inactivation of *Listeria monocytogenes* in beaker sausage and pepperoni. Journal of Food Protection 52 (4) 226-231, 235.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – *L. monocytogenes* survival and growth	Beef and pork sausage fermented at 32˚F (90˚C) with a lactic starter culture (*Pediococcus acidilactici)*	*L. monocytogenes* failed to grow during fermentation and was reduced by 1-2 log units.	Glass, K.A., and M.P. Doyle. 1989. (continued)
		Salami product (2.5% NaCl, 250 ppm KNO_3 0.3% sucrose) using a bateriocin producing strain of *Lactobacillus plantarum*	Bacteriocin producing lactic acid bacteria will prevent growth and survival of *L. monocytogenes.*	Campanini, M., I. Pedrazzoni, S. Barbuti, and P. Baldini. 1993. Behavior of *Listeria monocytogenes* during the maturation of naturally and artificially contaminated salami: effect of lactic-acid bacteria starter cultures. International Journal of Food Microbiology. 20 (3) 169-175.
		Salami product (2.5% NaCl, 250 ppm KNO_3 0.3% sucrose) using a unknown starter culture	Unknown starter cultures or known cultures that do not produce bacteriocin will prevent the growth of *L. monocytogenes* but will not destroy contamination.	
	B – B - *E. coli* O157:H7 survival through fermentation and drying	Product is fermented, using starter culture, at 20-30 C, for 1-3 days, at about 90% RH, followed by drying for up to 60 days at about 85% RH	Seven commercial processes were evaluated and it was found that fermentation can result in 0.3 to 1.3 log reduction of *E. coli* O157:H7; not sufficient to meet the required 2 log reduction. Three models have been developed to assist estimating the time required to achieve a 2 log reduction when parameters such as water activity, pH and drying time are used.	Pond, T.J., D.S. Wood, I.M. Mumin, S. Barbut and M.W. Griffith. 2001. Modeling the survival of *E. coli* O157:H7 in uncooked, semidry, fermented sausage. Journal of Food Protection. 64 (6) 759-766.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – Survival of *E. coli* O157:H7	Lebanon-style bologna: 92% lean beef (90/10) 3.3% salt, 2.9% sugar, 0.8% dextrose, 0.7% spices, 0.14% potassium nitrate, 0.01% sodium nitrite, 0.15% lactic acid starter culture stuffed into 115 mm or 90 mm diameter casings, fermented 8 hours at internal temperature 80°F (26.7°C), with 90%RH, 24 hours at internal temperature 100°F (37.8°C), with 80% RH then 24 hours at internal temperature 110°F (43.3°C) with smoke the final 2 hours, 80%RH, 0, 1, 2, or 5 hours of heating at internal temperature 115°F (46.1°C) . 90% RH was used throughout for 90mm	All counts were below detection level after heating processes (greater than 6 log reduction of *E. coli* O157:H7) for 115 mm diameter After all heating processes there was 2.4 to 2.7 log reduction of *E. coli* O157:H7 for 90 mm diameter	Gety, K.J.K., R.K. Phebus, J.L. Marsden, J.R. Schwenke, and C.L. Kastner. 1999. Control of *Escherichia coli* O157:H7 in large (115 mm) and intermediate (90 mm) diameter Lebanon-style bologona. Journal of Food Science. 64 (6) 1100-1107.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – B - *E. coli* O157:H7 survival through fermentation and drying	Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of *E. coli* O157:H7, 1.2 log units.	Hinkins, J.C., N.G. Faith, T.D. Lorang, P. Bailey, D. Buege, C.W. Kaspar, and J.B. Luchansky. 1996. Validation of pepperoni processes for control of *Escherichia coli* O157:H7. Journal of Food Protection. 59 (12) 1260-1266.
		Pork and beef pepperoni fermented at 96°F (35.5°C), 85% RH and 5.0 pH or less, heated to 128°F (53°C) for 60 minutes or 145°F (63°C) instantaneous, then dried at 55°F (13°C), 65% RH to a moisture, protein ration of 1.6:1	This processing decreased the counts of *E. coli* O157:H7, 5 log units or more, and did not visibly affect the texture or appearance of the product.	
	B- Staphylococcal enterotoxin production	Using a starter culture to reduce meat pH	Meat pH should decline to 5.0 within 12 hours, to prevent Staphylococcal enterotoxin production.	Good Manufacturing Practices for Fermented Dry and Semi-Dry Sausage Products, American Meat Institute Foundation, 1997.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Fermentation	B – Potential Staphylococcus growth	Fermentation to pH 5.3 or less	(Fermentation Temperature (˚F) – 60) X hours = degree hours Process acceptable if: Fewer than 1200 degree hours when the lowest fermentation temperature is less than 90˚F (32°C). Fewer than 1000 degree hours when the highest fermentation temperature is between 90˚F (32°C) and 100˚F (38°C). Fewer than 900 degree hours when the highest fermentation temperature is greater than 100˚F (38°C).	GMPs 1997. (continued)
	B - Survival of *Salmmonella seftenberg, C. perfringens,* and *E. coli* O128:B12	Dried fermented turkey sausage step-wise heat treated at 81˚F (27˚C) for 3 hours, 90˚F (32˚C) for 4 hours, 115˚F (46˚C) for 5 hours, spray cooled to 61 to 64˚F (16 to 18˚C) and dried at 50˚F (10˚C) 72% RH for 8 days	*S. seftenberg* decreased 1.5 to 20 log units. *C. perfringens* decreased 2 to 3.6 log units. *E. coli* O128:B12 decreased 1.4 to 2.1 log units.	Baran, W.L., and K.E. Stevenson. 1975. Survival of selected pathogens during processing of a fermented turkey sausage. Journal of Food Science. 40 (3) 618-620.

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heat Treatment	B – Growth and survival of *L. monocytogenes*	Hold product that has been fermented at 90°F (32°C) for 10 hours at 90°F (32°C)	After 10 hours there was greater than 1 log reduction of *L. monocytogenes.* Final results were below level of detection.	Glass, K.A., and M.P. Doyle. 1989. Fate and thermal inactivation of *Listeria monocytogenes* in beaker sausage and pepperoni. Journal of Food Protection 52 (4) 226-231, 235.
	B – Growth and survival of *L. monocytogenes*	Hold product that has been fermented at 90°F (32°C) for 8 hours at 115°F (46°C) after reaching that as the internal temperature	After 8 hours there was greater than 2 log reduction of *L. monocytogenes.* Final results were below level of detection.	
		Hold product that has been fermented at 90°F (32°C) for 8 hours at 125°F (52°C) after reaching that as the internal temperature		
		Hold product that has been fermented at 90°F (32°C) for 4 hours at 135°F (57°C) after reaching that as the internal temperature	After 4 hours there was greater than 2 log reduction of *L. monocytogenes.* Final results were below level of detection.	

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heat Treatment	B – Growth and survival of *L. monocytogenes*	Hold product that has been fermented at 90°F (32°C) for 4 hours at 145°F (63°C) after reaching that as the internal temperature	After 4 hours there was greater than 2 log reduction of *L. monocytogenes.* Final results were below level of detection.	Glass, K.A., and M.P. Doyle. 1989. (continued)
		Beef and pork sausage to at least 125°F (51.7°C) for 4 hours	When heated to at least 125°F (51.7°C) and held for 4 hours there was a 5 log reduction of *L. monocytogenes*.	
Heating/ Drying	B – Survival of *Ecoli O157:H7*	Beef strips marinated in a common jerky preparation (pH 4.3)	Application of marinade did not enhance or inhibit bacterial reduction.	Albright, S.N., P.A. Kendall, J.S. Avens, and J.N. Sofos. 2002. Effect of marinade and drying temperature on inactivation of *Escherichia coli* O157:H7 on inoculated home dried beef jerky. Journal of Food Safety. 22 155-167.
		Beef strips not marinated		
		Beef strips marinated (pH4.3) for 24 hours at 40°F (4°C) then dried at 144.5°F (62.5°C) (aw .65)	*E.coli O157:H7* decreased 2.2 log units in 10 hours of drying.	
		Beef strips marinated (pH 4.3) for 24 hours at 40°F (4°C) then dried at 154.94°F (68.3°C) (aw .64)	*E.coli O157:H7* decreased 3.0 log units in 10 hours of drying.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heating/ Drying	B – Survival of *Ecoli O157:H7*	Beef strips not marinated dried 10 hours at 144.5°F (62.5°C) (aw .83)	*E.coli O157:H7* decreased 3.2 log units in 10 hours of drying.	Albright, S.N., P.A. Kendall, J.S. Avens, and J.N. Sofos. 2002. (continued)
		Lean ground beef (90% lean) with spice mix heated to 160°F (71.1°C) then dried at 140°F (60°C) for 6 hours	*E. coli* O157:H7 was reduced by 1.6 log units after heating and 4.8 log units after 6 hours of drying.	Harrison, J.A., M.A. Harrison, and R.A. Rose. 1998 Survival of *Escherichia coli* O157:H7 in ground beef jerky assessed on two plating media. Journal of Food Protection 61(1) 11-13.
		Lean ground beef (90% lean) with spice mix and cure mix heated to 160°F (71.1°C) then dried at 140°F (60°C) for 6 hours	*E. coli* O157:H7 was reduced by 1.6 log units after heating and 5.2 log units after 6 hours of drying.	
		Lean ground beef (90% lean) with spice mix dried at 140°F (60°C) for 8 hours	*E. coli* O157:H7 was reduced by 4.3 log units after 8 hours of drying.	
		Lean ground beef (90% lean) with spice mix and cure mix dried at 140°F (60°C) for 8 hours	*E. coli* O157:H7 was reduced by 5.2 log units after 8 hours of drying.	

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Heating/ Drying	*Listeria monocytogenes* and *Salmonella* survival	Lean ground beef (90% lean) with spice mix	After heating and 6 hours of drying *Salmonella* was reduced by 3.9 log units and *Listeria monocytogenes* was reduced by 3.7 log units.	Harrison, M.A., M.A. Harrison, and R.A. Rose. 1997. Fate of *Listeria monocytogenes* and *Salmonella* species in ground beef jerky. Journal of Food Protection 60(9) 1139-1141.
			After heating *Salmonella* was reduced by 4.5 log units and by .9 log units after 6 hours of drying and *Listeria monocytogenes* was reduced by 2.8 log units after heating and 3.2 log units after drying 6 hours.	
			After 8 hours of drying *Salmonella* was reduced by 3.2 log units and *Listeria monocytogenes* was reduced by 2.5 log units.	
			After 8 hours of drying *Salmonella* was reduced by 4.2 log units and *Listeria monocytogenes* was reduced by 4.0 log units.	
Drying	B – Survival of *Ecoli O157:H7*	Beef Jerky non-marinade dried 10 hours 140ºF (60ºC)	*E.coli O157:H7* is reduced 3 logs after drying.	Calcioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall, G.C. Smith. 2002. Inactivation of acid – adapted *Escherichia coli* O157:H7 during drying and storage of beef jerky treated with different marinades. Journal of Food Protection. 65(9) 1394-1405.
		Beef Jerky marinade 10 minutes in traditional marinade (pH 3) dried 10 hours 140ºF (60ºC)		

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – Survival of *E.coli* O157:H7	Marinated Beef Jerky in a traditional sauce that includes 4.7% ethanol, (pH 3.0) for 24 hours at 40ºF (4ºC) then dried 10 hours at 140ºF (60ºC)	*E.coli* O157:H7 is reduced 4.5 logs after drying .	Calcioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall, G.C. Smith. 2002. (continued)
		Beef jerky marinated with 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 40ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC)	*E.coli* O157:H7 is reduced 4.5 log after drying.	
		Beef jerky marinated with 1% tween 20 for 15 minutes then 5% acetic acid. 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 39.2ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC)	*E.coli* O157:H7 is reduced by 5 log after drying.	

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – Survival of *E.coli* O157:H7	Beef jerky 5% pH 5.8 dried at 126ºF (52ºC) for 10 hours	Beef jerky processed at these times and temperature results in a 5 log reduction of *E. coli* O157:H7.	Faith, N.G., N.S. LeCoutour, M.B. Alvarenga, M. Calicioglu, D.R. Buege and J.B. Luchansky, 1998. Viability of *Escherichia coli* O157:H7 in ground and formed beef jerky prepared at levels of 5 and 20% fat and dried at 52, 57, 63, or 68ºC in a home-style dehydrator. International Journal of Food Microbiology. 41 (3) 213-221.
		Beef jerky 5% fat pH 5.8 dried at 145ºF (63ºC) for 8 hours		
		Beef jerky 5% fat pH 5.8 154ºF (68ºC) for 5 hours		
		Beef jerky 25% fat pH 5.8 ºF (52ºC) for 24 hours	Beef jerky processed at these times and temperature results in a 5 log reduction of *E. coli* O157:H7.	
		Beef jerky 25% fat pH 5.8 ºF (57ºC) for 16 hours		
		Beef jerky 25% fat pH 5.8 ºF (63ºC) for 8 hours		
		Beef jerky 25% fat pH 5.8 ºF (68ºC) for 4 hours		
	B – Survival and growth of *S. aureus, C. perfringens, B. subtilis,* and *Salmonella*	Beef jerky made from flank steak strips dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w = 0.66)	There was no log change in *S. aureus*. After 8 hours of drying *C. perfringens* decreased 4 log units and was below detection, *B. subtilis* decreased less than 2 log units and *Salmonella* decreased 1 log unit.	Holley, R.A., 1985. Beef Jerky: Viability of food-poisioning microorganisms on jerky during its manufacture and storage. Journal of Food Protection 48 (2) 100-106.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – Survival of *S. aureus* and fecal coliforms	Beef jerky made from inside round strips dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w < 0.69)	There was no log change in *S. aureus*. After 8 hours of drying fecal coliforms decreased 3 log units and was below detection.	Holley, R.A., 1985. Beef Jerky: Fate of *Staphylococcus aureus* in marinated and corned beef during jerky manufacture and 2.5°C storage. Journal of Food Protection 48 (2) 107-111.
	B – Survival of *S. aureus* and fecal coliforms	Beef jerky made from corned beef brisket dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w = 0.69)	There was no log change in *S. aureus*. After 8 hours of drying fecal coliforms decreased 4 log units and was below detection.	
	B – Survival of *E. coli* O157:H7 *L. monocytogenes, and S. typhimurium*	Beef loin sliced and marinated dried at 140°F (60°C) for 10 hours	After drying for 10 hours at 140°F (60°C) *E. coli* O157:H7, *L. monocytogenes*, and *S. typhimurium* decreased by 5.5 log units.	Harrison, J.A., and M.A. Harrison. Fate of *Escherichia coli* O157:H7, *Listeria monocytogenes,* and *Salmonella typhimurium* during preparation and storage of beef jerky. Journal of Food Protection 59 (12) 1336-1338.
		Beef loin sliced, marinated, heated to 160°F (71°C) then dried at 140°F (60°C) for 10 hours	After cooking to 160°F (71°C) *E. coli* O157:H7 decreased 5.0 log units, *S. typhimurium* and *L. monocytogenes* decreased 4.5 log units. After subsequent 10 hours of drying at 140°F (60°C) all pathogens were undetectable.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Drying	B – *S. aureus* growth	Water activity level 0.92-0.91, at 77˚F (25˚C) in salami	*S. aureus* growth is not inhibited when pH 6.0 or higher and a hazard is especially possible at a_w 0.92-0.91 because of a lack of competing flora. When pH is 5.0 or lower a 6 log unit reduction was found after 21 days.	Martinez, E.J., N. Bonino, and S.M. Alzamora. 1986. Combined effect of water activity, pH and additives on growth of *Staphylococcus aureus* in model salami systems. Food Microbiology. 3 (4) 321-329.
		Water activity level 0.90 or less, at 77˚F (25˚C) in salami	The pH is not a factor in *S. aureus* growth, and a hazard is not likely.	
	B – Growth of many yeasts	Water activity (a_w) level at or below 0.87 such as fermented sausage, and foods containing approximately 65% sucrose or 15%NaCl	These pathogens are inhibited at these water activity levels.	Beuchat, L.R. 1981. Microbial stability as affected by water activity. Cereal Foods World. 26 (7) 345-349.
	B – Growth of most molds (mycotogenic penicillia), *Staphyloccoccus aureus, most Saccharomyces(bailii) spp. Debaromyces*	Water activity (a_w) level at or below 0.80	These pathogens are inhibited at these water activity levels.	
	B – Growth of halophilic bacteria, *mycotoxigenic aspergilli*	Water activity (a_w) level at or below 0.75		

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Packaging and Storage	B - *E. coli* O157:H7 survival and growth	After fermentation at 76˚F (24˚C), 90% RH to pH <4.8, then dried at 55˚F (13˚C) 65% RH to pH approx. 4.6, a_w approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 40˚F (4˚C)	After 90 days of storage at 40˚F (4˚C), *E. coli* O157:H7 was still detectable.	Faith, N.G., N. Parniere, T. Larson, T.D. Lorang, C.W. Kaspar, and J.B. Luchansky. 1998. Viability of *Escherichia coli* O157:H7 in salami following conditioning of batter, fermentation and drying of sticks and storage of slices. Journal of Food Protection. 61 (4) 377-382.
		After fermentation at 76˚F (24˚C), 90% RH to pH <4.8, then dried at 55˚F (13˚C) 65% RH to pH approx. 4.6, a_w approx. 0.92, 4.41% salt, 44.5% moisture, M/Pr ratio of greater than 1.9:1, sealed in oxygen impermeable bags with air, or vacuum sealed, stored at 70˚F (21˚C)	After 90 days of storage at 70˚F (21˚C) no *E. coli* O157:H7 was detectable by direct plating but was found after enrichment.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival and growth of *S. aureus, C. perfringens, B. subtilis,* and *Salmonella*	Slices of flank steak dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w = 0.66). Stored for 28 days at 68°F (20°C) allowing a_w to rise to 0.83	No viable bacteria were found.	Holley, R.A., 1985. Beef Jerky: Viability of food-poisioning microorganisms on jerky during its manufacture and storage. Journal of Food Protection. 48 (2) 100-106.
	B – Survival and growth of *S. aureus, C. perfringens, B. subtilis,* and *Salmonella*	Beef jerky made from flank steak strips dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w = 0.66). Stored for 26 days at 36.5°F (2.5°C) a_w held constant at 0.66	*S. aureus, C. perfringens, B. subtilis,* and *Salmonella* were reduced 1 log unit only *Salmonella* was below detectable levels.	
	B – Survival of *S. aureus*	Beef jerky made from inside round strips dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w < 0.69), stored at 36.5°F (2.5°C) for 9 days	*S. aureus* decreased less than 1 log unit during refrigerated storage.	Holley, R.A., 1985. Beef Jerky: Fate of *Staphylococcus aureus* in marinated and corned beef during jerky manufacture and 2.5°C storage. Journal of Food Protection 48 (2) 107-111.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival of *S. aureus*	Beef jerky made from corned beef brisket dried for 4 hours at 127.2°F (52.9°C) then 4 more hours at 118.8°F (48.2°C) (Final a_w = 0.69) stored at 36.5°F (2.5°C) fpr 9 days	*S. aureus* decreased less than 1 log unit during refrigerated storage.	Holley, R.A., 1985. (continued)
		Beef steak with pH of 5.0 and water activity 0.732	Though highly variable *S. aureus* did decline over time on both these products.	Vora, Purvi; Andre Senecal, and Donald W. Schaffner. 2003. Survival of *Staphylococcus aureus* ATCC 13565 in Intermediate Moisture Foods is Highly Variable. Risk Analysis. 23 (1) 229-236.
		Chicken pockets with pH of 5.0 and water activity of 0.853		
	B – *S. aureus* growth	Greek pork sausage (more than 30% fat) dried, then smoked at 25°C for 40 minutes then 40°C for another 40 minutes stored at 3 or 12°C	Though pH, salt, nitrite and moisture can be used to prevent pathogen growth, it is recommended that a starter culture be used to compete and lower the pH below 5.4 rapidly.	Samelis, J. and J. Metaxopoulos. 1998. The microbiology of traditional greek country-style sausage during manufacture followed by storage at 3° and 12°C in air. Italian Journal of Food Science. 10 (2) 155-163.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.
	B – Survival of *E. coli* O157:H7	Beef Jerky marinade 10 minutes in traditional marinade (pH 3) dried 10 hours 140ºF (60ºC) then stored 42 days at 77°F (25°C)	*E.coli O157:H7* is reduced 5 logs after storage at 77ºF (25ºC).	Calcioglu, M., J.N. Sofos, P.A. Kendall. 2003. Fate of acid-adapted and non-adapted *Escherichia coli* O157:H7 inoculated post-drying on beef jerky treated with marinades before drying. Food Microbiology 20 (2) 169-177.
		Marinated Beef Jerky in a traditional sauce that includes 4.7% ethanol, (pH 3.0) for 24 hours at 40ºF (4ºC) then dried 10 hours at 140ºF (60ºC) then stored 42 days at 77°F (25°C)		

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival of *E. coli* O157:H7	Beef jerky marinated with 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 40ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC) then stored 42 days at 77°F (25°C)	*E.coli O157:H7* is reduced 5 logs after storage at 77ºF (25ºC).	Cal cioglu, M., J.N. Sofos, P.A. Kendall. 2003. (continued)
		Beef jerky marinated with 1% tween 20 for 15 minutes then 5% acetic acid (pH 2.5) for 10 minutes then 24 hours at 40ºF (4ºC) with a traditional marinade (pH 4.3) and dried 10 hours at 140ºF (60ºC) then stored 42 days at 77°F (25°C)		

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival of *E. coli* O157:H7	Beef strips marinated in a common jerky preparation (pH 4.3) stored for 30 days at relative humidity of 19 – 24%	No *E. coli* O157:H7 detected.	Albright, S.N., P.A. Kendall, J.S. Avens, and J.N. Sofos. 2002. Effect of marinade and drying temperature on inactivation of *Escherichia coli* O157:H7 on inoculated home dried beef jerky. Journal of Food Safety. 22 155-167.
		Beef strips not marinated stored for 30 days at relative humidity of 19 – 24%		
		Beef strips marinated (pH4.3) for 24 hours at 40°F (4°C) then dried at 144.5°F (62.5°C) (aw .65) stored for 30 days at relative humidity of 19 – 24%	*E.coli O157:H7* decreased 5.2 log units in 10 hours of drying.	
		Beef strips marinated (pH 4.3) for 24 hours at 40°F (4°C) then dried at 154.94°F (68.3°C) (aw .44) stored for 30 days at relative humidity of 19 – 24%		

Heat treated, shelf stable process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Storage	B – Survival of *E. coli* O157:H7	Beef strips not marinated dried 10 hours at 144.5°F (62.5°C) (aw .88) stored for 30 days at relative humidity of 19 – 24%	*E.coli O157:H7* decreased 3.2 log units in 10 hours of drying.	Albright, S.N., P.A. Kendall, J.S. Avens, and J.N. Sofos. 2002. Effect of marinade and drying temperature on inactivation of *Escherichia coli* O157:H7 on inoculated home dried beef jerky. Journal of Food Safety. 22 155-167.

Secondary Inhibitors, Not Shelf Stable Process

Includes: uncooked corned beef and cured pork

Secondary Inhibitors, Not Shelf Stable Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://www.ag.ohio-state.edu/~meatsci/borca2.htm
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium Nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c) To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301
	B- *E. coli* O157:H7 growth	Storage of *E. coli* O157:H7 at various temperatures, NaCl levels and pH levels	There was no growth of *E. coli* O157:H7 below 46.4°F (8°C), and slow to no growth when salt levels were above 20g/L. pH ranging from 4.5 to 8.5 did not greatly effect growth. All combinations of salt, ranging from 5 g/L to 35 g/L, pH (4.5 to 8.5) and temperature 82.4°F (28°C) and higher grew *E. coli* O157:H7.	Buchanan, R.L., and L.A. Klawitter. 1992. The effect of incubation temperature, initial pH, and sodium chloride on the growth kinetics of *Escherichia coli* O157:H7. Food Microbiology. 9 (3) 185-196.

Secondary Inhibitors, Not Shelf Stable Process

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Chopping	B – *E.coli* O157:H7 contamination	Chopping beef in a bowl chopper for 60 to 240 seconds	Once a batch has been contaminated with *E.coli* O157:H7 the bacteria are spread throughout the batch and without full clean up will contaminate subsequent batches.	Flores, Rolando A. 2003. Distribution of *Escherichia coli* O157:H7 in Beef Processed in a Table-Top Bowl Cutter. Journal of Food Protection. 67 (2) 246-251.
Fermentation	B – *S. aureus* growth	Country-style hams (60% sucrose and 38% salt) with lactic acid bacteria added	When inoculated with lactic acid bacteria, Staphylococcal growth was inhibited.	Bartholomew, D.T., and T.N. Blumer. 1980. Inhibition of *Staphylococcus* by lactic acid bacteria in country-style hams. Journal of Food Science. 45 (3) 420-425, 430.
Storage	B – Growth and toxin production of hemorrhagic *E.coli* (including O157:H7)	Storage time and temperatures	Hemorrhagic *E.coli* strains grew at temperatures as low as 46.4°F (8°C). However, all strains had at least 1 day lag time at that minimum temperature. All strains that produced toxin eventually did so at temperatures that supported growth. At 50°F (10°C) the shortest time for a 3 log increase was shown to be 4 days.	Palumbo, Samuel A., Jeffrey E. Call, Frankie J. Schultz, and Aaron C. Williams. 1994. Minimum and Maximum Temperatures for Growth and Verotoxin Production by Hemorrhagic Strains of *Escherichia coli*. Journal of Food Protection. 58 (4) 352-356.

Irradiation

This information crosses many process categories.
There is information in this section that has not been approved for use as of publication time, however it is included for future reference.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *Salmonella* survival	Irradiating mechanically deboned poultry with 0.75 to 3.00 kGy at 32˚F (0˚C)	Irradiating at 32˚F (0˚C), 0.75 kGy resulted in a 1 log decrease of *Salmonella*. 1.5 kGy resulted in a 3 log reduction, 2.25 kGy resulted in a 5 log reduction and 3.0 kGy resulted in a 7 to 8 log reduction.	Thayer, D.W. 1995. Use of irradiation to kill enteric pathogens on meat and poultry. Journal of Food Safety. 15 (2) 181-192.
		Irradiating mechanically deboned poultry with 0.75 to 3.00 kGy at 32˚F (0˚C) then cooking to an internal temperature of 140˚F (60˚C) for 2 minutes	Irradiating at 32˚F (0˚C) followed by cooking to 140˚F (60˚C) for 2 minutes, 0.75 kGy resulted in a 6 log decrease of *Salmonella*. 1.5 kGy to 3.0 kGy resulted in a 9 log reduction.	
		Broiler carcasses deep frozen at -20°C (-4°F) or chilled at 5°C (41°F) then irradiated with 250 krad	*Salmonella* was destroyed below detection levels on both chilled and frozen birds.	Mulder, R.W.A.W, S. Notermans, and E.H. Kampelmacher. 1977. Inactivation of *Salmonellae* on Chilled and Deep Frozen Broiler Carcasses by Irradiation. Journal of Applied Bacteriology. 42 179-185.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *S. typhimurium* survival	Irradiating mechanically deboned chicken with 0.75 to 3.0 kGy then heated for 2.0 minutes at 140˚F (60˚C)	The heat treatment after irradiation destroys 6 log units more than just irradiation at 1.5 kGy, and provides the same destruction as the irradiation increases.	Radomyski, T., E.A. Murano, D.G. Olson, P.S. Murano. 1994. Elimination of pathogens of significance in food by low-dose irradiation: a review. Journal of Food Protection. 57 (1) 73-86.
	B – *Campylobacter jejuni* survival	Irradiating chicken carcasses with 2.5 kGy at 37.4 to 38.3˚F (3 to 3.5˚C)	*Campylobacte*r is reduced by 4.19 log units, and remained at least 2.5 log units lower than non-irradiated carcasses when stored at 40˚F (4˚C) for 18 days.	
	B – *C. botulinum* survival and toxin production	Irradiated fresh pork with 1 kGy packaged with 10% to 20% oxygen stored at 59˚F (15˚C) for 14 days	Both irradiated and non-irradiated products were toxic after 14 days.	
		Irradiated fresh pork with 1 kGy packaged with 0% oxygen stored at 59˚F (15˚C) for 43 days	Irradiated pork showed no toxicity for 43 days while non-irradiated pork showed toxicity after 21 days.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – Survival of *E. coli* O157:H7, *Salmonella*, or *Campylobacter. jejuni*	Raw ground beef patties (low fat 8 to 14% and high fat 27 to 28%) frozen (-17°C (1.4°F) to -5°C (23°F)) refrigerated (3°C (37.4°F) to 5°C (41°F)) irradiated with 2.5 kGy	Regardless of temperature and fat level an applied dose of 2.5 kGy was sufficient to destroy 8.1 log *E.coli* O157:H7, 3.1 log *Salmonellae* and 10.6 log *Campylobacter jejuni. E coli* O157:H7 had a significantly higher D-value at frozen temperature but the D-values for *E.coli* and *Campylobacter jejuni* were less than 0.3 kGy and less than 1 kGy for *Salmonella*.	Clavero, M. Rocelle S., J. David Monk, Larry R. Beuchat, Michael P. Doyle, and Robert E. Brackett. 1994. Inactivation of *Escherichia coli* O157:H7, *Salmonellae,* and *Campylobacter jejuni* in Raw Ground Beef by Gamma Irradiation. Applied and Environmental Microbiology. 60 (6) 2069-2075.
	B – *Eschrichia coli* O157:H7 survival	Irradiation of ground beef at 1.5 kGy *in vacuo* at temperatures ranging from –76˚F (-60˚C) to 59˚F (15˚C)	1.5 kGy irradiation at temperatures ranging from –76˚F (-60˚C) to –4˚F (-20˚C) resulted in a 1 to 2 log reduction of *E. coli* O157:H7. 1.5 kGy irradiation at temperatures ranging from 32˚F (0˚C) to 59˚F (15˚C) resulted in a 4 to 5 log reduction of *E. coli* O157:H7.	Thayer, D.W. 1995. Use of irradiation to kill enteric pathogens on meat and poultry. Journal of Food Safety. 15 (2) 181-192.
	B – *Eschrichia coli* O157:H7 survival	Irradiation of raw gound beef at 4.5 kGy refrigerated and 7.0 kGy frozen	A maximum dosage of 4.5 kGy is allowed to control *E. coli* 157:H7 on refrigerated raw meat and 7.0 kGy when the meat is frozen.	CFR 179.26 Access on the internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *Eschrichia coli* O157:H7 survival	Irradiating raw mechanically deboned chicken meat or ground beef vacuum packaged or with air with 0.27 kGy to 0.42 kGy at temperatures between 41°F (5°C) and 23°F (-5°C)	*E. coli* O157:H7 is reduced 1 log unit with this treatment.	Thayer, D.W., and G. Boyd. 1993. Elimination of *Escherichia coli* O157:H7 in meats by gamma irradiation. Applied and Environmental Microbiology. 59 (4) 1030-1034.
		Irradiating vacuum packaged raw ground beef with 0.75 kGy to 3.0 kGy at 32°F (0°C) then stored at 95°F (35°C) for 20 hours	*E.coli* O157:H7 was reduced to less than 10 CFU/g (a 4.8 log reduction) and after 20 hours at 95°F (35°C) no verotoxin was detected.	
	B – *Trichinella spiralis* survival	Irradiation of ground pork	A minimum dose of 0.3 kGy and a maximum dose of 1 kGy is allowed to destroy *Trichinella spiralis.*	CFR 179.26 Access on the internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *Salmonella* survival	Irradiation of ground poultry	A maximum dose of 3 kGy is allowed to control *Salmonella* on raw poultry meat not excluding oxygen from the package.	CFR 179.26 Access on the internet at: http://www.access.gpo.gov/nara/cfr/waisidx_99/21cfrv3_99.html
	B – *L. monocytogenes* and *Salmonella* survival after irradiation	Irradiating raw and cooked hams and pork chops with 2.0 kGy and storage at 45°F (7°C) for 7 days and 2 days at 77°F (25°C)	2.0 kGy will reduce *L. monocytogenes* and *Salmonella* 6 log units, however after 7 days and storage at 45°F (7°C), then storage for 2 days at 77°F (25°C) shows a 5 log growth.	Fu, A.H., J.G. Sebranek, and E.A. Murano. 1995. Survival of *Listeria monocytogenes* and *Salmonella typhimurium* and quality attributes of cooked pork chops and ham after irradiation. Journal of Food Science. 60 (5) 1001-1005, 1008.
		Irradiating hams and pork chops with .75 kGy and storage at 45°F (7°C) and 2 days at 77°F (25°C) NOTE: Irradiation of ham products is currently not permitted by USDA/FSIS	0.75 kGy will reduce *L. monocytogenes* and *Salmonella* 2 log units, however after 7 days and storage at 45°F (7°C), then storage for 2 days at 77°F (25°C) shows a 5 log growth.	

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *L. monocytogenes* and *S. aureus* survival	Irradiating ground beef at 0.5 kGy	This treatment will result in 0.82 log reduction of *L. monocytogenes* and 1.10 log reduction of *S. aureus*.	Monk, J.D. M.A. Rocelle, S. Clavero, L.R. Beuchat, M.P. Doyle, and R.E. Brackett. 1994. Irradiation inactivation of *Listeria monocytogenes* and *Staphylococcus aureus* in low- and high-fat, frozen and refrigerated ground beef. Journal of Food Protection. 57 (11) 969-974.
		Irradiating ground beef at 1.0 kGy	This treatment will result in 1.64 log reduction of *L. monocytogenes* and 2.21 log reduction of *S. aureus*.	
		Irradiating ground beef at 1.5 kGy	This treatment will result in 2.46g reduction of *L. monocytogenes* and 3.11 log reduction of *S. aureus*.	
		Irradiating ground beef at 2.0 kGy	This treatment will result in 3.28 log reduction of *L. monocytogenes* and 4.42 log reduction of *S. aureus*.	
		Irradiating ground beef at 2.5 kGy	This treatment will result in 4.10 log reduction of *L. monocytogenes* and 5.12 log reduction of *S. aureus*.	
	B – *L. monocytogenes* survival	Irradiating ground pork with 0.25 to 1.25 kGy at room temperature.	*L. monocytogenes* was reduced 3 log units.	Tarté, R.R., E.A, Murano, D.G. Olson. 1996. Survival and injury of *Listeria monocytogenes, Listeria innocua,* and *Listeria ivanovii* in ground pork following electron beam irradiation. Journal of Food Protection. 59 (6) 596-600.
		Irradiating mechanically deboned chicken meat with 2.00 kGy	*L. monocytongens* is reduced 4 log units.	Radomyski, T., E.A. Murano, D.G. Olson, P.S. Murano. 1994. Elimination of pathogens of significance in food by low-dose irradiation: a review. Journal of Food Protection. 57 (1) 73-86.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Irradiation	B – *A. hydrophilia* survival and growth	Irradiating vacuum packaged pork loins with 3.0 kGy, then storage at 40°F (4°C) for 42 days	*A. hydrophilia* remained at less than 0.30 log units on irradiated loins whereas it grew to 2.51 log units on the non-irradiated loins.	Radomyski, T., E.A. Murano, D.G. Olson, P.S. Murano. 1994. (continued)
	B – *Yersinia* spp. survival and growth	Irradiating chicken carcasses with 2.5 kGy then storage at 40°F (4°C) for 18 days	The irradiation reduced the *Yersinia* spp. by 2 log units and counts on irradiated carcasses remained 2 log units lower than those carcasses not treated. However, *Yersinia* spp. increased by 4 log units on both irradiated and not irradiated carcasses.	

Thermally Processed, Commercially Sterile

Includes: canned products

This category contains only physical and chemical hazards.
These hazards are possible in all of the previous categories.

Process	Potential Hazards	Process Parameters	Decision Criteria	Scientific Documentation
Formulation	C –Excessive nitrite level in product	Addition of preblended cure including sodium nitrite	"[If] using sodium nitrite diluted [to 6.25% by weight] with sodium chloride, which is received from the manufacturer with a continuing letter of guarantee, then acute nitrite toxicity is not a problem." (due to self-limiting, high, salt concentration).	Borchert, L.L., and R. G. Cassens. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation Paper. http://www.ag.ohio-state.edu/~meatsci/borca2.htm
		Addition of pure sodium nitrite	"Extreme caution must be exercised if pure sodium nitrite is used." "The conservative estimate for a lethal dose in humans is 14 mg/kg, meaning the dose would be 1 g [(0.0022 lb)] for a 70 kg [(154 lb)] adult and 0.2 g [($8.8x10^{-5}$ lb)] for a 15 kg [(33 lb)] child."	
		Addition of sodium nitrite	Sodium Nitrite can be added up to 200 parts per million (or an equivalent of potassium nitrite) in the final product except in bacon where it can be added up to 120 ppm ingoing.	CFR 318.7(c) To access on the internet: http://www.access.gpo.gov/nara/cfr/waisidx_99/9cfrv2_99.html#301