Compliance Guideline for Controlling *Salmonella* in Poultry

First Edition

August 2006

This is the first edition of the Compliance Guideline regarding *Salmonella* control in poultry slaughter. Other editions will follow. Future editions will reflect feedback received from all stakeholders. In order to make this guideline as useful as possible, FSIS encourages all persons interested to submit their comments and concerns regarding any aspect of this document including but not limited to: content, readability, applicability, and accessibility.

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I. Purpose

This compliance guideline describes concerns and validated controls for each step in the broiler slaughter process. It targets small and very small poultry plants to help them better comply with regulatory requirements (9 CFR 417, 416, 381.65, 381.76, 381.92, 381.93, and 381.94).

FSIS encourages plants to reduce levels of *Salmonella* during poultry slaughter operations using best management practices outlined in this guideline. The interventions suggested cannot overcome, however, poor pre-harvest production practices, poor sanitary practices in slaughter and dressing, or poor slaughter facility sanitation. Use this guideline to improve management practices. When a plant makes changes at the right locations, process control should improve. As a result, plants should produce raw poultry products that have less contamination by pathogens including *Salmonella*.

For easy use, some sections of this guideline begin with best practice recommendations. The paragraphs that follow further explain concerns and controls specific to that step.

II. Background

The Food Safety and Inspection Service (FSIS) published a Federal Register Notice entitled, *Salmonella* Verification Sample Result Reporting: Agency Policy and Use in Public Health Protection (71 FR 9772) on 27 February 2006 (http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/04-026N.pdf). This document sets out the Agency's policy on *Salmonella*, explaining how the Agency will report sample results from its *Salmonella* verification sampling program for meat and poultry plants. It discusses how the Agency will use these results to improve current public health protection.

This document will help slaughter and slaughter/processing plants, particularly within the broiler industry, improve *Salmonella* control. The percent of broilers that test positive for *Salmonella* in "A" sets has increased steadily from 11.5% in 2002 to 16.3% in 2005. In positive sample sets, FSIS frequently identifies *Salmonella* serotypes commonly known to cause human illness. The rate of human salmonellosis from all sources of food was 14.6 cases/100,000 persons in 2005. This rate is more than twice the goal of 6.8 cases/100,000 persons set by the U.S. Department of Health and Human Services in its National Food Safety Objectives: Healthy People 2010. Therefore, FSIS is changing its *Salmonella* verification-sampling program. The Agency believes this change will help to reduce human exposure to *Salmonella* from FSIS-regulated products.

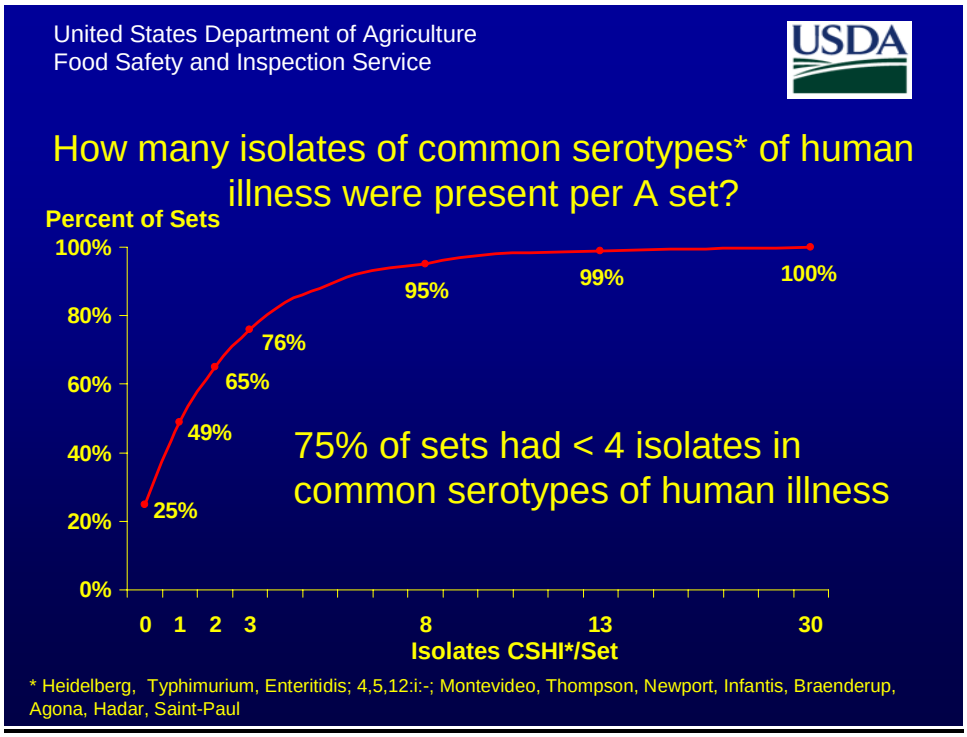
Plants are evaluated based on sample set results. Plants demonstrate **consistent process control** when they have two *Salmonella* sample sets in a row at or below 50% of the performance standard. These plants are tested for *Salmonella* less often than plants having less consistent process control. Plants that exceed the performance standard in their most recent set but do not demonstrate consistent process control have **variable**

process control. Plants that fail the performance standards have **poor process control.** FSIS tests plants in the last two groups more often than plants in the first group.

Once a plant achieves consistent process control, FSIS places that plant into the sampling population selected for scheduled testing at the lowest frequency. However, FSIS is also concerned about the serotypes of *Salmonella* found in positive samples. Plants that produce product with a high number of serotypes that commonly cause human illness are selected at a higher testing frequency than plants that produce product with a low number of these serotypes. All serotypes are compared to the Centers for Disease Control and Prevention's (CDC) list of top 20 most frequently isolated *Salmonella* serotypes from human sources reported to the CDC: www.cdc.gov/ncidod/dbmd/phlisdata/salmtab/2004/SalmonellaTable1_2004.pdf.

In 2005, all plants at or below 50% of the performance standard had fewer than four samples that contained a top 20 serotype. Seventy-five percent of all "A" sets had no more than three serotypes linked to human illness. FSIS is concerned with any sample set that has a serotype of common human illness. However, FSIS is particularly concerned with establishments whose sample set includes four or more positive samples that contain serotypes that are known to cause human illness. These operations do not demonstrate consistent process control. FSIS strongly recommends that plants recognize this cutoff as a trigger to take immediate action to improve their food safety systems. Plants with serotypes linked to human illness could expect FSIS to decrease the time between the scheduling of sample sets or schedule a specialized Food Safety Assessment (FSA).

This graph shows that 75% of all "A" sets have < 3serotypes linked to illness.



Food Safety Systems

Unlike the production of ready-to-eat product in which a lethality treatment can destroy pathogens of public health concern, slaughter and dressing operations do not have a treatment capable of destroying all pathogens. FSIS expects plants to have food safety systems designed to ensure that birds are processed in a manner that reduces possible contamination during slaughter and dressing. FSIS expects plants to have treatments in place to reduce the level of incoming contamination on the exterior of the birds throughout the operation. The procedures and treatments the plants use to reduce contamination should be documented as part of their food safety system.

HACCP Plan

If the plant decides through its hazard analysis that *Salmonella* is a food safety hazard that is likely to occur, 9 CFR 417.2 requires that the plant's HACCP plan address this food safety hazard. The HACCP plan must meet all parts of 9 CFR 417.2(c). In this case, the HACCP plan must have a CCP to address *Salmonella* even if the plant does not fail the performance standard. A plant should be able to support any decision that it makes during the reassessment. The HACCP plan should contain verification testing that the plant will do to ensure that the HACCP system is working as designed.

Sanitation SOP or Other Prerequisite Program

Plants may also address *Salmonella* in their Sanitation SOP or other prerequisite programs. The plant should have records associated with their Sanitation SOP or other prerequisite programs that support that these programs are effective in preventing food safety hazards from occurring.

If the process results in a high number of *Salmonella* serotypes associated with common human illness, the plant is expected to take appropriate action. If the control is addressed in the HACCP plan, 417.3 must be met. If the process is addressed in the Sanitation SOP, 416.15 must be met. If the process is addressed in another prerequisite program, the actions listed in the program are expected to be followed. The plant should determine specifically why its food safety system is not consistently ensuring that the level and type of contamination on broilers arriving at the plants, as well as during slaughter and dressing process is not appropriately minimized.

Food Safety Assessments: Common Findings

Designing and implementing an effective food safety system can be difficult. The Food Safety Assessments (FSA) conducted to date indicate that not all establishments have an effective food safety system in place. General findings include inconsistencies between the hazard analysis and the selection of the CCP and critical limits. Hazards are identified in the hazard analysis, but there is no indication why they are not reasonably likely to occur. Supporting documentation is lacking for decisions that a hazard is not

reasonably likely to occur. Prerequisite programs lack records showing how the prerequisite program was effective in preventing hazards from occurring.

In addition, there was often no support for decisions on selection of CCP and critical limits. There was no supporting documentation for monitoring and verification frequencies. When corrective actions were taken, they were often ineffective. Deviations would occur and reoccur. Documentation would reflect the deviation, but the corrective action would be carried out repeatedly without any regard to whether or not it was successful. To avoid regulatory action, plants should have a clear understanding of their HACCP plan, Sanitation SOP, and any other prerequisite programs. Plants need to execute their programs as designed. If not, FSIS expects that plants will reassess, re-evaluate, modify, or make appropriate improvements in how their programs are operating.

III. Pre-Harvest

Recommended Best Practices

- Implement biosecurity measures
- Use good sanitation practices
- Control litter moisture
- Use well-timed feed withdrawal

Research has shown that on-farm interventions have the greatest impact on reducing *Salmonella* (Campbell, et al, 1982). Bio-security and sanitation including pest control are very important at grow-out houses. According to the Association of American Feed Control Officials (AAFCO), feed should come from a source that follows best management practices for plant sanitation, equipment maintenance, employee training and supervision, material purchases, and receipt. Feed in pellet form, rather than in meal form, lowers the flock's risk of *Salmonella* contamination.

Controlling subsurface moisture in grow-out houses is a significant best management practice. It reduces levels of *Salmonella* in the environment and reduces cross contamination within flocks. Drying litter is recommended as a good strategy to lower *Salmonella* on the farms.

Feed withdrawal is recommended to reduce food and fecal contamination on the carcasses (NCC, 1992, NTF, 2004). Removing feed too late may result in carcass contamination because the gut may rupture during processing. Economically, non-digested food does not contribute to the final weight of the carcass. However, if feed is removed too early, the internal organs become more fragile. The crop and cloaca can easily tear during processing. One study reported that feed withdrawal periods greater than 14 hours made the intestine and gall bladder more fragile (Bilgili and Hess, 1997).

Research has shown that providing organic acid in the drinking water greatly reduces post-harvest crop contamination with *Salmonella* (Byrd, et al, 2001; Byrd, et al, 2003). Providing treated water does two things. First as with providing any drinking source, it distracts the birds from pecking at their droppings. Second, the organic acids protect the gastro-intestinal tract from an overgrowth of *Salmonella*. However, the amount and type of acid used must be carefully monitored. The acid must be of a type and strength that birds are willing to drink.

Plants may want to consider either purchasing from growers that use organic acids in drinking water during feed withdrawal, or if they own the birds, use organic acids in this manner. If plants use organic acids during feed withdrawal, they should consider this in their hazard analysis (9 CFR 417.2). Currently, lactic acid and acetic acid are considered, "general purpose food additives" by the Food and Drug Administration per 21 CFR 582.1.

Many of these pre-harvest interventions were discussed in greater detail during the meeting, "Advances in Pre-Harvest Reduction of *Salmonella* in Poultry" held August 25-26 2005. The written transcripts for this meeting can be found at:
http://www.fsis.usda.gov/PDF/Salmonella_Transcripts_082505.pdf and
http://www.fsis.usda.gov/PDF/Salmonella_Transcripts_082605.pdf

IV. Live Receiving and Live Hanging

Recommended Best Practices

- Sanitize and dry cages thoroughly
- Maintain positive air flow from inside to outside the plant
- Provide SOP and employee training

Research shows that washing the transport cages with water greatly lowers the levels of *Salmonella* found in the cages. Washing and then having the cages dry for 48 hours is the best way to reduce *Salmonella*. However, this approach may be expensive. Water use, employee time, storage space, and unused equipment are all costs that must be considered. One researcher suggested using removable cage floors that could be stored or dried thoroughly.

Cleaning followed by sanitation of the unloading and holding area is important. High levels of *Salmonella* found on incoming birds can overwhelm in-plant interventions. These levels are carried forward through the next steps of the slaughter process. Studies show links between *Salmonella* found at live receiving, and *Salmonella* found later in the process.

Employee traffic patterns and air flow should be controlled to prevent cross-contamination and reduce levels of *Salmonella*. There should be positive airflow moving from inside to outside of the plant. Standard operating procedures and training, including

changing clothes and boots upon arrival, separate facilities for "dirty" versus "clean" employees, and restricting employee movement can be put in place.

The feathers, skin, crop, and cloaca of the birds brought to slaughter are often highly contaminated with *Salmonella* (Kotula and Pandya, 1995). Cross-contamination of both birds and cages is frequently made worse when the birds are moved to the plants. There can be a 20-40% increase in *Salmonella* both inside and outside the birds during movement. Moving the birds causes them to pass more fecal material. If the birds have *Salmonella*, then the cages have *Salmonella* as well. Transport cages are important sources of cross contamination (Berrang, et al, 2003, Slader, et al, 2002). A recent study found that 5% of the cages sampled were positive for *Salmonella* before use and 10% after use.

V. Stunning and Bleeding

Recommended Best Practices

- Consider electrical stunning: cheapest and most effective method
- Use well-timed feed withdrawal practices to reduce feces release

Stunning makes the birds unconscious. Bleeding ensures death by slaughter. It also ensures that poultry have stopped breathing before going into the scalder per 9 CFR 381.65(b).

There are three types of stunning: electrical, mechanical, and chemical. Electrical stunning is the cheapest and most effective method. This method reduces struggling and convulsions, especially when it is followed by head removal. Body movement, such as wing flapping and quivering, can transfer bacterial pathogens from the inside to the outside of the birds as well as to nearby birds and equipment.

Birds release fecal material during stunning. As described earlier, good feed withdrawal practices can greatly reduce this problem. By decreasing the amount of feces expressed, plants can reduce fecal cross-contamination on the surface of the carcass, in the scald tank, and on the feather removal equipment. This decreases the level of *Salmonella* carried forward into the next steps.

VI. Scalding

Recommended Best Practices

To improve process control in the scald tank:

- Have water moving counter current to carcasses
- Have high flow rates of water with adequate agitation to dilute dry matter and bacteria
- Use multi-staged tanks
- Maintain water pH at either above or below the optimum pH for *Salmonella* growth (6.5-7.5)

Additional recommendations:

- Use pre-scald brush systems to clean birds prior to scald tank
- Use post-scald rinse

Scalding prepares carcasses for defeathering by breaking down the proteins that hold the feathers in place and opening up the feather follicles.

The National Chicken Council (NCC) recommends that best management practices include using counter current systems with adequate water replacement (NCC, 1992). Water in the tank should move through the system flowing against incoming carcasses. This flow creates a dirty to clean gradient. Carcasses moving through the tank are washed by ever cleaner water. Multiple stage tanks are better than single stage tanks because they create more opportunities to clean the carcasses (Cason, et al, 2000).

High flow rates of water and adequate agitation dilute the dry matter and bacterial load in the tank (Cason, et al, 2001). The NCC recommends at least one quart of clean water entered into the scald tank for each carcass processed. A carcass rinse (bird washer) is frequently used as the carcasses leave the scald tank. This type of rinse can improve the effectiveness of the scalding process. The NCC recommends using a post scald wash after the carcasses leave the scald tank but before they enter the picker. This wash reduces the *Salmonella* load for the next steps.

The water pH should be monitored carefully. A higher (alkaline) or lower (acidic) pH is best for reducing *Salmonella* in the water (Humphrey, et al, 1984, Okrend, e al, 1986). Plants should monitor the pH in scald tanks as frequently as necessary to determine the pH highs and lows occurring during operation. Once plants are able to maintain a desirable pH, less monitoring is needed.

Uric acid from poultry feces can reduce the pH from 8.4 to 6.0 in less than 2 hours (Humphrey, 1981). Organic matter in the tank acts as a buffer to maintain a more neutral pH (6-7). *Salmonella* are heat resistant at a neutral pH.

Understanding water characteristics is important. The source (well or surface), hardness, mineral content, and pH influence the killing action of chemicals that are added to the water. Plants using more than one water source should carefully monitor the effect of the water on the chemicals used. Water quality was discussed by Dr. Ken Byrd at the Post-Harvest meeting on *Salmonella* in Atlanta, Georgia. His presentation is at: http://www.fsis.usda.gov/News_&_Events/Presentations_PostHarvest_022306/index.asp.

There are two accepted methods for scalding: steam-spraying and immersion. Steam spray systems work by applying a mixture of steam and air at a temperature and pressure designed to scald the surface of carcasses. Immersion scalding is carried out by placing the carcasses into a tank of hot water. Tanks are either single or multi-staged. Immersion is more common than steam-spraying. However under the right conditions, both methods can reduce *Salmonella* on carcasses (Dickens, 1989).

Most U.S. poultry processors prefer a hard scald to a soft scald. A hard scald is for a shorter scald times at a higher temperatures. This allows better removal of the outer layer of skin (epidermis). The right water temperature at the right amount of time is important to prepare the carcasses for feather removal. This also reduces dressing defects. When the water temperature is too high, the carcasses become oily. This oiliness makes it easier for *Salmonella* to stick to the surface of the skin. If the carcasses are over-scalded, they may be marked unacceptable and rejected by inspectors. If the temperature is too low, the tank becomes a breeding ground for bacteria. *Salmonella* organisms cannot grow at temperature greater than 116.6 ºF (47ºC). Therefore, scalding temperatures higher than 116.6°F (47ºC) should be sufficient to control *Salmonella* growth.

Common Scalding Times and Temperature for Various Classes of Poultry

Broiler (hard scald)	30-75 seconds	138.2-147.2°F (59-64°C)
Broiler (soft scald)	90-120 seconds	123.8-129.2°F (51-54°C)
Turkeys	50-125 seconds	138.2-145.4°F (59-63°C)
Quail	30 seconds	127.4°F (53°C)
Waterfowl	30-60 seconds	154.4-179.6°F (68-82°C)

Scalding is an important step that can reduce levels of *Salmonella* on the carcass. Much of the dirt, litter, and feces on carcasses are removed here. One researcher reported a 38% decrease in the number of *Salmonella* positive poultry carcasses post scalding. **Two concerns at scalding are: cross-contamination carried forward from previous steps and *Salmonella* in the scald water**. *Salmonella* has been recovered from 100% of the skin and feather samples entering the scald tank. *Salmonella* has been shown to survive in the scald tank. Marker organisms introduced prior to carcasses entering the scald tank were recovered from the 230th carcass leaving the tank (Mulder, et al, 1978). Scalding cannot overcome very high numbers of pathogens carried forward from previous steps. Pre-scalder brushes can be used to clean the birds prior to putting them into the tanks.

Some religious traditions forbid scalding. Under Kosher slaughter, carcasses are soaked in cold water to make feather removal easier. This method as well as the steam spray method may produce carcasses with skin more susceptible to *Salmonella* (Clouser, et al, 1995). Plants should consider this potential effect in deciding what sanitary practices they employ downstream.

VII. Picking

Recommended Best Practices

- Prevent feather buildup on equipment
- Rinse equipment and carcasses continuously
- Use 18-30 ppm chlorine rinse post picking

The feather removal process is designed to remove feathers and the uppermost layer of the skin before evisceration. Carcasses typically pass through rubber picking fingers that mechanically remove feathers from the carcass. Most plants use a continuous process. However, batch and manual processes are sometimes used in low volume plants.

Good process controls at picking is critical and can improve a plant's performance on an FSIS *Salmonella* sample set. Cross-contamination of the carcasses occurs because of contact with contaminated rubber picking fingers and contaminated recycled water (Geornaras, et al, 1997, Wempe, et al, 1983).

Regular equipment sanitation and maintenance is recommended to minimize cross-contamination. The NCC recommends preventing feather buildup during the defeathering process by continuously rinsing the defeathering equipment and carcasses (NCC, 1992). An 18-30 ppm available chlorine rinse can help reduce *Salmonella* counts on carcasses exiting the feather removal step (Mead, et al, 1994). Post-feather removal rinses should be maintained at 160° F. Chlorine, acetic acid, and hydrogen peroxide are types of chemical rinses used during defeathering.

Recycled water use is addressed in 9 CFR 416.2(g)(3). This regulation states that water, ice, and solutions may be reused for the same purpose provided that measures are taken to reduce physical, chemical, and pathogen contamination or adulteration of product. A plant must have data to support all decisions regarding reuse, including a decision that reuse will not cause adulteration. Plants are expected to take measures necessary to ensure that their products do not become contaminated or adulterated.

VIII. Eviscerating

Recommended Best Practices

- Adjust and maintain equipment regularly and as needed
- Use 20 ppm chlorine for whole carcass rinses
- Enforce employee hygiene standards

Note: Feed withdrawal practices affect process control at this step

Evisceration begins at the transfer point (re-hang) and ends when the carcass enters the chiller. Evisceration processes remove the internal organs and any trim/processing defects from the poultry carcasses in preparation for chilling. Technology and methods vary widely across the poultry industry. Basic steps of evisceration include:

- Removing the leg from the knee to foot
- Removing the oil gland
- Severing the attachments to the vent
- Opening the body cavity
- Extracting the viscera
- Harvesting giblets
- Removing and discarding the intestinal tract and air sacs
- Removing and discarding the trachea and crop
- Removing and discarding the lungs

For the evisceration process to work well, carcasses need to be placed on the shackles correctly and monitored as they move through the system. The machines need to be maintained in good working order. Blades should be kept sharpened, and attention given to routine and thorough cleaning. Automated transfer (re-hang), rather then manual transfer, of carcasses between the defeathering and evisceration lines reduces external surface cross-contamination.

The National Chicken Council recommends whole-carcass water rinses using 20 ppm free available chlorine (NCC, 1992). Carcass rinses are effective interventions for removing loose material from the carcass surface during evisceration. A 20 ppm free available chlorine rinse post-evisceration can decrease microbial contamination and improve food safety (Waldroup, et al, 1992). The incidence of *Salmonella* positive carcasses can decrease by one third when carcass rinses are incorporated into the evisceration process (Notermans, et al, 1980).

Multiple *Salmonella* controls throughout the evisceration process are recommended. *Salmonella* is not effectively removed by using one carcass rinse. Testing carcasses for generic *E. coli* during slaughter and processing is an inexpensive method to determine the effectiveness of sanitary measures to reduce microbial contamination. Plants should already test poultry for generic *E. coli* (9 CFR 381.94).

Equipment setup, adjustment, and machine performance depend on the size, shape, gender, feed digestion capability, and live average weights of the birds. Processing flocks that greatly vary within a weight range can result in machinery performing poorly. If machines are set for the median weight of the flock, carcasses that are heavier or lighter may not be properly eviscerated. They are more likely to have their gastrointestinal (GI) tracts split open, contaminating carcasses and equipment. Carcasses not properly eviscerated mechanically may need to be finished manually. This results in increased costs.

In flocks with high *Salmonella* counts, a high percentage of crops and ceca contain *Salmonella.* Equipment such as crop removal devices can easily become contaminated with *Salmonella*, causing later carcasses to become contaminated (Mead et al, 1994). In some operations, at least half of carcass surfaces are contaminated with crop and upper GI contents immediately before evisceration. Retracting the viscera from the body cavity can transfer crop and upper GI contents to the interior body cavity (Byrd et al, 2002). Lung tissue can pick up contaminated water from the scald tank, contaminating equipment and product during evisceration. All of these factors can lead to cross-contamination of carcasses.

Some processors consistently produce *Salmonella*-positive carcasses while others produce *Salmonella*-free or very infrequently contaminated carcasses. These differences may be the result of differences in sanitary dressing practices. For example, rates of visible contamination on the carcasses after crop removal vary greatly depending on crop removal practices. In some plants, fewer crops rupture because the crops are extracted toward the head rather than toward the thoracic inlet (Buhr et al, 2000). This is an important consideration for *Salmonella* control, because crop tissue often contains *Salmonella*.

Some carcasses may become contaminated with feces and ingesta even with strict sanitary slaughter practices. However, with proper sanitary practices, fecal contamination should be minimal. Reprocessing systems are used to control *Salmonella* on visibly contaminated carcasses. Both on-line and off-line reprocessing systems are used to remove contamination. Washing equipment is used around the evisceration process to control contamination.

Off-line Reprocessing addresses disease conditions and contamination that cannot be removed by other means. When properly performed, off-line reprocessing should eliminate visible conditions and produce carcasses microbiologically equivalent to inspected and passed carcasses (Blankenship et al, 1975).

On-line Reprocessing addresses incidental fecal or ingesta contamination during evisceration. On-line reprocessing is automated and relies on washing systems in combination with antimicrobial agents to achieve desired results. In addition to the level of carcass contamination, water temperature, pressure, nozzle type and arrangement, flow rate, and line speed all influence the effectiveness of the washing system. Multiple

washers in a series are more effective than a single large washer (Bashor et al, 2004). On-line reprocessing that uses effective inside/outside bird washers can reduce the need for off-line reprocessing by 73-84% (Fletcher and Craig, 1997). If properly performed, on-line reprocessing can yield better results than off-line reprocessing and improve food safety and the microbiological quality of raw poultry (Kemp, et al, 2001).

Note: Carcasses must still be free of visible fecal material prior to entering the chilling systems.

The addition of antimicrobial agents generally increases the effectiveness of an on-line reprocessing system. Washes with 23 ppm free available chlorine can reduce *Salmonella* on carcasses (Fletcher and Craig, 1997). Ten percent TSP, 5% cetylpyridinium chloride, 2% lactic acid, or 5% sodium bisulfate can also reduce *Salmonella* on carcasses (Yang and Slavik, 1998). Plants should know how the pH of the on-line reprocessing carcass residue affects chemicals used in the chilling step (e.g., active chlorine).

IX. Chilling

Recommendations for Best Practices

Immersion Chilling

- If using chlorine, maintain chill water pH between 6.5 -7.5, at a temperature of less than 40°F
- Use high water flow rate and counter-current flow
- Use 20-50 ppm free available chlorine in the potable water measured at intake to reduce bacteria in the water and reduce carcass cross contamination.
- Use ORP pH meters

Air Chilling

- Meet regulatory requirements for chilling
- Clean and oil chains regularly
- Inspect and replace shackles as needed
- Maintain tension on chain to prevent carcass to carcass contact

The chilling process reduces poultry carcass temperatures as required in 9 CFR 381.66. Immersion chilling and air chilling are the two technologies used today. Both methods decrease carcass temperature and inhibit microbial growth.

Immersion Chilling is more commonly used than air chilling. When using chlorine in any one of the four Generally Recognized as Safe forms (calcium hypochlorite, sodium hypochlorite, chlorine gas, or electrolytically generated hypochlorous acid) at this step, chill water pH should be maintained between 6.0 and 7.5 (optimal pH range: 6-6.5), with a temperature of less than 40°F. Chlorine reacts with water to form hypochlorous acid

and hypochlorite ion, both forms of free available chlorine. However, hypochlorous acid is the chemical form that best kills pathogens. When the water pH is higher than optimal, hypochlorous acid breaks down forming hypochlorite ion, which does not kill pathogens as well. Therefore, to get the most benefit from using chlorine during immersion chilling, pH should be carefully and continuously monitored

Chlorine is a common and effective water treatment used to prevent carcass cross-contamination in immersion systems in the U.S. The effect is directly proportional to the free available chlorine concentration. For example, 10 ppm free available chlorine can eliminate *Salmonella* in 120 minutes. Thirty ppm produces the same result in 6 minutes, and 50 ppm works in only 3 minutes. Water chemistry management involves balancing pH (to maintain a free available chlorine concentration in the form of mostly hypochlorous acid) and reducing organic matter

Three factors determine the amount of organic matter in the immersion chiller: flow rate, flow direction, and cleanliness of the chiller water. When the chiller is more like a pond than a river, the water is still, and organic matter increases in the tank. When fresh water in-flow drops to <½ gallon/bird, organic matter accumulates in the chiller water, on the paddles, and on the sides of the chiller (Thomas et al, 1979). Organic matter in the chiller makes less chlorine available to kill *Salmonella*. The concentration of organic matter often increases near the chill tank exit (Allen et al, 2000). Filtering recycled water reduces the level of organic matter and spares free available chlorine.

High water flow rate and counter-current flow are recommended (Russell, 2005). Additionally, 20-50 ppm free available chlorine as measured at the intake water should reduce the total microbiological load in the chiller water (Waldroup, et al, 1992). The chiller reuse water in the red water system may contain up to 5 ppm free available chlorine measured at intake back into the chiller. Water temperature should be maintained to ensure that product temperatures meet 9 CFR 381.66.

An Oxidation Reduction Potential (ORP) pH meter is a scientific instrument that measures the sanitizing effect of water. It gives an indication of the effectiveness of the free available chlorine in the water. Two advantages for using ORP meters are monitoring in "real time" and affordability. These meters can be purchased from any reputable laboratory supply company. For additional information, go to the Agriculture and Natural Resources, University of California website: http://anrcatalog.ucdavis.edu. Publication 8149 which explains ORP can be downloaded for free. There are additional articles on chlorination (publication 8003) and water disinfection (publication 7256) which can also be downloaded for free.

If water chemistry management does not occur, water chilling can cause cross-contamination between *Salmonella*-positive and *Salmonella*-negative flocks. Broilers from *Salmonella*-negative flocks generally remain negative after chilling as long as broilers from *Salmonella*-positive flocks were not chilled in the tank first (Sarlin et al, 1998). Managing flock deliveries by *Salmonella* status of flocks may help maximize process control at a plant.

Air Chilling systems have shackled (or tiered) chains that move the carcasses through the chilled compartment (or rooms) until the carcasses are properly chilled (9 CFR 381.66). Effective air chilling requires effective maintenance. Plants should clean and oil the chains regularly. Shackling carcasses to balance the chain will maintain chain tension. Swinging chains may cause carcasses to touch. Plants should inspect the shackles for wear and replace as needed.

Research studies have shown that microbial counts on poultry carcasses can be lower in air chilling systems compared to immersion chill systems (Allen, et al, 2000 and Sanchez et al, 2002). The cooling efficiency of air and water chillers is similar. However there is less physical contact between carcasses in air chillers, reducing the potential for cross-contamination. When antimicrobials are used, immersion chilling can reduce biological hazards.

X. Reprocessing (On-line/Off-line) and Chilling: Antimicrobial Interventions

Recommendations for Best Practices

- Post-chill antimicrobial dips are used to reduce *Salmonella* loads

Simple water rinses, without the addition of chemicals, reduce *Salmonella* (Morrison and Fleet, 1985). Heated water, agitation, application under pressure, and calibrating pH can enhance the effect. Trials using hot water showed substantial reductions in *Salmonella* (Morrison and Fleet, 1985). Agitation, application under pressure, sonication (disrupting biological materials by using sound wave energy), and adjustments in pH may also improve the effect.

Chlorine, chlorine dioxide, and acidified sodium chlorite are the most common chlorine-based interventions found in poultry processing plants. These compounds are water-soluble and applied as a spray or dip. When applied in aqueous solution, the washing effect of the water enhances the bactericidal effect of chlorine. Agitation and application under pressure enhance the effect.

Chlorine is primarily used to treat poultry processing water and chiller water. Heat and pH above 7.5 decrease its effect. Alkaline conditions reduce ionic dissociation, reducing available chlorine. Heat increases the loss of the hypochlorite ion into the atmosphere.

Chlorine dioxide can be used as an antimicrobial agent in water used in poultry processing at an amount not to exceed 3 ppm residual chlorine dioxide. Chlorine dioxide is a highly reactive compound that rapidly reduces to chlorite and chlorate in process water. Its use leaves no detectable residues of chlorine dioxide, chlorite, chlorate, or byproducts on poultry carcasses after application.

Acidified sodium chlorite is a combination of citric acid and sodium chlorite. It is approved as a poultry spray or dip at 500 to 1200 ppm singly or in combination with other GRAS acids to achieve a pH of 2.3 to 2.9 as an automated reprocessing method. In chiller water, acidified sodium chlorite is limited to 50 to 150 ppm singly or in combination with other GRAS acids to achieve a pH of 2.8 to 3.2. Its residue, primarily chloride and chlorate salts, is safe.

Field and laboratory trials indicate that the bactericidal effect of chlorine-based compounds on pathogenic and non-pathogenic bacteria vary substantially at different chlorine concentrations under comparable and diverse application conditions. It also varies depending on the location of the organisms. The bactericidal effect of free residual chlorine on *Salmonella* suspended in chiller water is directly proportional to the concentration of free residual chlorine. The same is not true for *Salmonella* attached to the carcass passing through the chiller. When using any form of chlorine, establishments should be mindful of any limits placed on its use by other agencies, e.g., the Occupational Safety and Health Administration.

Trisodium phosphate (TSP) is an approved antimicrobial agent used in on-line reprocessing of raw poultry carcasses. TSP acts as a surfactant and prevents bacteria from attaching to the carcass. Residual TSP on carcasses carried over into the chiller can increase the chiller water pH, which decreases the effectiveness of chlorine in the chiller. To minimize the pH effect and maintain the effectiveness of chlorine, plants should monitor the chiller water pH and adjust the level as needed. Rinsing the carcasses prior to their entry into the chiller will also reduce the effect of TSP on chiller water pH.

TSP reduces the levels of pathogenic and non-pathogenic bacteria on raw poultry. However, TSP results vary based on concentration of the chemical used and the application parameters. As an antimicrobial agent for on-line reprocessing, TSP typically reduces microorganisms on carcasses by $\leq 2 \log_{10}$ CFU. TSP is more effective with air chilling than with immersion chilling, probably because the pH effect is absent.

Cetylpyridinium chloride is a quaternary ammonium compound. The FDA has approved its use as an antimicrobial agent in poultry processing for ready-to-cook products. Cetylpyridinium chloride is effective against a broad spectrum of pathogens, including *Salmonella*. It produces no adverse organoleptic effects when applied properly. Its pH is near neutral, and it is stable, non-volatile, and soluble in water.

The antimicrobial properties of **organic acids** are well known. Lactic acid is the most commonly used organic acid. When applied as a rinse, lactic acid decreases the levels of both pathogenic and non-pathogenic bacteria. In the scald tank, acetic acid decreases the pH and enhances the washing effect of the scald tank water. Under simulated chiller application, acetic acid, lactic acid, citric acid, malic acid, mandelic acid, propionic acid, and tartaric acid decreased *Salmonella* counts. Organic acids can have an organoleptic effect on raw product so their use is typically limited in poultry processing.

XI. Sanitation and Hygiene

Recommendations for Best Practices

- Clean before sanitizing
- Enforce employee hygiene

Cleaning followed by sanitizing is essential to eliminate and reduce pathogens in a plant. *Salmonella* can attach to processing equipment or grow on food materials left behind on product contact surfaces. Properly cleaning an area requires removing debris prior to using a cleaning agent (detergent). Alkaline detergents are frequently used and vary in strength. Examples are sodium hydroxide, nitrous oxide, sodium silicate, and trisodium phosphate. Acid detergents are also used and vary in strength. They include hydrochloric, sulfuric, phosphoric, and acetic acids. Quaternary ammonia is a type of synthetic detergent. Regardless of type, detergents should be in contact with soiled surfaces for 5-20 minutes.

Once a surface has been cleaned, sanitizers can be applied. There are several types of sanitizers commonly used: quaternary ammonia, industrial strength bleach, iodine compounds, peracetic acid, steam, and ozone. There are areas within a plant where it may be better to use one type of sanitizer over another. For example, to sanitize aluminum equipment, rubber belts, and tile walls, iodophors are recommended. Active chlorine is best for other types of walls, wooden crates, and concrete floors. A listing of various detergents and sanitizers as well as their properties can be found in Dr. Scott Russell's presentation during the Post-Harvest *Salmonella* meeting. The listing is on the FSIS website:
http://www.fsis.usda.gov/News_&_Events/Presentations_PostHarvest_022306/index.asp.

The National Chicken Council recommends enforcing employee hygiene standards. The production of wholesome products is difficult when employees do not maintain clean hands and clothing. Mandatory hand washes with sanitizing stations should be available and maintained. Hygiene requirements regarding dressing rooms, lavatories, and toilets should be followed per 9 CFR 416.2 (h)(1) and 416.2 (h)(2). It is important that all employees follow standard hygienic practices in accordance with 9 CFR 416.5(a), 416.5(b), and 416.5(c). Outer garments, head coverings, aprons, gloves, and protective shields should be worn as necessary. Furthermore, jewelry, food, and tobacco products should be restricted within the plant. Keeping track of employee foreign travel and health protects employees, product, and consumers.

XII. Technology

FSIS recognizes that new technologies provide opportunities to improve and strengthen process controls. The Agency strongly recommends that all plants be aware of new techniques, chemicals, and machinery that may improve their ability to produce wholesome products. FSIS maintains a list of new technologies on its website. This list is at:
http://www.fsis.usda.gov/Regulations_&_Policies/New_Technology_Table/index.asp.

XIII. Validating

Recommendations for Best Practices

- Repeat testing for validation
- Consider process mapping or line profiling as a challenge study tool
- Real life validation study example

Validation activities (9 CFR 417.4) are a critical tool for plants verifying the effectiveness of process control interventions that address pathogenic microorganisms like *Salmonella*. This compliance guideline describes interventions throughout the poultry slaughter process that a plant can use to create a food safety system that demonstrates consistent process control. However, FSIS expects establishments to validate interventions for their own unique food safety system.

Scientific research articles can be used to validate a critical limit addressing pathogens such as *Salmonella*. This guidance document and materials from the FSIS public meeting addressing pre- and post- harvest *Salmonella* interventions in poultry refer to relevant studies. When using a peer-reviewed article for validation, repeated testing is necessary to assess the adequacy of the CCP, critical limits, monitoring, recordkeeping, verification and corrective actions associated with the food safety hazard addressed by the intervention. Initial validation demonstrates that the plant is able to meet the parameters in the peer-reviewed article. It also verifies that the pathogen contamination is prevented, eliminated, or reduced to an acceptable level. In order to determine that the intervention given in the peer-reviewed article is controlling the pathogen, the validation process must be carried out in the plant, subject to the plant's facilities, processes, and unique conditions.

Poultry plants are unique environments. Each plant has its own equipment, antimicrobial interventions, and management style. All parameters used in a validation study must occur in the plant's process, including following manufacturer's operation specifications for the intervention. For example, a peer-reviewed scientific article may specify four parameters to be followed for the intervention to be effective. If the plant is only capable of meeting three of the parameters defined in the article, then the plant needs additional information to validate that the fourth parameter is unnecessary. If one parameter is changed, the interaction of the other parameters may change, compromising the

intervention's effectiveness. Challenge studies conducted in a laboratory or in-plant testing are other methods to validate a process control.

Note: Challenge studies with pathogens should be conducted in laboratories. Plants should never intentionally introduce *Salmonella* into their operations.

Process mapping or line profiling is a useful challenge study tool. Process mapping is defined as conducting microbial sampling at selected points in the process where contamination levels can be assessed. The assessment measures microbiological loads on carcasses against a specific target organism or class of organisms. Process mapping provides a baseline for assessing the effectiveness of certain interventions as well as the effectiveness of the overall food safety system. Process mapping shows areas where immediate improvements can be made or where there is a need for process adjustments. A process mapping (testing) protocol could contain procedures for obtaining multiple samples from a single flock after each processing step. Plotting these test results is used as a map of the microbial reduction at each intervention step in the system. The plot shows where process control is most effective, least effective or needs modification. FSIS strongly recommends that plants use process mapping techniques to develop their own sampling programs for *Salmonella* or indicator organisms.

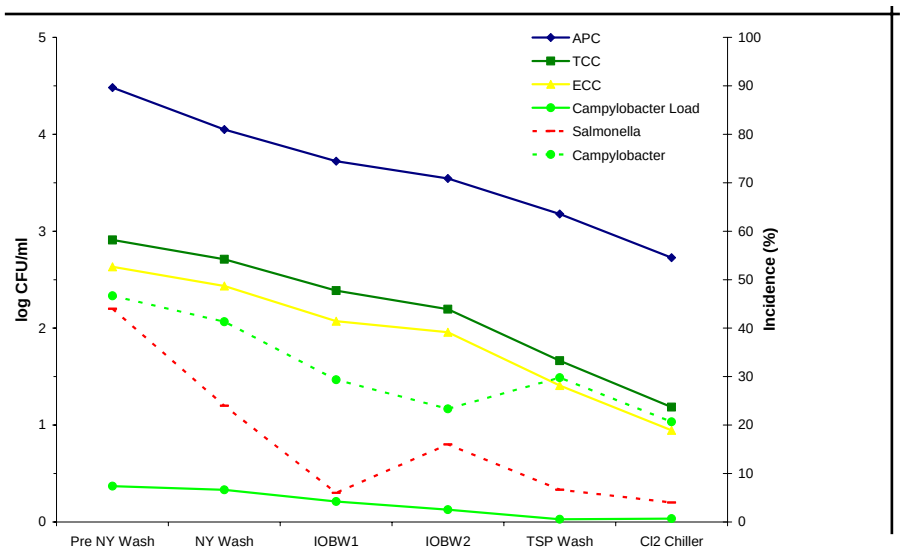
Example of a Validation Study

Here is a real-life example of Company X validating its process control. Company X looked at its slaughter process with regard to pathogen control. One of its main objectives was to see whether its system was reducing levels of indicator organisms (e.g., aerobic plate count) and pathogens, including *Salmonella.* Company X looked at individual intervention steps to see how well each one worked.

A third party laboratory came in for five different visits. Five steps in the slaughter process were sampled at each visit. At each step, 15 carcasses were sampled before the step and 15 after the step. A total of 150 samples were taken at each step. Carcass sampling was done by taking rinses of the carcasses. Company X looked at the level of *Salmonella* before and after the carcasses went through each step. The results showed that levels of *Salmonella* were reduced from 30% to 3%. For Company X, most pathogen declines took place at steps towards the end of the process. Through its validation study, Company X felt confident that it did have process control for pathogen reduction.

Below is a graph of the pathogen reduction for Company X's process. The dotted red line is the decline in *Salmonella*.

Pathogen Control: Validation Study (Atlanta, Ga., Post-Harvest Public Meeting; R. O'Connor)



The PowerPoint presentation of this validation study is at: http://www.fsis.usda.gov/PDF/Slides_022406_ROConnor.pdf.

This example shows how plants can monitor their own food safety systems' effectiveness. In this example, Company X showed that it was in fact reducing levels of *Salmonella*. Company X saw how each of its intervention steps works. Finally, Company X proved that its entire process reduced pathogens.

FSIS strongly encourages all plants to consider doing similar validation studies. These studies can be kept as documentation. They are sources of verification and future references. FSIS encourages plants to know and understand their food safety systems. For example, if heavier than usual birds are being processed, plants could test to ensure they maintain process control. Testing may include plants verifying that no visible fecal contamination is present. Testing may include more microbiological testing. Plants may want to take more samples at one time or sample more often to ensure pathogen control is still in place.

XIV. Website References

1. Food Safety and Inspection Service (FSIS): http://www.fsis.usda.gov.

2. International HACCP Alliance: http://www.haccpalliance.org.

3. Small Business Regulatory Enforcement Fairness Act (SBREFA): http://www.dol.gov/osbp/programs/sbrefa.htm.

4. State extension services: http://asred.msstate.edu/links/statepartners.htm.

5. Ohio State University Extension Services: http://extension.osu.edu.

6. Technical Services Center Website: TechCenter@fsis.usda.gov
   Hotline: 1-800-233-3935

Note: When emailing the Tech Center account, put "Outreach" in the subject line to direct the email to the Outreach Team for Small/Very Small Plants. This is for owner/operators of small/very small plants only. If you are a small/very small plant owner/operator calling the Tech Center, press zero to connect with a receptionist who will then connect you to a member of the Outreach Team.

7. Public meeting on Advances in Pre-Harvest Reduction of Salmonella in Poultry, August 25-26 2005.

   a. Meeting transcript, August 25, 2005: http://www.fsis.usda.gov/PDF/Salmonella_Transcripts_082505.pdf.
   b. Meeting transcript, August 26, 2005: http://www.fsis.usda.gov/PDF/Salmonella_Transcripts_082605.pdf.

8. Public meeting on Advances in Post-Harvest Reduction of Salmonella in Poultry
   a. Presentations from the meeting: http://www.fsis.usda.gov/News_&_Events/Presentations_PostHarvest_022306/index.asp.
   b. Meeting transcript, February 23, 2006: http://www.fsis.usda.gov/PDF/Transcript_022306_Postharvest.pdf.
   c. Meeting transcript, February 24, 2006: http://www.fsis.usda.gov/PDF/Transcript_022406_Postharvest.pdf.
   d. To order the meeting CD: http://www.fsis.usda.gov/News_&_Events/order_Postharvest_CD/index.asp.

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