FSIS Guideline

for Controlling *Salmonella* in Raw Poultry

June 2021

This guideline is designed to help poultry establishments, including those that are small and very small, to:

- Identify and implement pre- and post-harvest interventions to control *Salmonella* as part of their HACCP system
- Utilize microbial testing results to monitor the performance of the HACCP system and inform decision-making

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Preface

This is a revised version of the *FSIS Guideline for Controlling* Salmonella *and* Campylobacter *in Raw Poultry*. This 2021 revision of the guideline was split into two separate documents in response to comments received: one for *Salmonella* and one for *Campylobacter*. This guideline represents FSIS' current thinking on these topics and should be considered usable as of its issuance.

The information in this guideline is provided to assist poultry slaughter and processing establishments in controlling hazards and meeting the FSIS pathogen performance standards. The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the regulations. Under the regulations, establishments may choose to implement different procedures than those outlined in this guideline, but they would need to validate and support how those procedures are effective.

This guideline is focused on small and very small establishments in support of the Small Business Administration's initiative to provide small businesses with compliance assistance under the Small Business Regulatory Enforcement Fairness Act (SBREFA). However, all poultry establishments may apply the recommendations in this guideline. It is important that small and very small establishments have access to a full range of scientific and technical support, and the assistance needed to establish safe and effective Hazard Analysis Critical Control Point (HACCP) systems.

FSIS has other guidance documents availabe for establishments that slaughter and process raw poultry products, including:

- Information about the chilling of poultry products can be found in the Modernization of Poultry Slaughter Inspection: Amendments to Chilling Requirements.
- Information about designing and implementing a microbiological sampling plan can be found in the FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry.
- Information about controlling *Campylobacter* and *Salmonella* in chicken liver can be found in the FSIS Guideline: Chicken Liver.
- Information about controlling *Campylobacter* can be found in the FSIS Guideline for Controlling *Campylobacter* in Raw Poultry.

Congressional Review Act

Pursuant to the Congressional Review Act at 5 U.S.C. 801 *et seq.*, the Office of Information and Regulatory Affairs has determined that this guideline is not a "major rule," as defined by 5 U.S.C. 804(2).

Reason for Issuing the Guideline

FSIS developed this guideline to assist establishments that slaughter or process raw poultry products to prevent and minimize the risk of *Salmonella* in their operations. FSIS is updating and reissuing this guideline as part of continuing efforts to assess the scientific support and new technologies available to improve the effectiveness of policy documents and recommendations to industry.

Specifically, FSIS revised this guideline to respond to public comments on the 2015 guideline and provide updated information for establishments to use to control pathogens in raw poultry products with the goal of reducing human illnesses from consuming poultry contaminated with *Salmonella*. In addition, since the 2015 revision, FSIS has implemented pathogen performance standards for chicken parts and comminuted chicken and turkey products. This guideline can assist establishments in meeting the *Salmonella* performance standards and reducing illnesses associated with *Salmonella*.

This guideline describes concerns and controls for each step in the poultry slaughter process.

However, the interventions suggested in this guideline cannot overcome poor pre-harvest production practices, poor sanitary practices in slaughter and dressing, or poor slaughter and further processing facility sanitation.

Establishments can use this guideline to improve management practices, make changes at the appropriate locations, and improve process control. As a result, establishments can produce raw poultry products that have less contamination with pathogens, including *Salmonella*.

Again, the information in this guideline is provided as guidance to assist poultry slaughter and processing establishments in reducing *Salmonella* contamination and is not legally binding from a regulatory perspective.

Changes from the Previous Version of the Guideline

This guideline is final. FSIS will update this guideline as necessary when new information becomes available.

FSIS made the following specific changes to the guideline to reflect the peer-reviewed literature and address public comments received on the previous version of the guideline:

- Removed the word "compliance" from the document title and throughout the document to clarify that this document does not constitute regulatory requirements;
- Separated the *2015 Draft Compliance Guideline for Controlling Salmonella and Campylobacter in Raw Poultry (4th Edition)* into two distinct guidelines, one addressing *Salmonella* control and one addressing *Campylobacter* control;
- Removed redundant language related to other current FSIS guidelines, providing hyperlinks to those resources where appropriate;
- Added relevant, current peer-reviewed science related to poultry slaughter and processing, including a complete revision of the bedding and litter section, and additional literature resources specific to *Salmonella*;
- Added information about antimicrobial carryover and considerations to mitigate its effect on microbiological sampling;
- Updated data tables outlining the relative risk of various source materials used in further processed poultry products based on recent FSIS data; and
- Updated the sanitizer data table in response to a public comment that pointed to a more recent revision.

How to Effectively Use the Guideline

This guideline is organized to provide users with the current science and recommendations. To use this guideline, FSIS recommends that readers use the navigation headings to move efficiently through the document sections of interest. Hyperlinks, where provided, will quickly take you to the correct place in the document electronically and are also provided to other complementary documents.

The reference list at the end of the document provides resource material used in the development of this guidance (References).

Questions Regarding Topics in this Guideline

If after reading this guideline you still have questions, FSIS recommends searching the publicly posted Knowledge Articles ("Public Q&As") in the askFSIS database. If after searching the database, you still have questions, refer them to the Office of Policy and Program Development through askFSIS and select "Sampling" as the Inquiry Type or by telephone at 1-800-233-3935.

Documenting these questions helps FSIS improve and refine present and future versions of the guideline and associated issuances.

> ***Key Point***
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> Federally inspected poultry establishments are required to conduct a **hazard analysis** as part of their Hazard Analysis and Critical Control Point (HACCP) system. The hazard analysis is required to include "food safety hazards that can occur before, during, and after entry into the establishment" (9 CFR 417.2(a)).

Background

FSIS regulated poultry slaughter and processing establishments are required to determine the "food safety hazards that can occur before, during, and after entry into the establishment" (9 CFR 417.2(a)) in their hazard analysis. Pre-harvest interventions, adequate sanitary dressing procedures at slaughter, and adequate sanitary conditions during further processing are a part of an integrated approach to reduce the public health impact of *Salmonella*. This pathogen is a hazard that establishments producing raw poultry products can control through a HACCP plan or prevent in the processing environment through a Sanitation Standard Operating Procedures (Sanitation SOPs) or other prerequisite programs. FSIS has determined that contamination of poultry carcasses and parts by fecal material and enteric pathogens (including *Salmonella* spp.) is a hazard *reasonably likely to occur* (RLTO) in poultry slaughter establishments unless addressed in a Sanitation SOP or other prerequisite program.[1] For this reason, if an establishment relies on its Sanitation SOP or other prerequisite program to address enteric pathogens, the establishment's HACCP system must identify why such Sanitation SOP or other prerequisite program results in the enteric pathogens being *not reasonably likely to occur* (NRLTO). The measures outlined in this document will be most effective at decreasing *Salmonella* in raw poultry products when considered together.

Food Safety and the HACCP Framework

Unlike the production of ready-to-eat (RTE) product in which a lethality treatment destroys pathogens of public health concern, slaughter and further processing

[1] 79 FR 49565 (p.49613)

operations do not have as many available treatment options capable of destroying all pathogens in raw products. Under HACCP regulations, establishments are required to have a system designed to ensure that poultry is processed in a manner that prevents and controls potential contamination hazards that are RLTO during slaughter and processing. Slaughter establishments have controls and procedures in place to reduce the level of incoming contamination on the exterior of the birds and to reduce or mitigate any contamination that can occur throughout the slaughter process. Establishments must document the controls and procedures they use to prevent contamination in their HACCP plan, Sanitation SOP, or applicable prerequisite program in accordance with 9 CFR 417.5.
https://www.govinfo.gov/content/pkg/CFR-2020-title9-vol2/pdf/CFR-2020-title9-vol2-sec417-2.pdf

HACCP Plan to Control Hazards

If the establishment decides through its hazard analysis that *Salmonella* is a food safety hazard RLTO, 9 CFR 417.2 requires that the establishment's HACCP plan address this food safety hazard. The HACCP plan must meet all parts of 9 CFR 417.2(c), including having a critical control point (CCP) to address the pathogen. A CCP is defined as a point, step, or procedure in a food process at which a control can be applied, and, as a result, a food safety hazard can be prevented, eliminated, or reduced to an acceptable level. As an example, an establishment might have a CCP at a point during slaughter for applying a validated antimicrobial intervention to carcasses.

FSIS requires the establishment to develop critical limits (CLs) for CCPs to control hazards that are RLTO (9 CFR 417.2(c)(3)). CLs are the parameters that indicate whether the control measure at the CCP is in or out of control. A critical limit is the maximum or minimum value to which a physical, biological, or chemical hazard must be controlled at a critical control point to prevent, eliminate, or reduce to an acceptable level the occurrence of the identified food safety hazard (9 CFR 417.1). An example of CLs are the critical operational parameters for an antimicrobial intervention applied to carcasses at a point during slaughter. For example, critical operational parameters of an antimicrobial applied with a spray bar may include concentration, pH, and spray pressure.

To determine whether CLs are being met, establishments must monitor them (9 CFR 417.2(c)(4)). Monitoring is a planned sequence of observations or measurements to assess whether a CCP is under control and to produce an accurate record for future use in verification. Monitoring procedures usually involve either a measurement or an observation. For the example of a CCP of applying an antimicrobial intervention during slaughter, monitoring activities might include measuring the concentration, pH, and other critical limits of the antimicrobial intervention, at a frequency sufficient to determine whether the CCP is under control. If a CL is not met, the establishment must meet the corrective action requirements in 9 CFR 417.3. To document whether the establishment meets its CCP, the establishment records its measurements and corrective actions as part of a recordkeeping system.

Verification ensures that the HACCP plan is being implemented as written and confirms the accurate monitoring of the CCPs. Guidance on validation and ongoing verification is available in the FSIS HACCP Systems Validation guideline.

GENERAL CONSIDERATIONS

Sanitation

Cleaners and Detergents

Cleaning followed by sanitizing is essential to control pathogens (e.g., *Salmonella*) in an establishment. Pathogens can attach to processing equipment or grow on food materials left behind on product contact surfaces. Properly cleaning an area requires removing debris, including dry pickup and pre-rinsing of gross soils, before using a cleaning agent (detergent). Alkaline detergents are frequently used as cleaning agents and vary in strength; examples include sodium hydroxide, nitrous oxide, sodium silicate, and trisodium phosphate (TSP). Acid detergents are also used as cleaning agents and vary in strength; examples include hydrochloric, sulfuric, phosphoric, and acetic acids. Quaternary ammonia is a type of synthetic detergent. Regardless of type of detergent used, they will need to be in contact with surfaces for enough time to ensure effectiveness of the product. Establishments can follow the manufacturer's instructions regarding application and contact time for detergents.

Once a surface has been properly cleaned, sanitizers can be applied.
There are several types of chemical sanitizers commonly used: quaternary ammonia, industrial strength bleach, iodine compounds, peracetic acid, steam, and ozone. There are areas within an establishment 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 (e.g., betadine, iodine) are recommended. Active chlorine is best for other types of walls, wooden crates, and concrete floors. A study of *Salmonella* on food contact surfaces demonstrated biofilm formation on plastic, steel, and concrete surfaces; while iodophors and chlorine sanitizers were still generally effective, a higher contact time or concentration may be necessary when biofilms are present (Joseph, et al., 2000). A listing of various sanitizers and their associated properties is presented below in Table 1.

Table 1: Factors to Consider in Sanitizer Selection (Ecolab, 2016, 2020)

Sanitizer Type	Chlorine	Quaternary Ammonia Compounds	Peracetic Acid	Fatty Acid	Acid Anionic	Alcohol Quats	Iodophor
Soil Load Sensitivity	High	Low	Low	Low	Low	Low	Moderate
Water Temperature Sensitivity	Low	Moderate	Low	Moderate	Moderate	Moderate	Low
pH Sensitivity	Moderate	Low	Low	High	High	Low	High
Water Hardness Sensitivity	Low	Moderate	Low	Low	Moderate	Low	Low
Corrosive (Stainless Steel)*	High	Low	Low	Low	Low	Low	Moderate
Foam Level**	None	Variable	None	Low	Variable	Low	Variable
Residual Activity	None	Moderate	None	Low	Low	Moderate	None

Table 1 provides a comparison of several classes of sanitizers (X-axis) by associated properties (Y-axis).
***Corrosion properties will depend on grade of stainless steel; ratings were provided assuming 304 stainless steel.**
****"Variable" indicates that the sanitizer can be a formulated to specific outcome.**

As outlined in 9 CFR 416, each establishment's Sanitation SOPs, other prerequisite programs, or HACCP plans should address procedures that ensure that all slaughter and further processing equipment, food contact surfaces, and employees' hands, tools, and clothing are maintained in a sanitary manner to minimize the potential for cross contamination within and among lots of production. Establishments must develop and effectively implement Sanitation SOPs that address, at a minimum, the handling and cleaning and sanitizing of food contact surfaces, equipment, utensils, implements, and processing areas. The Sanitation SOPs must indicate the frequency with which these items will be cleaned and sanitized and the frequency at which the establishment will verify their cleanliness and removal of product residues.

In addition to achieving pre-operational sanitation, maintaining operational sanitation can minimize cross contamination during poultry slaughter and further processing. Establishments are required to clean and sanitize both food contact and non-food-contact surfaces as frequently as necessary to prevent the creation of insanitary conditions (9 CFR 416.4). Operational sanitation extends to active practices as well as maintaining sanitary equipment. Sanitation procedures are required to prevent cross-contamination from equipment, personnel, traffic, air flow, tables, and floors to product. Sanitation SOPs are required to ensure establishment employees regularly clean and disinfect knives or other product contact surfaces during use. When employees use knives during carcass trimming or cut-up operations, 9 CFR 416.4(a) requires an establishment to ensure that sanitation is maintained between carcasses. This may be achieved, in part, by sanitizing knives in 180°F water or antimicrobial-containing water between every carcass and using air or water knives instead of physical knives. Figure 1 shows an establishment employee washing their hands and their knife in water treated with an antimicrobial after cutting wings on each carcass; this is identified as a best practice.

Figure 1

Best Practice: Establishment employee washes hands and knife with water treated with an antimicrobial after cutting wings on each carcass. This set up and practice reduces cross-contamination.

Figure 2 shows cut-up stations in which fat and other product build up accumulates on the knife sharpeners, which establishment employees use as needed. No water for cleaning is available at each station. These practices are not recommended.

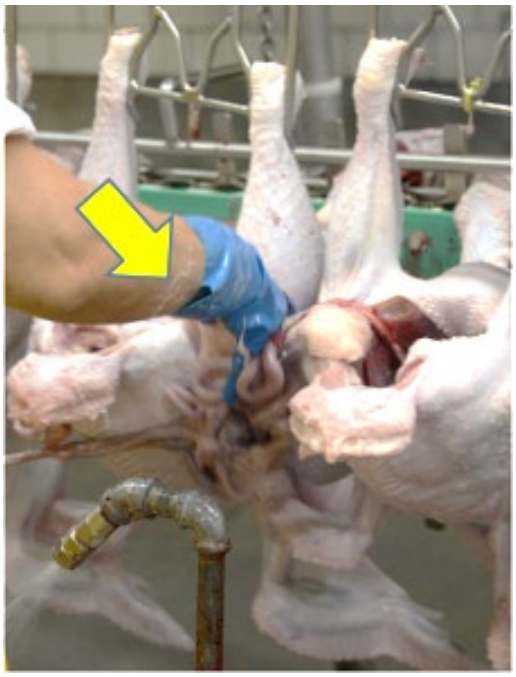
Figure 2

Not Recommended: Cut-up stations do not include a mechanism for cleaning knives. Knife sharpeners are available at each cut-up station and are used as needed. This set up and practice increases cross-contamination.

Employees are in continuous contact with the product. The production of wholesome products is difficult when employees do not maintain clean hands and clothing. Therefore, sanitation training and education, as well as supervision, are crucial. Sanitizing stations must be available and maintained for washing hands. It is important that all employees follow standard hygienic practices in accordance with 9 CFR 416.5. Outer garments, head coverings, aprons, gloves, and protective shields are worn to prevent contamination, and cleaned or changed as necessary. Jewelry, cell phones, food (including candy and gum), and tobacco products should be restricted within the establishment. In addition, care taken by employees when performing tasks, including sanitation procedures, prevents cross-contamination. For example, covering exposed product prior to hosing floors prevents splash-back from contacting product.

Figure 3 shows an establishment employee performing manual evisceration. The employee's arm is uncovered and is not being washed sufficiently to prevent cross-contamination, as shown by the organic material present on the bare arm, which may then enter another carcass.

Figure 3



Not Recommended: Organic material is present on an establishment employee's arm (yellow arrow). Water is available for washing, but the employee is not washing with sufficient frequency to prevent cross-contamination during manual evisceration. Plastic sleeves are more sanitary and easier to wash than bare arms

Sanitation requirements regarding dressing rooms, lavatories, and toilets must be followed per 9 CFR 416.2 (h)(1) and 416.2 (h)(2). Ensuring employee health and hygiene protects employees, product, and consumers. Keeping the processing areas and employee areas clean and in good repair is central to maintaining sanitary conditions.

The sections on Slaughter and Further Processing provide additional guidance regarding maintaining sanitation during those processes.

Intervention Use

Establishments may choose to implement the use of antimicrobial interventions to prevent or control *Salmonella* contamination. For interventions used that are part of an establishment's HACCP system (HACCP plan, Sanitation SOP, or other prerequisite

programs), establishments must maintain scientific support for their effectiveness and implement the interventions according to their support. Because interventions applied as part of an establishment's HACCP system affect decisions made in the hazard analysis, an establishment is required to maintain records associated with these interventions as supporting documentation for its hazard analysis (9 CFR 417.5(a)).

Guidance on identifying and selecting critical operational parameters for antimicrobial interventions and validation is available in the FSIS Compliance Guideline HACCP Systems Validation. The guidance document discusses how to apply those parameters within an establishment as part of a HACCP system. FSIS has found that some poultry establishments measure critical operational parameters, such as pH, temperature, and concentration, at the point where chemicals are mixed rather than at the point where they are applied. Values for these parameters can differ between these two locations. For this reason, values including pH, temperature, and concentration are best measured at the point they are applied to the product, rather than where they are mixed or prepared.

When selecting an antimicrobial intervention, establishments must ensure that antimicrobial interventions and levels used are safe and suitable. FSIS Directive 7120.1, Safe and Suitable Ingredients used in the Production of Meat, Poultry, and Egg Products, includes a web-based lookup table of antimicrobial agents that have been deemed safe and suitable when applied to certain products. This FSIS Directive is updated monthly. Together, 9 CFR 424.21 and FSIS Directive 7120.1 provide a complete list of substances that have been reviewed and can be used in the production of meat, poultry, and egg products. However, FSIS Directive 7120.1 by itself is not sufficient scientific support for establishments' use of interventions because it does not contain efficacy data or all of the critical operational parameters. FSIS does not endorse the use of any particular antimicrobial agent included in FSIS Directive 7120.1.

> ***Key Point***
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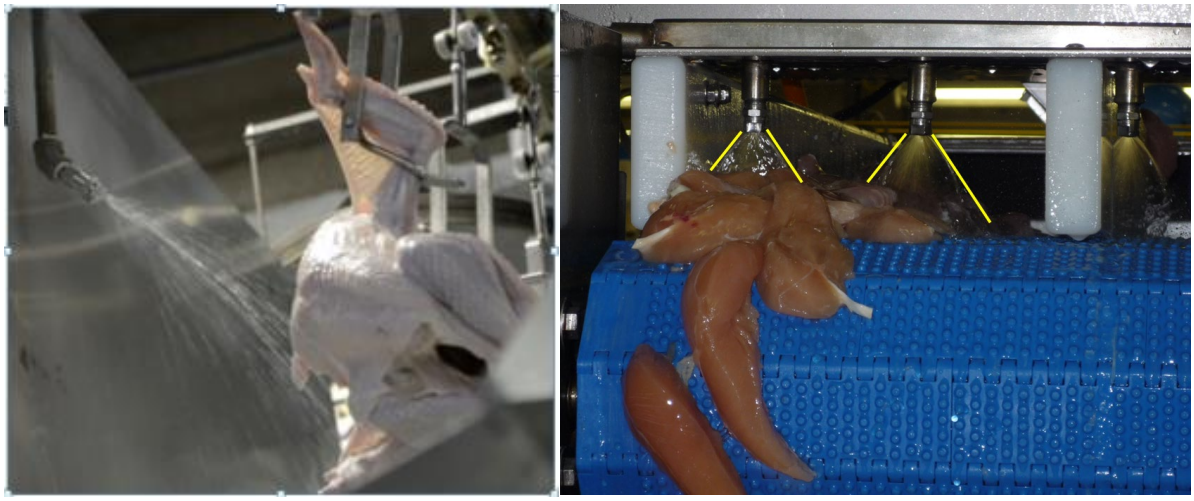
> FSIS Directive 7120.1 **by itself** is not sufficient scientific support for the efficacy of an establishment's interventions.

If a company or establishment wishes to use a substance (e.g., an antimicrobial processing aid applied as a dip or spray) in the production of meat or poultry products that is not listed in FSIS Directive 7120.1, or desires to apply it to a different product or use it at a different level than that for which the substance has been listed, it would need to submit a protocol to FSIS for review and determination. Additional information on New Technology Submissions and Protocols is available in the FSIS Guideline: Procedures for New Technology Notifications and Protocols.

With any antimicrobial intervention, carcass/product coverage is important. Figure 4 below shows examples of incomplete coverage of poultry carcasses and parts. An establishment can use simple verification procedures to ensure an antimicrobial intervention achieves carcass/product coverage. When applying antimicrobial interventions to ground product or to parts that are macerated (or otherwise not

smooth), establishments can consider how they will ensure that the intervention will be thoroughly mixed in and cover surfaces where bacteria may be present.

Figure 4



Not Recommended: Incomplete coverage is because of inadequate reach of antimicrobial spray in both images. On the left, only part of the carcass is receiving the spray. On the right, no spray is applied to the underside of products. In addition, not all pieces on the conveyor belt, nor all of the belt, are being treated because the arc of the spray (just inside the yellow lines) is too narrow to cover all product that could pass on the conveyor. Spray is also not being applied to all pieces due to product piling up and overlapping on the conveyor belt.

Using Microbiological Sampling and Testing

The FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry provides guidance to help small and very small poultry slaughter establishments meet the sampling and analysis requirements under the final rule to modernize poultry slaughter inspection. It is designed to assist establishments as they develop a microbiological sampling plan; utilize microbial testing results to monitor process control; and make decisions on process control throughout the poultry slaughter process (79 FR 49566) so that the establishment meets the minimum requirements set forth in the final rule. While the Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry Guideline provides guidance on how to meet the minimum requirements under the final rule, establishments may want to consider developing an integrated sampling program that addresses multiple points throughout the poultry production process and includes sampling at points during further processing as well as during slaughter.

Microbiological testing provides a measure of the extent of control at the step being evaluated and the steps preceding it. By performing microbiological analyses at several points within a process, it is relatively easy to identify the segment of the process where

there has been a loss of control if that occurs. For example, testing before and after an intervention application can demonstrate whether the expected reduction in contamination is achieved (e.g., that part of the process is "in control").

FSIS regulated establishments may perform microbiological testing (or contract with an outside laboratory to perform such testing) for a variety of reasons, including, but not limited to:

1. Fulfill regulatory requirements;
2. Support on-going verification of the establishment's HACCP plan (9 CFR 417.4 (a)(2);
3. Support decisions made in the establishment's hazard analysis and HACCP plan (9 CFR 417.5(a)(1) and 417.5(a)(2);
4. Evaluate the effectiveness of the establishment's sanitation program (9 CFR 416.14); and
5. Comply with customer's purchase specifications or requirements.

General Considerations for Establishment Ongoing Verification Testing

Verification testing is utilized to "verify" (i.e., confirm) that a process is performing as anticipated. Verification differs from validation in that validation utilizes an initial predetermined number of repetitions and tests, while verification involves ongoing, periodic testing. Process verification testing is intended to demonstrate that the validated process is functioning as designed, and that the results obtained during verification testing are not significantly different than those observed during validation. Verification testing works as one of the pieces of the HACCP system to help inform the establishment of any weak points that may exist in its process and that, consequently, may lead to a loss of process control.

Official establishments are responsible for ongoing verification of their entire HACCP system. Therefore, establishments could choose to sample at multiple points in the process to verify that each component of the HACCP system is continuing to function as designed. Testing only finished product will not typically provide the establishment with sufficient information to detect and correct vulnerabilities at specific steps in their HACCP system. Similarly, FSIS verification testing may reveal trends that indicate a vulnerability but are not adequate alone to trace the root cause.

Key Points

An establishment can sample at multiple points in its process to verify that each component of the HACCP system is continuing to function as designed.

Simply testing finished product will not typically provide sufficient information to detect and correct vulnerabilities at specific steps in the HACCP system.

Process Mapping

One way an establishment could ensure that its HACCP system is effective is to use process mapping. Process mapping (also known as carcass mapping or bio-mapping) can be used as a baseline for assessing the effectiveness of certain interventions as well as the effectiveness of the overall HACCP system. 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 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 creates 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 establishments use process mapping techniques to develop their own sampling programs for *Salmonella* or indicator organisms.

Recommended Best Practices, Statistical Process Control

1. When defining process control limits, verify that the establishment is maintaining process control, so that values within the control limits will be representative of performance when the system is functioning as designed.
2. Statistical control limits that are too tight may be more likely to indicate that process control issues are present when they are not, while limits that are too relaxed may be more likely to miss potential process vulnerabilities.
3. Consider using the *Salmonella* performance standards published by FSIS to establish internal pathogen controls.

Written Microbiological Sampling Program

The written microbiological sampling program at a slaughter establishment is designed in order to (at a minimum) meet the requirements of 9 CFR 381.65(g). Additionally, sampling at both slaughter and further processing may support the HACCP plan by demonstrating control of a hazard or effectiveness of an intervention.

The written procedures for sampling and analysis of microbial organisms must be incorporated into the establishment's HACCP Plan, Sanitation SOPs, or other prerequisite program (9 CFR 381.65(g)). The following are the basic elements of a written sampling program:

1. A description of the sample collection procedures, including how sampling that is representative of all lines and production shifts is achieved, how samples are

handled to ensure sample integrity, how the establishment ensures that samples are collected per the written program, and the establishment employees designated to collect the samples for testing;

2. Information on the method used to analyze the samples and the identity of the laboratory performing the analysis. The method used must be fit-for-purpose, such as an Association of Analytical Chemists (AOAC) official method or one validated by another recognized independent testing body. FSIS provides an online lookup table of Validated Test Kits to assist establishments with identifying applicable options;

3. The microbiological organisms (i.e., *Salmonella* or indicator organisms) that the establishment will test for to monitor the effectiveness of its process control procedures;

4. The locations within the process where samples are collected;

5. The methods to ensure integrity of the samples throughout collection, storage, and analysis;

6. The frequency of sample collection;

7. Scientific and technical documentation to support the design of the sampling program. Further information on scientific and technical documentation can be found in the FSIS Compliance Guideline HACCP Systems Validation;

8. The method for evaluating test results; and

9. Actions to take in response to test results.

Designing a Sampling and Testing Program

When a microbiological sampling and testing program is properly designed and implemented, it can provide valuable information about an establishment's process control. When not properly designed and implemented, the test results can provide inaccurate and unreliable information that may not represent the establishment's actual process control. This use of inaccurate or unreliable test results could lead to inaction or an inappropriate course of action by establishments and can lead to false assurances of product safety.

Effective testing depends on implementation within an establishment's food safety culture. Treating adverse test results as undesirable may introduce bias, as employees may be apprehensive in reporting these findings. A proactive approach to adverse sampling results can prevent a loss of process control at a greater level. Results from

laboratory or quality assurance staff may identify negative trends or vulnerabilities in the HACCP system before a hazard reaches the level of not meeting an FSIS pathogen performance standard.

There are a number of factors that need to be considered when designing a sampling plan. Sample collection and analysis involves multiple steps, all of which must be successfully performed and documented to maintain the identity and integrity of the sample. Before starting sampling, an establishment needs to consider the design of the sampling program.

Establishments can find information on criteria for selecting a commercial or private microbiological testing laboratory to analyze establishment samples in FSIS's Establishment Guidance for the Selection of a Commercial or Private Microbiological Testing Laboratory.

Target Organisms

Establishments can consider the advantages and disadvantages of testing for the presence of selected indicator bacteria and pathogens for ongoing HACCP verification. Sampling and testing costs for indicator species may be lower than costs for pathogens. However, while elevated levels of indicator bacteria are usually interpreted to mean pathogens are more likely, this relationship is not perfect. In other words, high levels of indicator organisms do not always mean that the pathogen is present, and low levels do not guarantee the pathogen is controlled. Only pathogen testing can effectively verify that pathogens are controlled to acceptable levels in finished product.

There are no identified indicator organisms that directly reflect the presence or absence of pathogens (e.g., *Salmonella)* in poultry. Therefore, FSIS recommends that an establishment test for pathogens at least intermittently and compare its results against the presence or absence of other non-pathogenic organisms (i.e., the indicator organisms the establishment is using) to assess whether it is maintaining process control.

The indicator organisms can provide evidence of control, while periodic testing for pathogens may verify that the establishment is reducing pathogens to acceptable levels. Establishments conducting their own ongoing verification sampling and testing of finished product for *Salmonella* can use the FSIS performance standards as indicators of process control. For example, an establishment could consider the FSIS "minimum number to assess" for each FSIS performance standard as a guide to ensure that they collect enough data points to have statistical confidence in their pathogen percent positive. For most products, that is roughly one *Salmonella* sample per month (11 samples/52 weeks for young chicken carcasses, 14 for turkey carcasses, and 10 for chicken parts and comminuted poultry). This approach is supportable if the analytical method has comparable sensitivity to the FSIS method; the less sensitive the method, the more samples are needed to increase confidence in the accuracy of the results.

Statistical Process Control

Statistical process control is a scientific visual method used to monitor, control, and improve processes by reducing variation from the process. Statistical process control provides a powerful tool for establishments to use to monitor and interpret data collected for ongoing HACCP verification. Statistical process control can provide establishments with an early warning that their process may not be functioning as designed. This early warning can allow establishments to make modifications to bring their process back into control prior to not meeting an FSIS pathogen performance standard or an individual establishment-identified pre-determined performance criteria. Statistical process control can provide establishments with reasonable assurance that their HACCP system is functioning as designed, and that they are likely to meet applicable performance standards.

The FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry provides additional information on sampling frequency and analysis, including the use of statistical process control.

A number of methods and approaches for statistical process control are available for establishments to follow. Establishments can consider available guidance and develop a statistically valid approach for interpreting sample results (Saini et al., 2011; De Vries & Reneau 2010). Establishments can consider available information provided by FSIS, including the *Salmonella* performance standards for young chicken and turkey carcasses, chicken parts and comminuted poultry,[2] to develop their own internal controls for pathogens in these products. FSIS has found that its category approach (Category 1, 2, and 3) to assess process control has worked to identify whether individual establishments are maintaining consistent process control. Establishments developing their own internal pathogen controls can consider how they may apply this concept.

Sample Collection Method

Proper sample collection techniques and procedures are necessary to ensure the accuracy of test results. Sample handling and collection procedures are specific to the type of product to be sampled (e.g., parts or comminuted), the sample collection method (e.g., parts rinse, comminuted product sampling), and the type of sample collected (e.g., rinsate sample, finished product samples, excision sample of skin). Individuals who will collect samples need to receive training on proper sample collection procedures.

[2] 81 FR 7285

Antimicrobial Interventions and Drip Time

An establishment can consider how sample results are affected by the antimicrobials used in the process and the timing of the sample collection. Antimicrobial interventions used during processing steps may make it more difficult to detect remaining bacteria, particularly when non-destructive or surface sampling is conducted. For destructive sampling, in which the tissue itself is collected for analysis at the laboratory, remaining antimicrobials will continue to be inactivated by organic material in the sample during shipment of the sample to the laboratory. Conversely, with rinsate or through other surface sampling, capturing the antimicrobial in a buffer or other sampling solution may prolong the antimicrobial's effective time. For example, consider poultry carcasses exiting a chiller tank where antimicrobial interventions are used. Contaminated carcasses may have bacteria that survived the chiller tank. However, those bacteria may not be detected through sampling if the carcass is not allowed adequate drip time before the establishment collects a rinse sample. Adequate drip time will allow excess antimicrobials to drip off the carcass. Immediate sample collection will include a significant amount of residual antimicrobials, which suspended in rinsate will remain active and make it harder for the laboratory to detect live bacteria. If the carcass is allowed adequate drip time, the sample will contain less residual antimicrobials, and the laboratory will be more likely to detect live bacteria. At this time, FSIS generally recommends establishments wait at least 60 seconds after application of antimicrobial interventions before collecting a sample to reduce the amount of antimicrobial carryover. A longer drip time may be recommended by the antimicrobial manufacturer for particular solutions. Tipping over the carcass to allow drainage of chiller water that has accumulated in the body cavity can also result in greater accuracy of the test result. Establishments could consider whether a neutralizing agent is available which could stop the action of any residual antimicrobial intervention, making it possible to more accurately detect live bacteria remaining on the sample. Examples of a neutralizing agent suited for particular antimicrobials would include lecithin for Cetylpyridinium Chloride (CPC), sodium thiosulfate for Peroxyacetic Acid (PAA), or sodium thiosulfate plus bicarbonate for Acidified Sodium Chlorite (ASC) (Gamble et al., 2016).

To effectively use quantitative data to evaluate process control, the collection, handling, storage, and transportation of samples are carefully controlled to prevent temperature abuse, sample leakage, and other events that could affect sample integrity and lead to unreliable test results. Procedures for maintaining sample integrity are particularly important when samples need to be transported from the establishment to an off-site laboratory (e.g., by a delivery service, such as FedEx or courier) where they may not be under the direct control of the establishment or the laboratory for a period of time.

Recommended Best Practices, Ongoing Verification Testing

1. Establishments must maintain support for their verification procedures and frequencies. (9 CFR 417.2(c)(7))
2. Both indicator bacteria and pathogens can provide useful information.
3. Allow at least 60 seconds before sampling after application of any antimicrobials, to prevent excessive antimicrobial carryover in the collected sample.

Selection of Products for Sampling

The samples are selected and collected in a manner and at a frequency that will ensure that they are representative of the establishment's production. If more than one shift is operating at the establishment, a sample can be taken on any shift. All shifts are sampled with sufficient frequency in order to assess process control for each shift.

The FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry provides information on methods for selection of carcasses for sampling during the slaughter process. In order to meet the requirements of 9 CFR 381.65(g), slaughter establishments must sample carcasses at the pre- and post-chill locations (very small establishments are only required to test at post-chill). The same selection techniques can also be applied to further processed products in support of a HACCP system.

Different methods of selecting the specific products for sampling can be used, but all require the use of random numbers to reduce bias. Examples of methods for selecting products for sampling include random number tables, calculator- or computer-generated random numbers, or drawing cards.

Sample Analysis

To obtain the most accurate microbiological testing results, establishments ensure the following:

- The collected sample is either analyzed in the establishment the same day as it is collected or by the following day. If shipping to an offsite laboratory, the sample can be held under refrigeration until overnight shipment to the laboratory the day of collection or the following day.

- Samples can be held at refrigerated temperature, not frozen, and shipped cold to the laboratory in an insulated shipping container with frozen gel packs. Frozen samples are discarded since the sample results may not be accurate.

> ***Key Points***
>
> To obtain the most accurate results, samples are analyzed as soon after collection as possible.
>
> If samples must be transported to an off-site laboratory, they can be refrigerated and then shipped refrigerated, on the same day they were collected or the following day, via an overnight delivery service to the laboratory.

Microbiological Testing Method

An establishment needs to determine whether sample analysis will be performed by an outside (third party) laboratory or in its own onsite microbiological testing laboratory (if available).

Because of the costs and the logistics involved with maintaining an onsite microbiological testing laboratory, establishments may choose to have samples analyzed by an outside laboratory. FSIS has available the resource titled Establishment Guidance for the Selection of a Commercial or Private Microbiological Testing Laboratory. This guideline is intended to be useful to very small establishments when they are selecting a commercial or private laboratory to analyze their microbiological samples.

NOTE: Establishments can (and often do) analyze samples for non-pathogenic organisms, such as generic *E. coli* and APC, on-site.

Recordkeeping

Upon implementation of its sampling program, an establishment must maintain daily records sufficient to document the samples collected and subsequent test results. For slaughter establishments, records must document the required sampling, as outlined by 9 CFR 381.65(h). Daily sampling records that best support analysis of the sample results include:

- Time, date, and location of the sample collection;
- Sample collector's name;
- Name or description of the product or sample source; and
- Lot information and producer.

A best practice is for all sample records to be dated and initialed by the sample collector immediately upon completion of the entry. If an outside laboratory is used for testing, then these sample records would also include information such as date the sample was shipped to the laboratory for analysis. The receiving laboratory will document the:

- Date received;
- Condition of the sample upon receipt, including sample temperature;
- Date the analysis was started and completed; and the
- Analytical result.

Test results are best recorded and linked to the sample collection records by a sample number, form number or some other unique identifier. Data integrity is a key consideration when determining how to maintain these records. These records can be maintained in an electronic format, provided there are measures in place to ensure the security of the information. These records must be available for FSIS inspection program personnel upon request.

Actions in Response to Test Results

As part of its process control procedures, an establishment defines the actions it will take if the test results obtained through its sampling are above the limits it has set. The establishment delineates what its actions will be, who will take each action, how the outcome of these actions will be documented, and how it will be verified.

If the establishment determines that the trends in its test results indicate a loss of process control, the establishment can first take action to investigate the cause. As discussed in the previous section on process control, an establishment can consider how the pieces of the HACCP system work together, and how they impact the entire system. To do this, the establishment can evaluate the process control procedures and sanitary dressing practices to identify the cause and to take steps to correct the problem. This determination can include a review of its process monitoring records as well as an evaluation of the process during normal operations. The establishment can consider any implementation problems or changes in its practices, including but not limited to the following:

1. Implementation problems or changes in procedures for routine cleaning and sanitizing of equipment, including hand tools that are used to remove contamination or to make cuts into the carcass;

2. Changes in the design, configuration, and calibration of equipment to ensure proper function within operational parameters to prevent the contact between carcasses and parts and prevent contamination of carcasses during operation;

3. Implementation problems or changes in employee hygiene practices, to ensure that employees frequently wash hands and aprons that come in contact with carcasses; and

4. Implementation problems or changes in antimicrobial or mechanical intervention treatments, such as carcass washes, sprays, dips, drenches, or brushes, in accordance with the limits selected by the establishment.

Following its investigation, the establishment responds appropriately to its findings using decontamination procedures and antimicrobial intervention treatments as necessary to address any contamination that may have occurred on the carcasses and parts. The establishment can also take steps to initiate any necessary equipment repair or recalibration and employee training when identified during the investigation as potential root causes of the loss in process control. Depending on how the establishment has incorporated sampling and sanitary dressing into the written programs, the establishment may also need to perform and document corrective actions as required by Sanitation SOP (9 CFR 416.15) or HACCP (9 CFR 417.3(a))

PRE-HARVEST

Pre-Harvest Interventions and Management Practices

Pre-harvest interventions and practices can prevent or reduce *Salmonella* colonization of live birds, increasing the effectiveness of post-slaughter interventions and establishment controls. This section identifies available pre-harvest interventions/practices, and how slaughter and processing establishments can encourage their use by poultry producers. This section covers poultry production from breeder stock through transport to the slaughter establishment. Live receiving and subsequent slaughter steps are covered in the following section.

Food Safety Hazards

Colonization of the poultry gastrointestinal tract with *Salmonella* is a food safety hazard that can occur at pre-harvest (i.e., at grow-out, the hatchery, or at the breeder farm). Colonization can then result in fecal shedding of bacteria, which can contaminate skin and feathers during many steps from breeder farm to arrival at the slaughter establishment. External contamination can also occur during slaughter from rupture of the gastrointestinal tract and transfer of pathogens on contaminated equipment. FSIS-regulated establishments can, as part of their overall HACCP system, address these hazards through purchase specifications or other agreements to require that their suppliers implement certain pre-harvest management controls.

Pre-Harvest Interventions & Management Practices

FSIS recommends that establishments use two main practices for managing pre-harvest colonization of poultry with *Salmonella*. Together, these practices are expected to reduce the number of birds colonized with or shedding pathogens, reduce the number of these pathogens in colonized birds, and reduce the likelihood that contamination will be transferred from colonized to uncolonized birds.

First, FSIS recommends that slaughter establishments receive birds from grow-out farms, hatcheries, and breeder flocks that implement the recognized pre-harvest interventions described in this section. Implementing these interventions can decrease the *Salmonella* contamination on birds received by slaughter and processing establishments (Cox & Pavic 2010; Volkova et al. 2011). Establishments may include specifications in their grow-out contracts for growers to incorporate strategies that address the potential contamination of *Salmonella* during hatching and grow-out. Reducing or eliminating *Salmonella* on incoming birds at slaughter establishments can reduce contamination of finished products and increase the likelihood that the establishment will meet FSIS performance standards for *Salmonella*.

Alternately, if an establishment does not require that *Salmonella* is addressed at pre-harvest, FSIS recommends that slaughter and processing establishments test incoming birds and poultry products before entry into the establishment and make processing decisions based on those test results. Further information about using pre-harvest sampling data for decision-making can be found in the following section, Scheduled Slaughter and Processing. Using these test results, an establishment could decide to implement a scheduled slaughter and processing plan based on the presence or absence ("status") of *Salmonella*. Other decisions could be to utilize additional chemical interventions or divert products from positive flocks to lethality treatment (such as cooking).

Scheduled Slaughter & Processing

Maximizing the amount of finished product that is negative for *Salmonella* can be achieved by implementing a scheduled slaughter and processing plan based on the status of incoming birds.

Scheduled slaughter and processing depend on lotting definitions that ensure lots are microbiologically independent. To implement a scheduled slaughter and processing plan, establishments must determine the *Salmonella* status of poultry flocks before their entry into the establishment. Using this information, establishments can then schedule pathogen-negative flocks for slaughter and processing separately from pathogen-positive flocks. "Separately" can be defined as different slaughter and processing establishments, different production lines in the same establishment, or at different times on the same production line (negative before positive and lines are cleaned and sanitized before negative flocks or products). Establishments can also choose to utilize

additional interventions or lethality treatments, such as cooking, for product derived from pathogen-positive flocks.

Step One: Determine Salmonella Flock Status

The first step in scheduled slaughter and processing is to obtain accurate and reliable information about the *Salmonella* prevalence in the live birds at pre-harvest. Status can be determined as close to slaughter as possible in order to increase the likelihood that *Salmonella* will be detectable through drag swabs, boot samples, or litter samples. However, the results need to be available to the establishment early enough to take action. This typically means sampling between 2 and 5 days before transport to slaughter.

Further information on sampling in the grow-out house can be found under the heading Determining Flock Pathogen Status Prior to Harvest, in the Pre-Harvest section of this guidance.

Step Two: Separate Slaughter and Processing

Positive or negative flock status can be maintained throughout slaughter and processing, including if carcasses or parts are moved to other establishments for further processing. For example, if a negative flock is slaughtered separately from a positive flock, but the carcasses and parts are commingled during storage or further processing, all product can be considered positive (microbiological independence is not in place).

In cases where positive and negative flocks are slaughtered and processed on the same line, establishments will need to evaluate their process to determine where to establish independence between lots. If there is no clear break, the establishment can consider carcasses or other raw poultry components to be positive until the next cleaning and sanitizing is performed. For example, all carcasses in the chiller tank at the time the first carcass from a positive flock enters the tank can be considered positive, even if some of the carcasses originated from negative flocks. Then, the establishment can consider all carcasses passing through the tank to be positive until the production line is cleaned and sanitized.

> ***Key Point***
>
> Status can be maintained throughout slaughter and processing, including if carcasses or parts are moved to other establishments for further processing.

Step Three: Further Processing or Cooking

Establishments can also choose to utilize additional interventions for poultry products derived from positive flocks. Use of interventions could be based on the establishment's knowledge of the log reduction achievable through the interventions and processes used. Alternatively, positive birds and products could be sent to cooking or another lethality treatment in order to achieve full lethality for any *Salmonella* present in the affected product.

Recommended Best Practices, Scheduled Slaughter & Processing

1. Use microbiologically independent lotting practices to minimize commingling or cross-contamination.
2. Determine the presence or absence of *Salmonella* before flocks are transferred to slaughter.
3. Slaughter and process negative flocks separately from positive flocks (different establishment, different line, or on sanitized equipment).
4. Consider the use of additional interventions or cooking for product derived from positive flocks and poultry products.

Pre-harvest Recommendations to Control *Salmonella*

This section provides information on interventions intended to prevent the exposure of birds to pathogens and available products intended to reduce the incidence or level of *Salmonella*. Interventions to prevent exposure and colonization in live birds are typically more effective than products that treat birds exposed to *Salmonella* to reduce incidence or levels, as it is more difficult to eliminate *Salmonella* from infected flocks. There are numerous routes of exposure to *Salmonella* during pre-harvest including:

Key Points

Interventions to prevent exposure and colonization in live birds are preferable as it is more difficult to eliminate *Salmonella* from flocks once infected.

Preventive interventions in live birds lose effectiveness if the flock is already infected. Consider using multiple interventions throughout pre-harvest.

- Transmission through the egg from the breeder flock to chicks (vertical transmission) and transmission between birds during hatch and grow-out;
- Exposure to contaminated water, feed, and bedding in the grow-out house; and
- Environmental exposures due to poor biosecurity practices and inadequate pest control.

FSIS is not aware of a single pre-harvest intervention that eliminates *Salmonella* as a pre-harvest hazard. Instead, FSIS recommends that a "multi-hurdle" approach be employed; this means that multiple sequential pathogen interventions are used that can have an additive effect to reduce pathogens. Implementing multiple interventions and controls beginning at pre-harvest extends the multi-hurdle approach to *Salmonella* prevention and control across each bird's life. Using interventions with differing modes of action can further improve the extent of pathogen reduction when using a multi-hurdle approach. In this Guideline, FSIS is providing available effectiveness data for pre-harvest interventions, as identified in scientific literature. However, because many factors during the pre-harvest period can contribute to pathogen colonization of individual birds, the spread of pathogens between birds in a flock, and the excretion of pathogens by birds, use of a particular

intervention may have different efficacy than specified. Thus, the concept of a multi-hurdle approach is important to keep in mind.

Establishments can consider requiring suppliers to use the interventions listed here. Establishments can use these pre-harvest controls as part of their HACCP system (through purchase specifications or other agreements) and to support their decision-making. FSIS will work with other federal agencies, such as USDA-Animal and Plant Health Inspection Service (APHIS), Food and Drug Administration (FDA), and USDA-Agricultural Research Service (ARS), to develop additional information on pre-harvest interventions.

This Guideline breaks the pre-harvest interventions into six categories focused on physical, biological, and hygienic approaches to reduce pre-harvest exposure to *Salmonella*: Breeder Flock & Hatchery, Grow-out House, Bedding, Feed, Water, and Transportation. When considering the control of hazards on incoming birds, slaughter establishments can consider exposure-reducing interventions combined with one or more of the products available for pre-harvest control to reduce incidence or levels of *Salmonella* in poultry that may be exposed to these pathogens (Table 2). These products have different modes of action, but all produce the same result: reduced incidence of pathogen colonization and reduced pathogen levels in colonized birds. Efficacy depends on the specific product, and most can be used in consultation with a veterinarian. Using both types of pre-harvest approaches — those to reduce exposure and those that reduce incidence of colonization and levels of pathogens — will minimize pathogens on birds at harvest.

Using the interventions and best practices recommended in this guideline can help to provide for animal welfare and bird health at pre-harvest, thereby reducing stress in poultry and reducing *Salmonella* in birds presented at slaughter. Evidence suggests that stress at pre-harvest can have adverse effects on food safety (Rostagno, 2009). Understanding the mechanism by which stress alters normal intestinal characteristics and induces susceptibility to enteric infections may help in developing additional pre-harvest strategies to reduce pathogen contamination in poultry.

NOTE: In this section, the term “young chickens” refers to all chickens raised for slaughter to distinguish it from chicken breeder stock. The term here is not limited to “broilers” as defined in 9 CFR 381.170(a)(1)(iii). In this section, “young turkeys” refers to all turkeys raised for slaughter to distinguish it from turkey breeder stock.

Table 2. Pre-harvest products to reduce colonization and number (level) of *Salmonella* in poultry.

Definition	Notes on Use
Vaccines: increase immunity to *Salmonella* by exposing the immune system to a controlled preparation. Vaccine types include live vaccines (an attenuated strain of *Salmonella*), sub-unit vaccines (a vaccine with minimal parts of the target for immune response), and autogenous vaccines (developed from bacteria isolated from the farm environment).	Approved live-attenuated[3] vaccines are available for use in breeder flocks and in young chickens and young turkeys and are administered orally or by injection. Other vaccine types, such as inactivated vaccines, may require multiple doses in order to produce the immune benefits. Special approvals from APHIS are required for long-term use of autogenous vaccines or for use of these vaccines with multiple flocks. Some vaccines were found to show a 9% reduction in *Salmonella* prevalence, a 1-2 log reduction, or a 2-3 log reduction of *Salmonella* recovered from poultry challenged after vaccination.
Competitive Exclusion & Probiotics: preparations of beneficial bacteria that compete with *Salmonella* in the gut for space or nutrients. Also known as direct-fed microbials.	Some products can be used on the day of hatch to establish healthy gut flora in chicks. Other products can be added to water and feed for both breeders and young chickens and used to boost competition against pathogens throughout the bird's lifetime or when otherwise indicated (e.g., stress). One study on the effectiveness of a competitive exclusion culture in poultry found up to a 92% reduction of *Salmonella* following a *Salmonella* challenge.
Prebiotics: specific nutrients that will allow beneficial bacterial species to more effectively compete against *Salmonella*.	Can be added to the feed of both breeders and young chickens. The most common supplements include yeast extracts, such as beta-glucans and mannan oligosaccharides A study on the effectiveness of a prebiotic in poultry found a 34% reduction of *Salmonella* prevalence following *Salmonella* challenge.
Organic Acids: increase the acidity of the gut, which can kill *Salmonella*. Because each bacterial species has a different susceptibility to organic acids, this	Can be added to both feed and water for breeders and young chickens. Adding to water during feed withdrawal is particularly important. After feed is withdrawn, birds may be more likely to peck at litter and may ingest pathogens. Additionally, during feed withdrawal, the gastrointestinal (GI) tract becomes

[3] Live *Salmonella* vaccines administered to poultry presented for slaughter may have the potential to introduce a hazard into the establishment. Establishments should support how their use of such vaccines does not affect safety of poultry products derived from vaccinated poultry and does not interfere with FSIS inspection procedures.

mechanism also increases the ability of beneficial bacteria to compete against pathogens.	more susceptible to colonization by *Salmonella* because of the reduced organic acid concentration and higher pH. Organic acids added to the water will lower the pH in the crop and reduce pathogen colonization and growth. A review article found that use of most organic acid products resulted in up to a 1 log reduction of *Salmonella*.

(References: Berge and Wierup 2012; Callaway et al. 2008; Desin, Köster, and Potter 2013; Feberwee et al. 2001; Hume et al. 1998; Khan et al. 2003; Penha et al 2009; Spring et al. 2000; Wales et al. 2013)

Breeder Flock & Hatchery

Breeder flocks and hatcheries can be the original source of *Salmonella* colonization for young chickens because infection can be transmitted through the egg (vertical transmission). Establishments can obtain broiler and turkey chicks from breeder flocks and hatcheries that follow National Poultry Improvement Plan (NPIP) procedures and recommendations. The NPIP was established in the early 1930's to provide a cooperative industry, state, and federal program through which new diagnostic technology can be effectively applied to the improvement of poultry and poultry products throughout the country. Because of the possibility of vertical transmission, establishment parent companies and independent growers can consider placing chicken and turkey chicks from breeder flocks free of *Salmonella* onto grow-out farms (Liljebjelke et al. 2005; Crespo et al. 2004). (Note that pathogen-free breeder stock is not a requirement for participation in NPIP.) Chicken breeders also demonstrate variability in innate immunity to *Salmonella;* some chicken breeder stocks have been shown to be more resistant to colonization (Swaggerty et al. 2009). Utilization of these parental breeding stocks can produce broiler chicks that are more resistant to on-farm colonization.

Consider the use of one or more of the products listed in Table 2 to prevent or reduce colonization with *Salmonella* in live birds that are destined for slaughter. Several of the probiotic, prebiotic, and organic acid products can be administered to both breeder flocks and young chickens, often through feed and water. Of special note for breeder flocks are vaccines for *Salmonella*, which can reduce the likelihood of vertical transmission to chicks (Desin, Köster, & Potter, 2013). Compared to the short grow-out period for young chickens, breeder flocks may remain productive for several months or longer. As a result, a greater number of vaccine options are available in breeders compared to young chickens and turkeys.

Competitive exclusion and probiotics can be administered to chicks on the day of hatch to inoculate the gastrointestinal tract with beneficial bacteria (Table 2). Inoculation with beneficial bacteria at the hatchery can be followed with use of appropriate prebiotics and organic acids at the grow-out house to maintain beneficial bacteria through grow-out. Chicks can be transported from the hatchery to the grow-out house in new or

cleaned/sanitized, and ideally lined, containers (Cox & Pavic, 2010). Limit the number of individuals handling the chicks from the truck to the interior of the grow-out house to minimize chances for exposure.

Recommended Best Practices, Breeder Flock and Hatchery

1. Obtain chicks from pathogen-free breeder flocks and from breeders and hatcheries following NPIP procedures.
2. Use breeding stock with innate resistance to *Salmonella.*
3. Consider using one or more of the products listed in Table 4.
4. Transport chicks to grow-out in new or sanitized containers.

Although the following sections focus on young chickens and turkeys, the best practices identified also apply to chicken and turkey breeders and can serve to minimize pathogens in these flocks.

Grow-out Houses

Farms and houses can be designed to facilitate cleaning and disinfection between flocks (Cox & Pavic, 2010; Volkova et al., 2011). All poultry farms can develop and implement written biosecurity and hygiene plans. Poultry health is best monitored under the supervision of a veterinarian.

Available research suggests that the following practices are correlated with a decreased likelihood of *Salmonella* in birds presented for slaughter (Cox & Pavic, 2010; Volkova et al., 2011; C. Wray et al., 1999):

- Housing a single species (e.g., only chickens or only turkeys) on the farm;
- Keeping birds of different ages in different houses;
- Limiting the number of people with access to grow-out houses and using disinfecting boot dips or disposable foot coverings and disposable coveralls when entering the house (a study by Rabie et al. (2015) found that correct use of a boot dip effectively reduced *Salmonella*, although organic material can negatively impact effectiveness);
- Removing vegetation around buildings, installing screens on windows and other openings, and increasing physical integrity of buildings to prevent access by rodents, birds, or insects; and
- Using pest control measures including bait and traps.

In addition to reducing exposure to *Salmonella* with the measures described above, consider the use of one or more of the products in Table 2 to reduce colonization and the incidence or level of pathogens in exposed birds. Most probiotics, prebiotics, and organic acids can be used with both breeder and broiler flocks as feed or water additives. Vaccines remain an option for broiler flocks; however, manufacturer information can be used to determine whether immune protection can be achieved during the short grow-out period.

Approved live-attenuated vaccines are available for use in young chickens and turkeys. Biologics, including vaccines and antibody products, are licensed for use by USDA-APHIS, which updates the complete listing on their webpage. Live vaccines may introduce *Salmonella* into flocks presented for slaughter; the establishment can consider this possibility when developing the HACCP plan and sampling programs accordingly.

Key Points

Pre-harvest interventions must **not**:

1) Negatively impact product safety,

2) Jeopardize the safety of Federal inspection program personnel,

3) Interfere with inspection procedures, including FSIS sampling, or

4) Conflict with the Agency's regulations.

Recommended Best Practices, Grow-out House

1. Implement on-farm biosecurity and hygiene plans,
2. Minimize the number of people with access to the grow-out house.
3. Require the use of disposable foot coverings or boot dips.
4. Consider the use of products in Table 4.

Bedding

Litter or bedding can be considered a reservoir for *Salmonella* contamination (Bryan et al., 1979; Corrier et al., 1999). Downtime between flocks is recommended at around 10 -14 days, which allows moisture removal and desiccation of litter. Ensure that no new moisture is added and that wet caked areas are removed during the litter turn over (fluff). There are technologies that allow composting or windrowing of litter between flocks (Malone & Johnson, 2011; Wilkinson et al., 2011; Macklin et al., 2008). It is important to note that litter is not uniform in moisture, organic carbon availability, pH, or microbial populations, which are all factors that can influence pathogen destruction or growth in litter during and following composting.

Water activity (Aw) and pH of the litter are positively correlated with pathogen growth (Opara, 1992; Terzich, 2000). Consider chemical treatment of the litter to reduce pH and Aw during production to reduce pathogen growth and contamination of the flock, which could reduce pathogen recovery at the processing establishment.

Litter treatments to reduce pH are commonly added prior to flock placement because the early grow-out phase (~1st week for young chickens, ~ 3 weeks for turkeys) is when the birds are most susceptible to pathogen colonization (Santos et al., 2005; Payne et al., 2007). Several chemical additives have been used to decrease the pH of poultry litter, such as aluminum sulfate (Moore & Miller, 1994; Line, 2002), ferrous sulfate (Huff et al., 1984), phosphoric acid (Reece et al., 1979), sodium bisulfate (Moore et al., 1996) (Terzich, 1997), and acetic acid (Parkhurst et al., 1974). Experts recommend a pH of less than 4 to control *Salmonella* growth in litter and to prevent acid-tolerance in some strains of *Salmonella*. (Hardin & Roney, 1989; Payne et al., 2002; Payne et al., 2007). Reducing litter pH to less than 4 can reduce *Salmonella* to below detectable limits (Payne et al., 2007). Since litter pH increases to near neutral after the first week of production, reapplication of the litter treatment may be needed (Pope & Cherry, 2000).

During grow-out, moisture in the house can be controlled with the use of tunnel ventilation systems. If the moisture in the litter is too high (as observed in the winter months due to decreased ventilation) *Salmonella* growth can increase. Wet litter can also be caused by environmental conditions (rain, poor drainage, leaky roofs), evaporative cooling systems, excess drinking, health problems, panting, excess bird density, and watering systems such as type of waterers (bell, trough, nipple), leaky valves, maladjusted waterers, too many birds per drinker, or broken water lines. *Salmonella*-positive birds can also spread the pathogen via aerosol when the environment is too dry (Gast et al., 2004).

Recommended Best Practices, Bedding

1. Use a litter treatment to reduce litter pH < 4 and Aw < 0.84.
2. Use a composting or windrow treatment during flock downtime.
3. Allow 10-14 days between flocks to desiccate litter and verify destruction of pathogens.

Feed

Select growers that use feed that is free of *Salmonella*. Specifically, obtain feed from manufacturers that follow Good Manufacturing Practices to reduce or eliminate pathogens, such as those certified by the Safe Feed/Safe Food program administered by the American Feed Industry Association. Safe Feed/Safe Food producers may also conduct finished product testing to verify the product is negative of certain hazards. Clean and disinfect feeders between flocks and keep feeders in good repair. Consider adopting the use of feed additives that are effective in young chickens (Table 2).

Protect feed from contamination during transportation and storage. Transport the feed to the farm in accordance with the FDA's Sanitary Transportation of Human and Animal Food final rule (81 FR 20091), which includes provisions for cleaning transportation vehicles before transport of feed and measures to prevent contamination or tampering of feed during transportation. Store feed on-farm in a manner that reduces the likelihood of contamination through contact with pests, fomites, or the environment (Berge & Wierup, 2012). If feed is stored on-farm in a manner that could result in contamination (such as open bins or bags), poultry producers can conduct periodic sampling of the feed to determine whether contamination has occurred during storage. Some research indicates that pelleted feed is more resistant to contamination during storage than mash, and that the addition of organic acids to the feed may also protect against contamination. The Association of American Feed Control Officials (AAFCO) provides additional recommendations on the production and distribution of animal feed in its document titled "Best Management Practices for Manufacturing, Packaging & Distributing Animal Feeds and Feed Ingredients."

Time feed withdrawal appropriately; withdrawal from feed can occur between 8 – 12 hours before slaughter (Cox & Pavic, 2010). Withdrawing feed before slaughter can ensure that birds have an empty gastrointestinal tract during transport, slaughter, and evisceration, which can reduce external contamination with fecal material. However, some research indicates that early withdrawal may lead the birds to peck at the litter in the grow-out house and increase the likelihood that the bird will ingest pathogens and be contaminated at slaughter (Berge & Wierup, 2012). Also, the decrease in the acidity of the crop caused by the removal of feed that beneficial crop bacteria use to form organic acids allows *Salmonella* to grow in the crop (Hinton et al., 2000a, 2000b) because of a lower organic acid concentration and higher pH. Growers can consider providing water with organic acids (Table 2 and discussed below) during feed withdrawal to prevent colonization of the crop. Extended feed withdrawal may also make internal organs more fragile, increasing the likelihood that the crop or other organs will tear during processing and contaminate the carcass (Cox & Pavic, 2010). Most studies support a feed withdrawal period of 8-12 hours to prevent organ tearing (Rostagno et al., 2006; Cox & Pavic, 2010).

Recommended Best Practices, Feed

1. Clean feeders between flocks.
2. Use feed that is pathogen free.
3. Consider use of appropriate feed additives (Table 4).
4. Protect feed from contamination during transport and storage
5. Pelleted and acidified feed may be more resistant to contamination during storage.
6. Time feed withdrawal appropriately (between 8 – 12 hours) and supply water with organic acids during feed withdrawal.

Water

Provide abundant, potable water (Cox & Pavic 2010). If water is not from a chlorinated or municipal source, routine testing is recommended to ensure that the source is free of pathogens. Clean the water distribution system between flocks, ensuring that biofilms, which may be reservoirs for pathogens, are removed when possible. Ensure that the water system is free of cracks and leaks to minimize waste and to keep bedding dry.

A number of the products listed in Table 2 are available as water additives for young chickens. Of note are organic acids added to water, particularly during feed withdrawal (Berge & Wierup 2012). Providing water during feed withdrawal distracts birds from pecking at the litter. Adding organic acids to this water source will increase the acidity of the crop, which can help protect the bird against any *Salmonella* they may ingest when pecking at the litter.

Key Points

Boot Swabs: single-use covers are placed over the wearer's boots. After walking through the grow-out house, the covers are sent for lab analysis. Provides a measure of the entire house.

Drag Swabs: collection swabs are dragged on strings throughout the grow-out house and sent for lab analysis. Provides a measure of the entire house.

Litter Samples: a portion of the litter is collected and sent for lab analysis. Can only indicate contamination for the collected sample.

Cloacal Swabs: a swab is used to collect material from the cloaca of a single bird. Multiple swabs can be collected but results will only represent the birds that are tested.

Recommended Best Practices, Water

1. Provide abundant, potable water.
2. Clean water distribution systems between flocks.
3. Consider feed and water additives listed in Table 4, particularly organic acids during feed withdrawal.

Determining Flock Pathogen Status Prior to Harvest

Understanding pathogen status on farm or at grow-out, prior to collecting birds for harvest, can provide valuable information to inform establishment decision-making for slaughter and further processing. Additional information and considerations to

maximize use of on-farm sampling results can be found under the Scheduled Slaughter & Processing section.

Pathogen status of the birds in each grow-out house can be determined. This may provide more accurate information than only sampling on farms, where only a portion of houses have colonized birds. In addition, this gives establishments the option to schedule negative houses separately from positive houses, provided the birds in negative versus positive houses can be transported separately.

Several methods are available for collecting and analyzing samples from grow-out houses. Some studies suggest that boot swabs may be more sensitive than drag swabs, litter samples, or cloacal swabs; boot swabs provide establishments with a single sample site that represents conditions throughout the poultry house (Mueller-Doblies et al., 2009). Samples can be analyzed for *Salmonella*. Recent research has shown that at least 30% of broiler flocks are *Salmonella* negative, based on testing fecal samples collected on the farm prior to slaughter or cecal samples collected at slaughter (Thakur et al., 2013). Flocks and houses that are negative for *Salmonella* can be considered negative for scheduled slaughter purposes. Flocks and houses that are positive for *Salmonella* can be considered positive for scheduled slaughter purposes.

Transportation

The presence of *Salmonella* on birds at receiving at slaughter has been linked to dirty transport cages (Cory, et al., 2002; Slader, et al., 2002). Cross contamination of both birds and cages is frequently made worse when the birds are transported to the establishment.

To prevent such contamination, transport birds in clean containers (Cox & Pavic 2010). Clean, single-use paper liners can be used when transporting chicks but are not recommended for transporting young chickens to slaughter. In all cases, clean and disinfect transportation cages between each load. Minimize the number of individuals involved in removing birds from the grow-out houses. Figure 5 shows a chicken transport crate that is not washed after every load.

Figure 5

Not Recommended: Transport crate that is not washed with sufficient frequency. There is a buildup of fecal material and feathers that can contaminate subsequent flocks during transport.

Using cleaned and disinfected transport cages for each load of birds is especially important after flocks have been sampled prior to harvest. This is because contamination from dirty cages can change the pathogen status of a flock from negative to positive and reduce the effectiveness of scheduled slaughter and processing decisions.

Research suggests that a two-step process that first cleans and then disinfects the cages is effective at reducing *Salmonella*. Pre-cleaning the cages prior to immersing in hot water for 30 seconds at 60 ºC (140 ºF) or higher or immersing for 30 seconds in a solution of sodium hypochlorite at 750 ppm or higher reduces *Salmonella* on transport cages (Ramesh, et al., 2004).

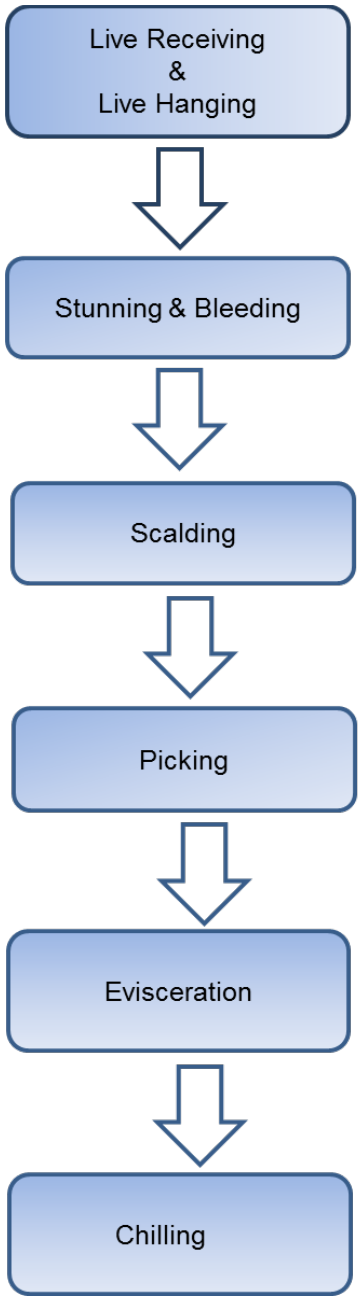
Recommended Best Practices, Transportation

1. Use clean containers and sanitize containers between loads.
2. Use new disposable paper liners when transporting chicks to the farm.
3. Minimize number of individuals involved in transport.
4. Clean and disinfect transport crates between each load.

SLAUGHTER AND PROCESSING

Slaughter

This section of the guideline provides information for establishments that slaughter poultry. The diagram below presents the steps in poultry slaughter addressed in this section.



How well an establishment conducts its slaughter dressing procedures has a direct bearing on whether the decontamination and antimicrobial intervention treatments in place in a poultry operation will have their intended effects. When contamination

overwhelms the decontamination efforts and antimicrobial intervention treatments, the establishment may need to take additional steps to reduce pathogens.

Live Receiving and Live Hanging

This is the point in the slaughter process where poultry arrive at the establishment in transport crates or cages, are unloaded, and are hung on shackles. There is a potential for contamination with enteric pathogens including *Salmonella.* The feathers, skin, crop, colon, ceca, and cloaca of birds brought to slaughter are often highly contaminated with *Salmonella* (Kotula & Pandya, 1995).

As described in the previous section, transport cages have been found to be sources of cross contamination of pathogens onto live birds transported to slaughter.

Cleaning followed by sanitation of the unloading and holding area is important. High levels of *Salmonella* found on incoming birds can overwhelm establishment interventions. These levels are carried forward to the next steps of the slaughter process. Studies show links between *Salmonella* at live receiving and later in the process (Fluckey, et al., 2003).

Key Points

The feathers, skin, crop, colon, ceca, and cloaca of birds brought to slaughter are often highly contaminated with *Salmonella.*

Transport cages are an important source of cross contamination of birds with *Salmonella*.

Employee traffic patterns and air flow can be controlled to prevent cross contamination and reduce levels of *Salmonella*. There can be positive airflow moving from inside to outside of the establishment. Standard operating procedures and training, including changing clothes and boots upon arrival, separate facilities for "dirty" versus "clean" employees, and restricting employee movement are measures that can be put in place.

Most establishments keep detailed records of suppliers and slaughter schedules by lots to monitor output or yields of products. An establishment could use these records to correlate its own in-house testing programs to determine if there are suppliers that routinely deliver birds carrying a high microbial load.

Addressing potential contamination sources with suppliers could lower the microbial level of incoming birds at receiving and thereby reduce microbial loads, particularly pathogens, in chilled carcasses.

Recommended Best Practices - Live Receiving and Hanging

1. Control airflow and traffic patterns.
2. Provide SOP and employee training.
3. Schedule flocks for slaughter based on pathogen loads.

Stunning and Bleeding

This is the point in the slaughter process where the bird is stunned, cut, and bled. Stunning methods render birds unconscious. The method of stunning may be electrical, mechanical, or chemical. Bleeding ensures death by slaughter and ensures that poultry have stopped breathing before going into the scalder (9 CFR 381.65(b)).

Stunning reduces struggling and convulsions. However, wing flapping and quivering that may happen because of the electrical stunning can transfer bacterial pathogens from the inside to the outside of the bird and to nearby birds and equipment. Continuous Gas Stunning, or Controlled Atmospheric Stunning (CAS), is an additional available stunning method that uses a combination of gases to stun the birds before they are hung on the line. Any stunning method must be monitored and controlled to ensure effectiveness. By decreasing the amount of feces expressed, establishments can reduce fecal cross-contamination on the surface of the carcasses, in the scald tank, and on the feather removal equipment. This decreases the level of *Salmonella* carried forward into the next steps. Figure 6 shows young chickens entering the stunner with minimal external fecal contamination.

Figure 6

Best practice: These young chickens show minimal fecal contamination on their feathers as they enter the stunner. These birds are calmly entering the stunner.

Recommended Best Practices – Stunning and Bleeding

1. Electrical stunning and chemical (gas) stunning are very effective stunning methods when implemented correctly.
2. Use well-timed feed withdrawal practices to reduce feces release during stunning.

Scalding

Scalding prepares carcasses for defeathering by breaking down the proteins that hold the feathers in place and opening up the feather follicles. It is the point in the slaughter process where the carcasses are placed in hot water in order to facilitate feather removal and is the first location during processing where carcasses are exposed to a common bath, which can allow *Salmonella* cells from positive carcasses to spread *Salmonella* to negative carcasses (Russell, 2012). However, scalding can reduce levels of *Salmonella* on the carcasses, since much of the dirt, litter, and feces on carcasses is removed at this step. *Salmonella* contamination consistently decreases when scalding is well controlled.

Scalder water that contains high concentrations of fecal material is a problem. Birds may come into slaughter facilities with excessive fecal material on the feathers, which gets washed off in the scalder water. Figure 7 shows an immersion scald tank with excessive fecal material contamination. *Salmonella* has been recovered from 100% of the skin and feather samples entering the scald tank in some experiments (Geornaras, et al., 1997) and has been shown to survive in the scald tank. Bacteria present in the dirty water may be massaged into the skin and open feather follicles. Also, the organic material may be retained on the surface of the bird through evisceration and end up in the chiller, deactivating the chlorine and preventing disinfection. Scalding cannot overcome high numbers of pathogens carried forward from previous steps. To reduce this problem, a bird brush and washer used prior to the scalder can remove some of the incoming dirt and fecal material.

There are two methods for scalding:

- steam-spraying
- 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-stage. Immersion is more common than steam-spraying. However, under the right conditions, both methods can reduce *Salmonella* on carcasses (Dickens, 1989).

Figure 7

Not recommended: Excessive fecal material is present in the scalder

Several considerations can mitigate contamination at the scalding steps. Water flowing into the tank ideally moves 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 stages 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 water pH is a key operational parameter to monitor. A higher, more alkaline pH (9.0 ± .2) is best for reducing *Salmonella* in the water (Humphrey & Lanning, 1987). Making the pH more acidic (3-4) is also effective at decreasing levels of *Salmonella* (Okrend, et al., 1986)). Establishments can initially monitor the pH in scald tanks as frequently as necessary to determine the pH highs and lows occurring during operation. Once establishments can maintain a desirable pH, less monitoring is needed.

Key Points

Scalding is an important step that can reduce levels of *Salmonella* on the carcasses.

Water pH is a key parameter to monitor.

Scalding can be used as an intervention if pH is properly maintained in the scald tank.

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* is more heat resistant at a neutral pH (Okrend, et al., 1986).

Understanding water characteristics is an important aspect in poultry slaughter operations. The source (well or treated surface water or municipal water), hardness, mineral content, and pH influence the killing action of any antimicrobial chemicals that are added to the water, and water hardness may affect the ability of water to wash

bacteria from the skin of carcasses during processing (Hinton & Holser, 2009). Poultry establishments using more than one water source might consider the potential effect of the water source on the chemicals used. FSIS Directive 7120.1 Safe and Suitable Ingredients used in the Production of Meat, Poultry, and Egg Products and 9 CFR 424.21 provides a lookup table of approved chemicals that can be used in scalders.

Most U.S. poultry processors prefer a hard scald to a soft scald. A hard scald is a shorter scald time at higher temperatures compared to a soft scald. This approach allows better removal of the outer layer of skin (epidermis). The correct water temperature for the appropriate amount of time is important to prepare the carcasses for feather removal. The correct water temperature 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, the meat may start to cook, and the carcasses may be marked unacceptable and rejected by inspectors for over-scald per 9 CFR 381.92. If the temperature is too low, the tank becomes a breeding ground for bacteria. *Salmonella* cannot grow at temperatures greater than 116.6 ºF (47ºC). Therefore, scalding temperatures higher than 116.6°F (47ºC) can be sufficient to control *Salmonella* growth. Table 3 shows common scalding times and temperatures for various classes of poultry.

Table 3. Common Scalding Times and Temperatures

Class of Poultry	Time /seconds	Temperature /°F	Temperature/°C
Broiler (hard scald)	30-75	138.2-147.2	59-64
Broiler (soft scald)	90-120	123.8-129.2	51-54
Turkey	50-125	138.2-145.4	59-63

Reduction of *Salmonella* during scalding generally increases with higher water temperatures (Yang et al., 2001). While scalding above 116.6 ºF (47 °C) controls *Salmonella* growth and initiates inactivation, scalding at 140 ºF (60 °C) reduced counts by an additional 0.3–0.5 log units more than scalding at 125.6 ºF (52 °C) or 132 ºF (56 °C) (Slavik et al.,1995). Yang et al. (2001) also found that scalding at 140 ºF (60 °C) resulted in reductions similar to scalding at 131 ºF (55 °C).

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). Establishments can consider this potential effect in deciding what sanitary practices they employ downstream because the high number of

pathogens not reduced during scalding can be transferred to future steps in the slaughter process.

Recommended Best Practices – Scalding

1. Have water moving counter current to carcasses.
2. Have high flow rates of water with adequate agitation to dilute dry matter and bacteria.
3. Use multi-staged tanks.
4. Maintain water pH at either above or below the optimum pH for *Salmonella* growth (6.5-7.5).
5. Use pre-scald brush systems to clean birds prior to scald tank.
6. Maintain hard scald temperatures of 140 ºF and above.

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 establishments use a continuous process. However, batch (not continuous; done at specific, defined and limited times) and manual processes are sometimes used in low-volume establishments.

Good process controls at picking are critical. Cross-contamination of the carcasses with *Salmonella* occurs during picking because of contact with contaminated rubber picking fingers and contaminated reuse water (Geornaras, et al., 1997). Fecal material is released when picking fingers agitate and rub the carcasses and can lead to cross-contamination with fecal material between the carcasses (Allen, et al., 2003). Several researchers have determined that levels of *Salmonella* increase during this step (Berrang, et al., 2011).

Regular equipment sanitation and maintenance are recommended to minimize cross-contamination when using either batch or continuous picking. Post-feather removal

rinses for carcasses is ideally maintained at 160° F. Chlorine, acetic acid, and hydrogen peroxide are types of chemical rinses used during defeathering. If birds are plucked manually, the establishment can prevent cross-contamination by keeping the picking area as clean as possible and preventing feather buildup.

Establishments can apply washes or antimicrobial interventions post-picking. However, cut surfaces of hocks must not be washed until FSIS postmortem inspection is complete (9 CFR 381.76, Post-mortem inspection). Otherwise pathological exudate could be removed or obscured and prevent detection of synovitis by inspectors.

Key Points

Good process control procedures at picking are critical and can reduce *Salmonella*.

Fecal material is released when picking fingers agitate and rub the carcasses and can lead to cross-contamination between the carcasses.

Water reuse is addressed in 9 CFR 416.2(g)(3). This regulation states that water, ice, and solutions may be reused for the same purpose if measures are taken to reduce physical, chemical, and microbiological contamination so as to prevent contamination or adulteration of product. An establishment is required to have data to support all decisions regarding reuse, including a decision that reuse will or will not cause adulteration (9 CFR 416.2(g)(2)).

Recommended Best Practices – Picking

1. Prevent feather buildup on equipment.
2. Regular cleaning and maintenance of rubber picking fingers.
3. Ensure coverage of sanitizer on picking rails and equipment.
4. Use a post picking antimicrobial intervention rinse.
5. Scientifically support any water reuse plan.

Evisceration

Evisceration is the point in the process where removal of the internal organs, and any processing defects, from the poultry carcasses occurs in preparation for chilling. Evisceration includes multiple processes. It begins at the transfer point (i.e., re-hang) and ends when the carcass enters the chiller. It is the point in the slaughter process where the removal of the viscera (including the gastrointestinal tract and edible offal such as heart, liver, and gizzard) occurs by automated or manual means, along with any trim of processing defects from the poultry carcasses in preparation for chilling. If viscera are not handled properly, or if employee hygiene practices are not followed, an increase in microbial contamination can occur. Feed withdrawal practices affect process control at this step.

Key Points

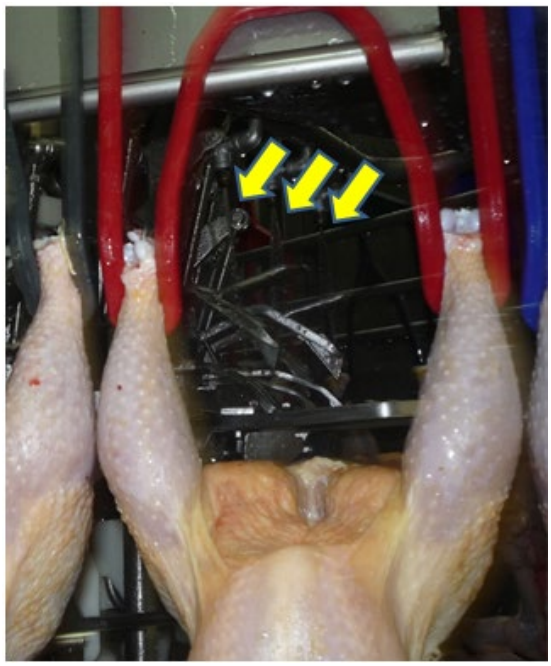
Evisceration begins at rehang and ends when the carcass enters the chiller.

Feed withdrawal practices affect process control throughout the evisceration step.

For the evisceration processes to work efficiently, carcasses need to be placed on the shackles correctly and machinery needs to be adjusted to accommodate bird size.

For the evisceration process to work well, carcasses need to be placed on the shackles correctly and monitored as they move through the system. Blades are ideally kept sharpened, and attention given to routine and thorough cleaning. Figure 8 shows an automated opener system that utilizes replaceable blades that are cleaned between each carcass.

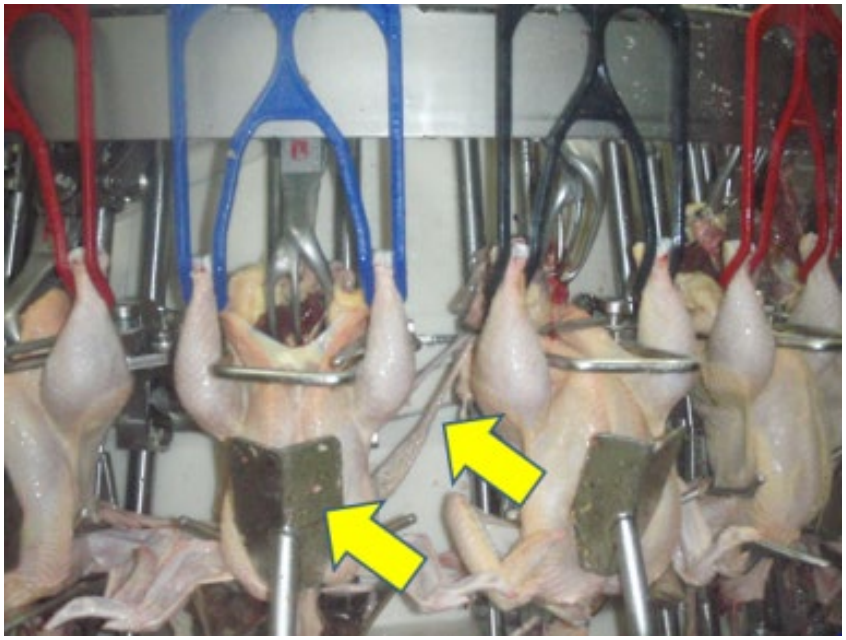
Figure 8



Best practice: Replaceable blades (middle of picture) are washed between each carcass (yellow arrows) to reduce cross contamination. Blades are replaced daily, which minimizes cross contamination as compared to blades that are replaced less often.

Keeping the equipment in good sanitary condition, free from intestinal contents and segments, is important for maintaining good process control. Figure 9 shows viscera that was caught in the machine as well as fat and tissue build up on breast plates and other surfaces that is not being sufficiently rinsed and cleaned between carcasses. These practices can lead to cross contamination.

Figure 9



Not recommended: Viscera are stuck in machine and there is product build up on breast plates and bars around wings and legs (yellow arrows).

Automated transfer (re-hang), rather than manual transfer, of carcasses between the defeathering and evisceration lines can reduce external surface cross-contamination. Equipment used throughout the evisceration process can be installed, adjustments made, and machine performance calibrated effectively to handle the size, shape, gender, feed digestion capability, and live average weights of the birds to be slaughtered. These considerations apply to manual evisceration processes as well. Figure 10 shows a manual venting gun that is rinsed with chlorinated water between each carcass.

Processing flocks with varying weight ranges can result in evisceration machinery performing poorly. Inconsistent carcass sizes (for example, because of poor bird size uniformity within a grower house or processing male and female birds together) can result in mis-cuts and fecal contamination. If machines are set for the median weight of the flock, poultry carcasses that are heavier or lighter may not be properly eviscerated. If carcasses are lighter or heavier than the machines can accommodate, the carcasses are more likely to have their gastrointestinal (GI) tracts split open, resulting in contamination of both carcasses and equipment. The machines need to be maintained

in optimum condition and be properly aligned. Failure to maintain eviscerators in optimum condition can result in damaged intestines leading to carcass contamination.

Equipment such as crop removal devices can easily become contaminated with *Salmonella,* causing carcasses to later become cross contaminated (Mead et al., 1994). Retracting the viscera from the body cavity can transfer crop and upper GI contents to the interior body cavity (Byrd et al., 2002). In some operations, at least half of carcass surfaces are contaminated with crop and upper GI contents immediately before evisceration (Byrd et al., 2002). Poultry establishments can benefit from awareness of these factors that lead to contamination and can implement necessary machinery checks to ensure that evisceration equipment is indeed functioning effectively.

Figure 10

Best practice: This manual venting gun is rinsed with chlorinated water, supplied to the gun by the red hose, between each carcass

Carcass rinses or sprays can be effective interventions for removing incidental contamination from the carcass surface during evisceration. Studies have shown that *Salmonella* prevalence on carcasses can be reduced by 50-90% following rinses (Buncic & Sofos, 2012). These rinses complement consistent sanitary dressing procedures to control pathogens. 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

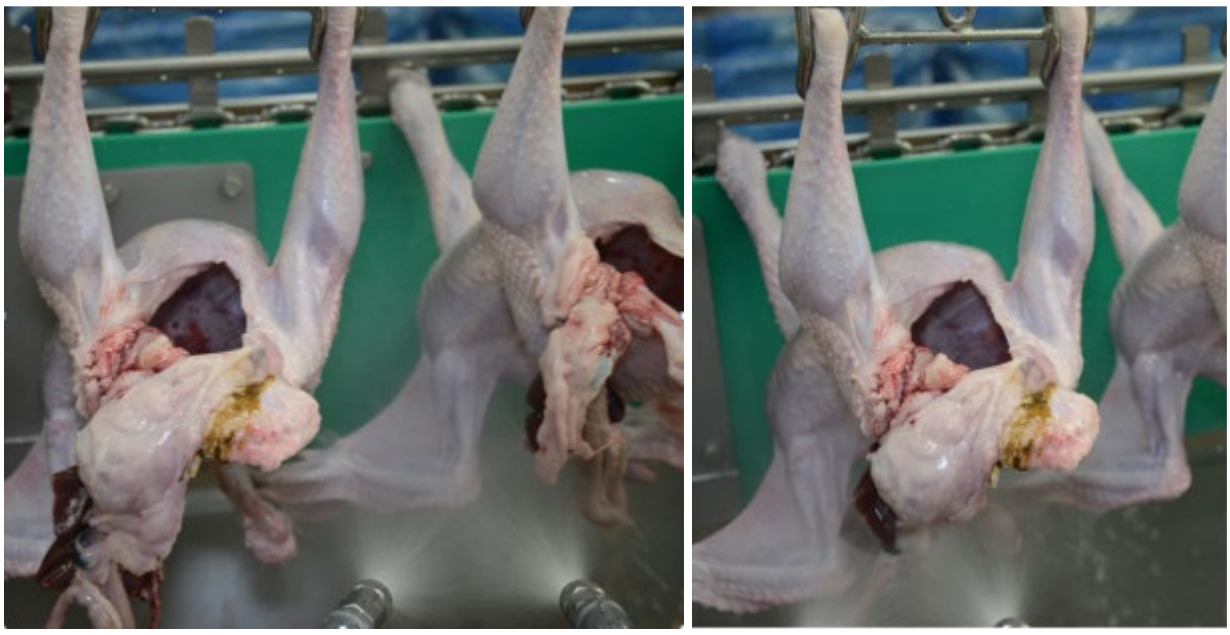
when carcass rinses are incorporated into the evisceration process (Notermans, et al., 1980). When applying water rinses and sprays, establishments can consider the water pressure applied. Some studies have found that elevated spray pressure may force bacteria into muscle or skin rather than washing it off (Buncic & Sofos, 2012).

> ***Key Point***
>
> Antimicrobial interventions are <u>not</u> a substitute for consistently implementing sanitary dressing practices

Note: This guideline uses the term "free available chlorine" when referring to parts per million (ppm) chlorine. Free available chlorine is the concentration of hypochlorous acid (HOCL) and hypochlorite ions (OCL) existing in chlorinated water. (Reference: Handbook of Chlorination and Alternative Disinfectants, Geo. Clifford White, Fourth Edition 1998. Wiley Interscience).

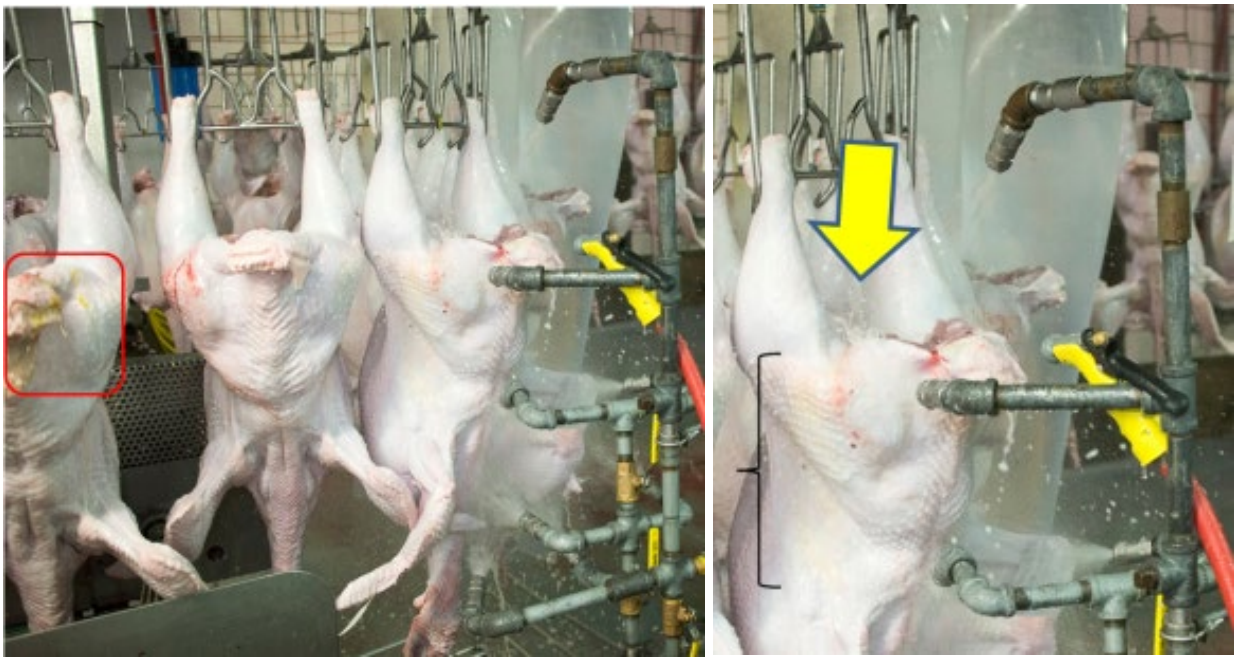
Rinses or sprays can be designed, installed, and calibrated to remove incidental contamination. When not properly designed or implemented, rinses or sprays may not effectively remove contamination and may even spread contamination from one part of the carcasses to another part or even to adjacent carcasses. Figure 11 shows a rinse that is not calibrated to wash contamination. Figure 12 shows sprays that spread contamination onto other parts of the carcass.

Figure 11



Not recommended: Rinses are not positioned to wash contamination off tail area. On the left, a contaminated carcass moves on the line toward two washes. On the right, the carcass has moved past the washes, and the contamination remains. In this situation, if the nozzles are moved up, it is likely that due to the high pressure and angle of the spray, contamination may not be washed off but instead may spread to surrounding areas of the carcass.

Figure 12



Not recommended: Overspray spreads contamination to adjacent areas of the carcass. In the closeup on the right, the middle spray bar results in splashing of water from the thigh up over the back of the thigh and onto the abdomen area (under yellow arrow), where it will run down the breast area. The contaminated vent area visible on the left (inside the red box) will not be washed off when it goes through the middle spray bar. Instead it will spread contamination to adjacent areas. This is also true of the faint yellow contamination on the outside of the thigh and bird's side (black bar of the right image).

Multiple *Salmonella* controls throughout the evisceration process are recommended. Pathogens are not effectively removed by using one carcass rinse, and a multiple hurdle approach works best against pathogens.

Some poultry processors consistently produce *Salmonella* positive carcasses, while others produce carcasses that upon testing typically do not have detectable levels of *Salmonella*. These variable test results may be the result of differences in sanitary dressing practices. Sanitary dressing practices are implemented throughout the slaughter process, in a manner that produces a clean, safe, wholesome poultry product in a sanitary manner. For example, rates of visible contamination on the carcasses after crop removal vary greatly depending on crop removal practices. In some establishments, fewer crops rupture because the crops are extracted toward the head (and downward) rather than toward the thoracic inlet (and upward) (Buhr et al., 2000). This is an important consideration for *Salmonella* control because crop tissue often contains *Salmonella* (Hargis et al., 1995).

Note that some carcasses may become incidentally contaminated with feces and ingesta even with strict sanitary dressing practices. However, fecal contamination can be minimized with strict sanitary dressing practices.

Recommended Best Practices – Evisceration

1. Adjust and maintain equipment regularly as needed to accommodate bird size.
2. Implement an antimicrobial rinse to reduce equipment contamination.
3. Implement multiple hurdles to reduce pathogens.

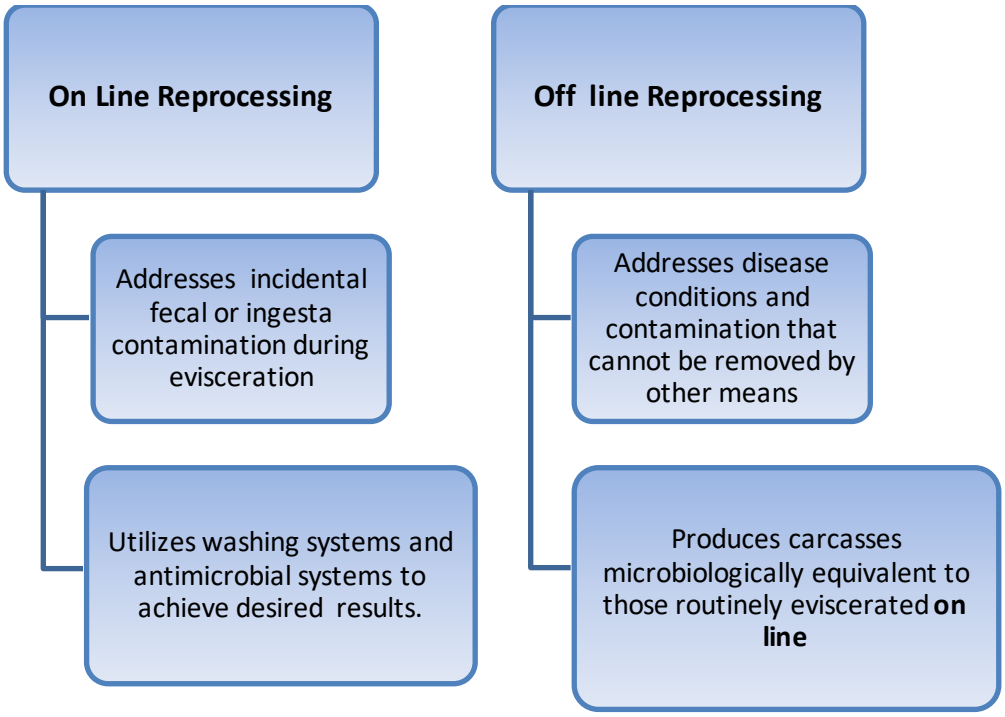
Chilling

This is the point where eviscerated carcasses are chilled in order to inhibit microbial growth and meet the regulatory requirements of 9 CFR 381.66(b)(3). Additional information on chilling requirements can be found in the FSIS compliance guide Modernization of Poultry Slaughter Inspection: Chilling Requirements.

Antimicrobial Intervention Use for On-line and Offline Reprocessing and for Chilling Procedures

Reprocessing systems are used to control *Salmonella* on visibly contaminated carcasses. Both on-line (OLR) and off-line (OFLR) reprocessing systems can be used to remove incidental contamination during evisceration. On-line reprocessing is not a "remedy" or a substitute for poor sanitary dressing practices during evisceration. The on-line reprocessing system may be able to remove visible contamination, but the invisible contamination can remain if the intervention is overwhelmed.

NOTE: Carcasses must be free of visible fecal contamination prior to entering the chilling system as required by 9 CFR 381.65(f).



FSIS has posted lists of the approved OLR and OFLR systems. The lists are regularly updated and attached to FSIS Directive 7120.1, Safe and Suitable Ingredients Used in The Production of Meat, Poultry, and Egg Products.

If an establishment desires to use an OLR or OFLR system that has not been approved by FSIS's Risk Management and Innovations Staff (RMIS) or wishes to modify an approved OLR or OFLR system, the establishment is responsible for submitting a protocol requesting permission to conduct an in-plant trial. Per the Memorandum of Understanding (MOU) between FDA and FSIS, FSIS would consult with FDA regarding safety of the proposed chemical. FSIS would review the protocol for any prohibitions that can potentially affect product safety, safety of inspection personnel, interfere with inspection procedures, or require a change to the Agency's regulations. If the in-plant trial is granted, FSIS would issue a letter granting permission to conduct an in-plant trial. More information regarding in-plant trials can be found in the FSIS Compliance Guideline Procedures for New Technology Notifications and Protocols.

An establishment that uses chlorine or other antimicrobials as a part of its sanitary dressing and process control procedures or employs a pre-chill carcass wash that may affect the pH of the chiller water should consider the effect of pH on the efficacy of any antimicrobials used in the chiller.

Further Processing

This section of the guideline provides information for establishments that further process raw poultry carcasses to produce products such as:

- Poultry parts
- Injected, mechanically tenderized, or vacuum tumbled poultry products
- Comminuted (including ground) poultry products (includes products such as patties and sausages that are made using comminuted poultry)
- Stuffed chicken products

> ***Key Point***
>
> Comminuted products are those that are ground, mechanically separated, or hand- or mechanically-deboned and further chopped, flaked, minced or otherwise processed to reduce particle size.

Raw Source Material Considerations and the HACCP System

There are two different sources for raw materials used in further processing: 1) in-house source materials (e.g., source materials from an establishment's own slaughter operation) and 2) incoming source materials from one or more supplying establishments. An establishment's knowledge of the production of source materials from its own slaughter operation is different than the knowledge of the production of purchased or otherwise incoming product because it will have more information about product derived from its own slaughter operations.

Whether the source of raw materials used in further processing is another establishment, an establishment's own slaughter operations, or both, an establishment can consider how the source materials it uses in its processes can affect food safety decisions. A prudent establishment would incorporate this knowledge into its hazard analysis decisions to inform development of its HACCP system, including developing Sanitation SOPs and other prerequisite programs, and CCPs in the HACCP plan.

Along these lines, if an establishment produces a raw or otherwise Not-Ready-To-Eat (NRTE) chicken product from parts received from other establishments, it can consider using only parts that are at or below a specific *Salmonella* percent positive as the source material for making this product. The receiving establishment may also specify maximum levels for contamination (enumeration). In this scenario, considering the carcass category of the supplying establishment (e.g., only accepting parts from FSIS Salmonella Performance Standards carcass category 1 establishments) would not be as useful because parts and not carcasses are the immediate source materials. FSIS sampling of the industry indicates that pathogen prevalence increases as products are further processed from carcasses, to parts, to comminuted product. It is unclear what benefit requirements for carcasses would provide when the incoming source materials used to produce the finished products are not carcasses. Category 1 carcasses may go on to further processing within an establishment and be cross-contaminated or

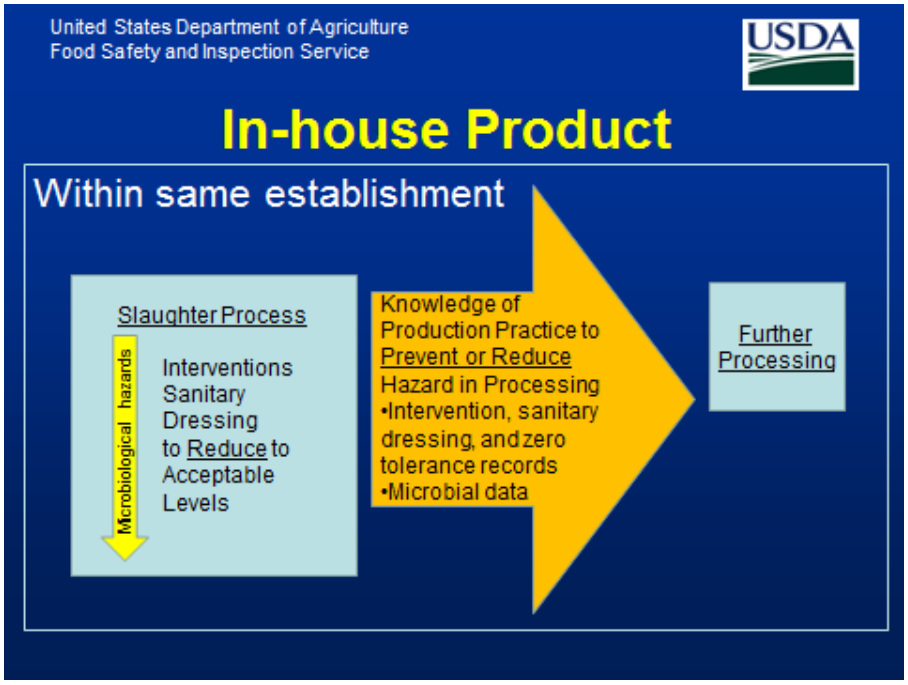
otherwise processed to result in a higher level of pathogens on chicken parts (or comminuted) than the carcass results would suggest.

In-House Source materials

Slaughter establishments that further process carcasses they produce are self-suppliers (they produce in-house source materials). For in-house source materials, the establishment has direct knowledge regarding the source materials' production, including pre-harvest information, sanitary dressing procedures, zero tolerance findings, antimicrobial treatments and records of critical operating parameters, and any microbial testing data. The establishment also has direct control of its processes and can monitor, verify, and correct its own processes more quickly than for product received from outside suppliers. It can verify that sanitary dressing and any interventions are being applied consistently as designed; it can implement corrective actions when it identifies that sanitary dressing procedures and any interventions have not been applied as designed; and it can identify and correct underlying problems that result in any repeated sanitary dressing or intervention failures.

Figure 13 below shows the direct knowledge the slaughter establishment has concerning the production of in-house source materials during the slaughter process.

Figure 13



If an establishment identifies problems in its own slaughter operations, for example, that sanitary dressing was not consistently implemented, it can consider how this problem may impact food safety decision-making during further processing. Similarly, if an establishment identifies problems during further processing, for example, that ground

poultry sampling identified that a lot exceeded acceptable pathogen levels, the establishment can identify whether factors at slaughter may have contributed to the problem.

Incoming Source Materials from Supplying Establishments

Establishments have less knowledge available about and control over source materials that are produced at other supplying establishments. However, there are a number of actions that establishments receiving raw poultry for further processing can take to limit *Salmonella* in their incoming source materials. All establishments receiving raw poultry from supplying slaughter establishments can require the supplier to follow good sanitary dressing procedures to prevent contamination of poultry during slaughter. In addition, establishments can consider requiring that incoming raw materials be treated with interventions shown to reduce *Salmonella*. Establishments could also require that suppliers test source materials for pathogens of concern and have a plan for how to use test results in their decision-making.

> ***Key Point***
>
> As part of the entire HACCP system, food safety decisions made at slaughter impact further processing, regardless of where further processing occurs.

Establishments receiving source materials from outside suppliers can consider implementing the above requirements as purchase specifications and incorporating such specifications in their HACCP plans, Sanitation SOPs, or other prerequisite programs. If establishments producing raw poultry products require their suppliers (both within and outside their corporate structure) to meet purchase specifications, they can also ensure that their suppliers actually meet these purchase specifications. They may accomplish this in several ways, by requiring, for example:

- a document (e.g., letter of guarantee (LOG)) from each supplier that provides assurance that the supplier employs CCPs or other control points that address *Salmonella* and that describes the CCP, the monitoring of the CCP, and the use of any interventions; and
- certificates of analysis (COAs) (i.e., actual test results) and the sampling method used by the supplier of the source material.

A further processing establishment receiving source materials can maintain records (e.g., its own testing results, ongoing communication with suppliers, or third-party audits) that verify on an on-going basis that the supplier is executing its program in a consistent and effective manner. Ongoing verification ensures that the receiving establishment consistently receives product in which *Salmonella* is prevented or controlled to acceptable levels.

Establishments that receive source materials from outside suppliers can still consider applying validated interventions during further processing. Approved interventions are listed in the FSIS Directive 7120.1 lookup table along with any required parameters for each entry. Such establishments can also consider carrying out their own testing of

incoming source materials. As described in the Sampling and Testing section, testing can measure the pathogen load of incoming source material so that establishments can ensure that their processes are not overwhelmed by the incoming pathogen load. In addition, they can consider testing finished products to verify their systems reduce pathogens to acceptable levels.

An establishment may be able to obtain detailed information concerning the purchased/incoming source material on a lot-by-lot basis (preferably, lots are defined as being microbiologically independent) from its supplier. In this situation, the receiving establishment may be able to support that *Salmonella* is NRLTO at receiving based on the implementation of a prerequisite program (e.g., purchase specifications) that prevents the potential hazard from becoming RLTO. Such establishments that address pathogens in this manner can do the following:

- have a written program that describes the purchase specifications that it will implement to show that pathogens are NRLTO at receiving;

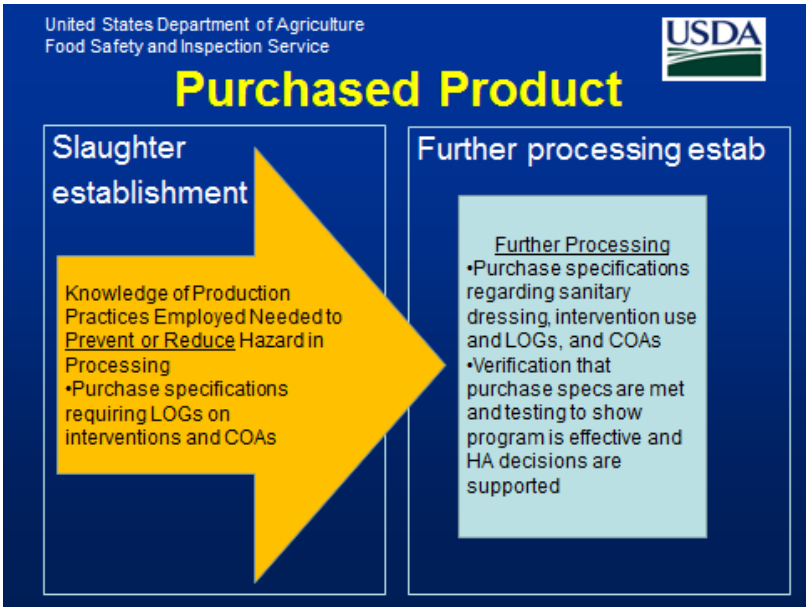
- require information (for example, through letters of guarantee) on the supplying establishment's interventions that provide assurance that the supplier uses interventions that address pathogens, such as *Salmonella*;

- obtain certificates of analysis (COA) affirming that source materials have been tested (with results available at purchase). If a receiving establishment is unable to obtain COAs, the establishment can obtain other evidence that each shipment or lot of purchased/incoming source materials was tested. In these situations, establishments can:

    - be aware of the sampling and testing method the supplier uses, and
    - be aware of the supplying company's information concerning the specific product codes that were sampled and tested.

Figure 14 below shows the knowledge of the source materials' production that the receiving establishment is able to obtain by having a relationship with its suppliers.

Figure 14



It is possible that a receiving establishment is not able to obtain detailed information concerning the purchased product's production on a lot-by-lot basis from its supplier. When a receiving establishment is only able to obtain general information concerning the production of purchased/incoming source materials, the establishment must take other measures to support its hazard analysis decision-making (9 CFR 417.5(a)(1)) at receiving in order to justify the conclusion that pathogens are NRLTO. These measures may include, but are not limited to, the following options:

1. The receiving establishment may determine that pathogens such as *Salmonella* are RLTO on incoming source materials and apply an antimicrobial treatment as a part of their HACCP system.
2. The receiving establishment may be able to support that *Salmonella* are NRLTO in incoming source materials at receiving based on the implementation of a prerequisite program (e.g., antimicrobial treatment preventive measures on incoming raw materials) that prevents the potential hazard from becoming RLTO during its process, including rigorous recordkeeping documentation. For this situation, establishments can do the following:
    - have a written program that describes the antimicrobial treatment preventive measures that it will implement to show that *Salmonella* are NRLTO at receiving;
    - maintain supporting documentation for the program;

- maintain records that demonstrate that the program is being implemented as written (i.e., verification records of the critical operating parameters);
- maintain records that provide on-going evidence that the program effectively reduces pathogens to acceptable levels (e.g., its own verification testing) to support its decision that pathogens such as *Salmonella* are NRLTO at receiving; and
- describe actions that the establishment will take when it fails to implement the program, or when it otherwise finds that the program has failed to prevent the hazard.

Note that for option 2, if establishments determine that *Salmonella* are hazards NRLTO because of prerequisite programs, they are required to have records associated with their Sanitation SOP or other prerequisite programs that show these programs are preventing a food safety hazard from being RLTO as part of their HACCP decision making documents. When prerequisite programs are not effectively designed or consistently implemented, the hazard analysis is not supported, and FSIS would consider the hazard to be reasonably likely to occur. In this case, establishments must then take corrective actions (including reassessment) as set forth in 9 CFR 417.3(b).

3. The receiving establishment may be able to support that pathogens including *Salmonella* are NRLTO in the purchased source materials at receiving based on the implementation of its own verification testing measures in conjunction with purchase specifications that require information on the supplying establishment's interventions that provide assurance that the supplier employs CCPs that address pathogens such as *Salmonella*.

Sanitation and Reducing Cross-Contamination

Poultry carcasses processed as parts or used to make ground products have a higher incidence of pathogens because of possible cross contamination between positive and negative parts and carcasses during further processing. The sanitation considerations discussed in the Sanitation section also apply to further processing operations. This section discusses factors that establishments producing parts or comminuted poultry can consider to maintain sanitation and minimize cross-contamination during further processing.

> ***Key Point***
>
> *Salmonella* can be found inside feather follicles in the skin. When skin is cut, these pathogens can be exposed and spread during processing to previously uncontaminated product.

Opportunities for cross-contamination during further processing exist in various situations. One situation is when products are commingled (for example, parts are collected in combo bins for further processing). Another situation when pathogen spread and cross-contamination may occur is during parts cut-up or during the grinding (or other comminuting) process, specifically when skin is cut, ground, or otherwise

broken. *Salmonella* can be found in feather follicles in the skin (Kim et al 1996; Wu et al., 2014). These areas may not be accessible until they are disturbed, for example during cut-up or grinding, when these processes can result in exposure of and spread of pathogens. National prevalence data from FSIS's Chicken Parts Baseline sampling indicate that skin-on parts were more likely to be positive for *Salmonella* than parts without skin (FSIS, 2014).

Opportunities for cross-contamination also occur following the heat treatment step during production of raw but heat-treated poultry (for example, NRTE breaded, stuffed poultry products). For these products, it is essential that the finished product be processed in a manner to reduce the frequency and level of contamination before packaging at the establishment (e.g., by controlling cross-contamination between the time when products emerge from the hot oil or other batter-setting process until they are in final packaging). Approaches may include aseptic handling (gloves, sterile implements), designated clean spaces or containment to prevent exposure to contamination after the heat treatment. Handling of these types of products by the consumer may contribute to cross contamination in the home.

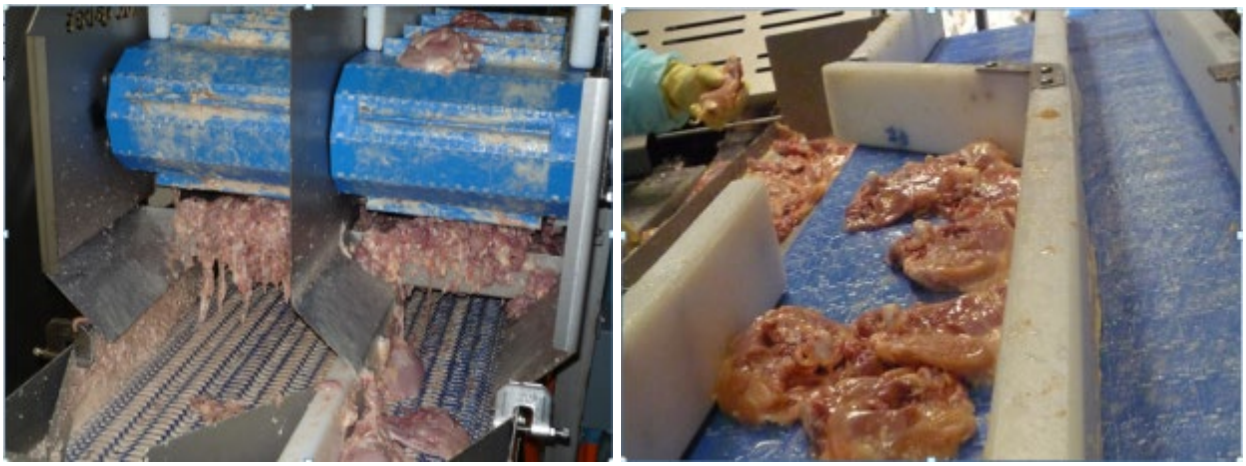
Cross contamination can also occur anytime that raw poultry products are produced in one part of an establishment and further processed in another part. How product containers are handled within an establishment can increase cross contamination. Figure 15 shows tub containers used to hold poultry parts for further processing. The tubs were stored on dirty pallets, and employees touched the bottoms of the tubs when they emptied their contents into a hopper before using their gloved hands to push the contents into the hopper. Not only does this practice result in cross contamination, it is also an example of an insanitary practice.

Figure 15

Not recommended: Plastic tubs used to hold raw poultry parts are stacked on wooden pallets, which are moved to another area in the establishment for further processing. Establishment employees picked up the tubs and frequently touched the bottoms of the tubs when emptying them into the hopper. Then, without first sanitizing their gloves, employees pushed the parts into the hopper. This is an example of both cross contamination and not maintaining operational sanitation.

Product contact surfaces such as belts, augers, paddles, knives, hooks, and other implements can be regularly cleaned and sanitized to reduce cross contamination during operations. Figures 16a and 16b show that sanitary conditions during further processing are not being maintained due to buildup of organic material.

Figure 16a



Not recommended: Sanitary operation is not being maintained. There is significant buildup of fat and other organic material on the belts. This presents an increased risk of cross contamination.

Figure 16b

Not recommended: Sanitary operation is not being maintained. There is a significant buildup of fat and other organic material on the conveyors, blades, and associated product contact surfaces. This presents an increased risk of cross contamination.

Establishments can keep in mind that the finished poultry products they produce that go for further processing at other establishments may be used to produce non-intact products such as those that are injected, tenderized, or vacuum tumbled. Finished

poultry products may also be used as source materials for comminuted products, such as ground, mechanically separated, or similarly processed products, including patties and sausages. Because processes used to manufacture such products may increase the risk of cross-contamination and pathogen spread, establishments producing poultry parts for further processing can minimize opportunities for cross-contamination and consider whether the use of additional interventions for such products may prevent or reduce pathogens to acceptable levels.

Establishments can also consider how their lotting practices can be designed to minimize cross-contamination. Achieving microbiological independence between lots can also limit product that may be implicated in a recall associated with an outbreak.

Recommended Best Practices, Sanitation and Reducing Cross Contamination

1. Clean product contact surfaces, including knives, as often as required to maintain sanitation during operations.
2. Knives and other tools can be sanitized between each carcass.
3. Consider using an antimicrobial intervention on parts.

Additional considerations for Non-intact parts and products (mechanically tenderized, injected, or vacuum tumbled)

Mechanical tenderization, such as needle and blade tenderization, injection with solutions, and vacuum tumbling are methods that some establishments use to tenderize products, add flavor, or add ingredients to raw poultry parts and carcasses. However, these processes can contribute to cross-contamination with pathogens. Any contamination on the outside of carcasses or parts may be carried to the inside through penetration by needles and other devices. Reusing injection solutions, such as brines or marinades, also presents risk for contamination of the solution by pathogens. A prime example of this mechanism of internalizing pathogens is an outbreak of *Escherichia coli* O157:H7 in beef steaks that occurred in 2007 (FSIS, 2007).

Contamination can also occur through introduction of contaminated liquid that is injected or forced into the muscle by injecting or vacuum tumbling. Contamination may be increased the longer solutions are reused and the greater the volume of product treated.

Establishments should consider the effects of injected solutions in its hazard analysis (9 CFR 417.2(a)) and

Key Points

Blades and needles can push outside contamination into the interior of muscle.

Injection solution picks up bacteria from contaminated product.

Reused injection solution can push high levels of bacteria into the interior of muscle.

The longer injection solution is reused, the greater the contamination.

support all decisions made in the hazard analysis, 9 CFR 417.5(a)(1). Establishments that choose to tenderize, inject, or vacuum tumble raw poultry should consider the following factors:

Operational sanitation should be maintained during the process, including evaluating the frequency that needles need to be replaced to minimize product residue buildup on the inside of the needle, which can be very difficult to remove.

Establishments should consider the microbiological impact of introducing pathogens mechanically (through needles and blades) and by reusing a solution. Any solution reuse should be addressed in the HACCP plan or in the Sanitation SOP or another prerequisite program. Risk from microbial pathogens introduced during non-intact processes may be reduced in several ways:

- by limiting this process to products that will undergo a lethality treatment at another federally inspected establishment
- applying antimicrobial interventions to product just prior to treatment with needles or blades
- limiting the time that solution is reused and maintaining a solution temperature of less than or equal to 40 °F (4.4 °C) to prevent pathogen outgrowth
- treating reused solution with interventions to minimize or eliminate pathogens. Ultraviolet (UV) light treatment (Beers et al., 2010) can reduce pathogens in recirculated brine.

Establishments can also consider how any solution reuse affects the establishment's lot designation.

Recommended Best Practices, Sanitation During Production of Non-Intact Products

1. Consider applying antimicrobial interventions to products prior to tenderizing or injecting.
2. Do not reuse injection needles if product residue cannot be removed.
3. Limit reusing injection solution to poultry that will receive a lethality treatment.
4. Establishments that choose to reuse injection solution can consider adding antimicrobial processing aids to the solution and can limit the time it is reused prior to sanitizing the injection system.

Additional considerations for comminuted products

Producers of comminuted poultry products can also consider that because of the fine texture of these products, meat and protein residues of these products may extend into very small or unexpected food contact surfaces in grinding and other equipment. In addition to the factors already discussed, establishments that make comminuted poultry products can consider the information in this section with regard to minimizing microbial pathogens and creating and maintaining sanitary conditions.

Surfaces of processing equipment, including grinders, blenders, pipes, and other components and surfaces in contact with the product require focused attention to ensure adequacy of sanitation procedures. These surfaces may include hoppers, augers, blades, grates, product blenders, and patty makers. Establishments can consider parts of equipment that can harbor bacteria, such as rubber gaskets and similar pieces that may be difficult to reach and sanitize and ensure that they are sanitized when other surfaces are.

> ***Key Point***
>
> Contaminated source materials going into a grinder, mechanical separator, or other comminuted poultry equipment can result in contamination of all product until the next cleaning and sanitizing is performed.

The fine texture of comminuted product and the processes used to make them create a situation where one contaminated component can spread contamination into multiple batches of product. Systematic sanitizing of belts and other implements can break the chain of any contamination that slips through. Rather than the contaminant being spread across lots, it will be stopped or at least diminished.

Different source materials used to produce comminuted products can present different risks of pathogen contamination. Establishments can consider the information below when making processing decisions for comminuted products.

Source Materials Can Affect Pathogen Status of Comminuted Product

Certain poultry parts may be more likely to be contaminated with pathogens and are therefore riskier to use as source materials to produce comminuted poultry products. The FSIS Chicken Parts Baseline study (FSIS, 2013) found that chicken necks were significantly more likely to be contaminated with *Salmonella* (55%) than other parts, including breasts, legs, and wings (between 20-44%). Establishments can consider not using chicken necks in comminuted poultry products or only using them in comminuted products that are intended for a lethality treatment.

Similarly, skin-on and bone-in source materials used in comminuted chicken products present increased risk of contamination with *Salmonella*. As previously discussed, skin can contain *Salmonella* in feather follicles that can be exposed during the grinding or other comminuting process and spread throughout a lot. Chicken neck skin has

typically been found to be more contaminated than other parts of the carcass. Research by Wu et al. (2014) concluded that neck skin included in ground chicken presents a significant risk for the introduction of pathogens. Table 4 shows that ground and other raw comminuted chicken products (such as sausages and patties) sampled by FSIS that were produced using either bone-in or skin-on source materials were more likely to be contaminated with *Salmonella*[4] than those fabricated from deboned, skinless source materials. Table 5 shows the risk for use of bone-in source materials for comminuted turkey products.

Table 4. FSIS exploratory sampling testing results, raw comminuted chicken by source material composition (6/1/13-6/30/15, 2,688 samples)

Comminuted Chicken Products	*Salmonella* prevalence in this source material	*Salmonella* presence risk relative to the lowest prevalence source material (Deboned & skinless)[5]
Mechanically separated	83.4%	2.4-fold increase
Ground and Other Comminuted Chicken Products	*Salmonella* prevalence in this source material	*Salmonella* presence risk relative to the lowest prevalence source material (Deboned & skinless)
Bone-in & Skin-on	56.0%	1.6
Bone-in & Skinless	58.4%	1.7
Deboned & Skin-on	54.8%	1.6
Deboned & Skinless	34.8%	N/A

The interior of poultry bones can contain pathogens as well. In a recent study, 0.8% of chicken bones sampled were positive for *Salmonella* (Wu et al., 2014). In a different study, 5.2% of turkey bones sampled were positive for *Salmonella* (Cui et al., 2014). Although these may appear to be low percentages, again because of the nature of comminuted processes, contamination can spread throughout an entire batch or lot from a few contaminated bones through cross contamination. FSIS sampling data indicate that both chicken and turkey raw comminuted products produced using bone-in source materials are more likely to be contaminated with *Salmonella* than those

[4] FSIS Not Ready-to-Eat Comminuted Poultry Exploratory Sampling Project results from samples collected June 1, 2013 through June 30, 2015.
[5] For bone-in and skin-on source materials, *Salmonella* prevalence in comminuted chicken was 56.0%. The lowest prevalence product, made from deboned and skinless source materials, was 34.8%. To calculate the relative risk, each source material type was divided by the lowest risk product: 56.0/34.8 = 1.6.

produced using deboned source materials. Table 4 shows this for comminuted chicken products, and Table 5 shows this for comminuted turkey products.

Tables 4 and 5 indicate pathogen prevalence for comminuted products based on whether source material contained bone (chicken and turkey) or skin (chicken only). Analysis of FSIS comminuted poultry sampling results shows that it is more likely that comminuted chicken will be positive for *Salmonella* when its source materials contain bone, skin, or both bone and skin (58.4, 54.8, and 56.0%, respectively). Comminuted chicken made from deboned and skinless source materials had the lowest prevalence for both pathogens (34.8%). The tables also indicate how much more likely products made from different source materials are to contain pathogens, as compared to the product with lowest prevalence (products made from deboned and skinless source materials). Raw comminuted chicken products made from bone-in and skin-on source materials were 1.6-1.7 times more likely to be positive for *Salmonella* compared to those made from deboned and skinless source materials.[4]

Mechanically separated poultry product nearly always contains skin and bones in their source materials, because of the nature of the processing of this product. FSIS sampling results indicate for comminuted chicken, *Salmonella* prevalence was highest for mechanically separated poultry. For this reason, establishments can consider not using mechanically separated poultry as a component in NRTE comminuted products, or only using it in comminuted products that are intended for a lethality treatment.

Table 5. FSIS exploratory sampling testing results, raw comminuted turkey by source material composition (6/1/13-6/30/15, 934 samples)

Comminuted Turkey Products	*Salmonella* prevalence in this source material	*Salmonella* presence risk relative to the lowest prevalence source material (Deboned)
Mechanically separated	52.4%	1.4-fold increase
Ground and Other Comminuted Turkey Products	*Salmonella* prevalence in this source material	*Salmonella* presence risk relative to the lowest prevalence source material (Deboned)
Bone-in	56.8%	1.5
Deboned	37.7%	N/A

It is important to keep in mind that the data in Tables 4 and 5 represents FSIS data from all establishments sampled in the exploratory program, without consideration of the amount of skin or bone going into comminuted processes. Each individual

establishment can determine the extent that skin-on and bone-in source materials may contribute to pathogens in finished product. This determination can be made by sampling and testing comminuted products made from different source materials.

Establishments that do not test products by source material can consider the information provided in the tables during decision-making in their processes. Using the information in the prevalence column of the tables, establishments can compare the relative risk of using different types of source materials. For example, in the absence of its own sampling results, an establishment can compare using bone-in and skin-on source materials (56.0% *Salmonella* prevalence) with using deboned and skinless source materials (34.8%) to determine that the relative risk is 1.61 (56/34.8). This means there is about a one and a half times greater chance that the bone-in, skin-on source material will result in *Salmonella* being present in the finished product. Therefore, there is likely a benefit to using the deboned skinless source materials instead of the bone-in, skin-on source materials.

Interventions

Unless otherwise stated, interventions (antimicrobial processing aids) described in this section have been reviewed for safety and suitability and are listed in FSIS Directive 7120.1. Establishments, intervention manufacturers, and other users that would like to implement interventions not listed in FSIS Directive 7120.1 would need to submit for review a protocol to FSIS describing the proposed function of the substance in the specific poultry or meat product and conditions of use, as described in the Intervention Use section.

Establishments may consider using interventions during further processing to decrease pathogens. Antimicrobial interventions may be applied to source materials prior to further processing, to parts, during grinding or other comminuting process, and during blending of ground or comminuted products. Establishments should consider all applicable labeling requirements when choosing an antimicrobial, in particular when adding aqueous solutions to products with a standard of identity that does not allow added water (e.g., “ground chicken”; 9 CFR 319.15(a)). High pressure pasteurization (HPP) is another intervention that may be applied to raw comminuted product. Although applying interventions to source materials used in comminuted products can reduce pathogens in finished product, contamination may still occur during the process itself when skin or bones are broken, releasing bacteria that were not exposed to the antimicrobial application. Establishments can consider these factors when evaluating their use of interventions.

Establishments can evaluate the adequacy of any *Salmonella* interventions they apply to parts during further processing, including those source materials that are specifically intended for non-intact use (such as grinding or other comminuted processes). Part of the evaluation can include consideration of variability of *Salmonella* levels on source materials. The same considerations discussed in the general Interventions section apply to selecting and applying interventions during further processing. Those

considerations also apply to parts that are sent to other establishments for any kind of further processing because they may be used as source materials in comminuted or otherwise non-intact raw product.

Interventions to control *Salmonella* can be applied by spraying or dipping (immersion). Generally, immersion is more effective than spraying because it ensures better coverage and longer contact time (Buncic & Sofos, 2012; McKee, 2014). Loretz et al. (2010) reported that acetic acid (20 ppm at 4°C) resulted in a *Salmonella* log reduction (log CFU) of 1.4 when applied as a dip (immersion), compared to a log reduction of 0.8 when applied as a spray. A potential challenge with immersion is maintaining the proper level of active chemical as it becomes absorbed and neutralized by organic material such as fat and protein. Another challenge with immersion is maintaining the active concentration of the intervention despite the natural decomposition of the compound as a result of chemical reactions, heat, or light. It is important to verify with sufficient frequency that the critical operational parameters of an antimicrobial dip are maintained. It may be necessary to either add more chemical or even to completely change the solution to maintain effectiveness. Figure 17 shows an antimicrobial dip being applied to boneless, skinless poultry parts prior to grinding.

Figure 17

Best practice: Boneless, skinless poultry parts receive an antimicrobial dip prior to being ground.

The following pages present information on some antimicrobial interventions that may be used during further processing and which have been studied to control pathogens during further processing. This information is summarized in the attachment to this guideline.

Establishments need to adhere to the limits in the conditions of use for chemicals as described in FSIS Directive 7120.1 and 9 CFR 424.21. In addition, the establishment

needs to determine the optimum concentration for its process based on the critical operational parameters in its scientific support documentation. Any ranges for pH, concentration, or other parameters included in this section are provided to give a general indication of these values, but they do not represent critical operational parameters.

Recommended Best Practices, Interventions during Further Processing

1. Applying antimicrobial interventions during further processing can be part of an effective multiple hurdle approach to reducing pathogens.
2. Dipping is generally a better application method than spraying as it ensures full coverage of an intervention for a longer period of time.

Inorganic and Organic Chlorine-based Treatments

Chlorine is relatively inexpensive, has a broad spectrum of activity, and is quick acting. Its drawbacks include corrosiveness to processing equipment at low pH, loss of effectiveness at higher pH values, loss of effectiveness with increasing organic matter load, and longer contact time required as compared to some other antimicrobial interventions. Commonly used chlorine compounds include liquid chlorine, hypochlorites, inorganic chloramines, and organic chloramines. Chlorine is typically used at pH 6.0 – 7.5. A number of chlorine entries for use with poultry are in the FSIS Directive 7120.1 lookup table along with their acceptable uses.

Chlorine added to water produces free available chlorine in the forms of hypochlorous acid and hypochlorite ions. Hypochlorous acid is the form most lethal to microorganisms.

Acidified sodium chlorite

Acidified sodium chlorite (ASC) is a type of chlorine compound that is a strong oxidizer. It enters bacterial cells and weakens or kills them by lowering the pH inside. ASC is safe and suitable for use on poultry carcasses and parts at concentrations of 500-1200 ppm, as indicated in FSIS Directive 7120.1. It is used at pH 2.3-2.7 and acidified with an organic acid, such as lactic acid, citric acid, or acetic acid. A benefit of ASC is that it is not as highly affected by the presence of organic material as chlorine. Mehyar et al. (2005) reported a 1.1 log reduction in *Salmonella* on inoculated drumsticks when treated with ASC.

Trisodium Phosphate

Trisodium phosphate (TSP) is an inorganic, non-chlorine-containing compound with a high pH. Its pH is 11-13 and is used at concentrations of 8-12%. A benefit of high pH is that it gives TSP detergent-like activity, which can improve effectiveness against microorganisms. The main disadvantage of using TSP is disposal, as the high discharge of phosphate into the sewer may be a violation of local, state, or federal Environmental Protection Agency sewer discharge regulations.

Quaternary Ammonium Compounds

Quaternary ammonium compounds (QAC) are a group of positively charged organic compounds that may have detergent-like properties (Schmidt, 2012). Most have a high pH (pH 6-10), are used at concentrations ≤1%, and are effective in killing a wide variety of microbes. Cetylpyridinium chloride (CPC) is an example of a QAC. CPC is an odorless, colorless, stable compound that does not self-decompose and is not affected by organic material. QACs persist in solution for a relatively long time. QACs are not compatible with soaps, anionic detergents, or low pH solutions. CPC must be rinsed off poultry after use with water containing no more than 50 ppm chlorine. The major disadvantage of QAC is that some may be less effective in hard water that contains >500 mg/L hardness (Miller, 2012).

Organic Acids and Organic Oxidizers

Organic acids and organic oxidizers used at the proper pH are effective in being able to enter bacteria to inhibit or kill them from the inside. Peroxyacetic acid (PAA) is an organic oxidizer. It has been studied on poultry parts to control pathogens. PAA is a mixture of the peroxy compound, hydrogen peroxide, and acetic acid. It is a versatile compound, as different formulations are available that may be used over a wide temperature range (0 to 40°C) and wide pH range (3 to 7.5). PAA is affected by protein or other organic materials to a lesser degree than chlorine is (Bauermeister et al., 2008).

Studies comparing chemical interventions

In one study, Del Rio (2007) evaluated acidified sodium chlorite (ASC), trisodium phosphate (TSP), citric acid, and peroxyacids (PAA) against *Salmonella* on chicken legs. The concentrations used were: ASC 1200 ppm with citric acid added until pH 2.7 was reached (final pH 2.70); TSP 12% (final pH 13.03); and peroxyacids 200 ppm (Inspexx 100, Ecolab, St. Paul, MN; final pH 3.75). The temperature of the disinfection solution at use was 18°C. Chicken legs containing approximately 9 log CFU/ml *Salmonella* were dipped in the disinfection solutions for 15 minutes and drained at 20°C for 15 minutes. The number of bacteria killed was then measured. All treatments

resulted in *Salmonella* reduction, with ASC and TSP having greater effectiveness than PAA (log reduction of 2.05, 1.86, and 0.93, respectively).

In another study (Chen et al., 2014), researchers treated *Salmonella* inoculated chicken parts (bone-in and skin-on) with chlorine, PAA, and cetylpyridinium chloride (CPC) at various concentrations in a chilled immersion system for 25 sec. PAA and CPC significantly reduced *Salmonella* in a dose-dependent manner. Water and chlorine had little effect in reducing *Salmonella*.

A study by McKee et al. (2013) compared the pathogen reduction of antimicrobial interventions applied to chicken parts, including those used to produce ground product. Chicken parts were treated with different concentrations (0.35% and 0.60%) of cetylpyridinium chloride (CPC), (0.07% and 0.10%) peracetic acid (PAA), and (0.003%) chlorine in a parts decontamination tank. Preliminary research shows that parts immersed/dipped into PAA had the greatest reductions of *Salmonella* followed by CPC. Chlorine was the least effective. However, this lack of effect may be related to short contact times (<20 sec) for chlorine. Findings from this study suggest that dips/immersions are more effective than single spray systems when treating parts because of their longer contact times and complete coverage.

Bacteriophages

Bacteriophages (also called phages) are naturally occurring organisms (viruses) that infect only a specific host bacterium (Hagens & Loessner, 2010). Phages cannot infect humans (Lu & Breidt, 2015). Phages are ubiquitous in the environment – in the water, in soil, and on food consumed (Guenther, 2009). Once phages infect bacteria, they can multiply inside of the bacteria, destroy the cell wall of the bacteria, and then be released into the environment where the can infect other susceptible bacteria.

Several phage applications demonstrated to infect *Salmonella* are listed in Directive 7120.1 for use with poultry.

The phage application researched by Sukumaran, et al. (2015) was on chicken skin and skinless chicken breast filets. The study combined a 20 second dip at 4°C in organic antimicrobial compounds followed by a spray application of anti-*Salmonella* phage (10^8-10^9 PFU/g). The organic antimicrobial compounds tested were: cetylpyridinium chloride (CPC) at 0.6%; lauric arginate (also known as lauramide arginine ethyl ester; LAE) at 200 ppm; and peroxyacetic acid (PAA) at 50 and 400 ppm.

Chicken skin treated in this manner achieved the following *Salmonella* reductions: CPC, 2.1 log reduction; LAE, 2.4 log reduction; PAA (50 ppm), 1.7 log reduction; and PAA (400 ppm), 0.9 log reduction.

Skinless chicken breast treated in this manner achieved the following *Salmonella* reductions: CPC, 2.2 log reduction and LAE, 2.6 log reduction (the PAA dip was not studied on skinless chicken breast).

Physical Interventions

Electrolyzed Oxidizing Water Treatment

Electrolyzed oxidizing (EO) water is inexpensive, must be generated on-site with specialized equipment, has strong bacterial killing effect, and has little residual (long-lasting) effect. EO water is acidic and is an effective antimicrobial immersion/dip solution (Northcutt et al., 2007). However, it usually requires much longer contact time than other interventions, so spraying may not be an appropriate application method.

EO water is produced by passing direct current voltage through a dilute sodium chloride (salt) solution. The result of the reaction is the production of two types of water (Hsu, 2005). It is the EO water that has low pH (2.3-2.7), high oxidation-reduction potential (>1000 mV), and high dissolved oxygen. A high oxidation-reduction potential means that more oxidation will occur. That translates to a greater capacity to form free radicals that kill bacteria (Venkitanarayanan, 1999). Huang (2008) and Hsu (2005) provide detailed descriptions on the concepts. The production of EO water containing sodium chloride (1-12% w/v) results in the formation of sodium hypochlorite (NaOCl) and hypochlorous acid (HOCl). HOCl functions as if chlorine gas was added into the poultry parts disinfection solution without the need to store a dangerous gas.

It is important to point out that although EO water is strongly acidic, it is different from strong acids, such as hydrochloric acid or sulfuric acid, in that it is not corrosive to skin, to mucous membranes in the nose and lungs, or to poultry carcasses or parts (Huang, 2008). However, the HOCL (sodium hypochlorite) generated by the EO process may cause breathing irritation that can be reduced with proper ventilation (Huang, 2008).

High Pressure Inactivation

A typical high pressure pasteurization (HPP) system consists of a pressure vessel, pressure transmission fluid (usually water), and pressure generating pumps. HPP is a technology by which a product is treated at a very high pressure. HPP requires specialized equipment and is usually applied off-site where that equipment is located.

HPP treatment kills or inhibits microorganisms, and researchers have studied its effectiveness in reducing pathogens in comminuted chicken and chicken parts. An advantage of using HPP is that surviving microorganisms can be more sensitive to other types of antimicrobial interventions as compared to bacteria that have not been exposed to HPP (Alpas, 2000).

Escriu (2009) treated finely minced chicken inoculated with 6 log CFU/g *Salmonella* with HPP at 400 MPa at 20°C for 2 min with a water-oil mixture used as the pressure transmission fluid. *Salmonella* was reduced 3.26 to 4.35 log CFU/g.

Tananuwong (2012) applied HPP to chicken breast inoculated with *Salmonella* (7 log CFU/g) at 300 MPa at 35°C for 1 min and achieved approximately 2 log reduction.

Irradiation using Ionizing Radiation

Food irradiation is the process of exposing food to high levels of radiant energy and is applied by directing ionizing radiation to food products. Food can be irradiated commercially for several purposes: to extend shelf-life, eliminate insect pests, or reduce numbers of pathogenic microorganisms. Ionizing radiation can penetrate deeply into food, killing insect pests and microorganisms without raising the temperature of the food significantly (Jaczynski, 2003). Ionizing radiation kills bacterial cells and pests by damaging DNA (Tahergorabi, 2012; Verma, 2001).

Ionizing radiation results from cobalt-60, cesium-137, x-rays, and electron beams. Cobalt-60 (^{60}Co) is a common source of a form of ionizing radiation called gamma irradiation. It has high penetrating power (Ahn, 2013), which allows the treatment of poultry of variable sizes, shapes, and densities (including frozen and unfrozen). X-rays are also used to produce ionizing radiation. X-rays have high penetrating power but are typically not used for treatment of food because it is not an efficient process (Tahergorabi, 2012). Another way of producing ionizing radiation is by applying an electron beam (e-beam). In this approach, a stream of high-energy electrons is applied to products. Because the radiation penetrates only a few centimeters, it is useful to treat thin layers of food (Jaczynski, 2003; Ahn, 2013). The electron beam may be applied over moving food on a conveyor, unlike some other sources of ionizing radiation. Electron beam systems require regular maintenance, high electric power, and cooling as the equipment produces high heat (Ahn, 2013).

The maximum dosage of ionizing radiation is 3 kGy absorbed by raw poultry (fresh and frozen). The maximum dosage limit allowed for poultry is based on the safety determination that was made by FDA (21 CFR 179.26(b)(6)). A requirement that FDA placed on the use of irradiation is that the packaging of irradiated poultry must be air permeable and does exclude moisture and microorganisms from penetrating the package barrier.

To promote processing flexibility and innovation that will lead to improvements in food safety, FSIS does not specify at which point irradiation may or may not be applied. Under HACCP, an establishment must control the conditions under which product is held from initial processing through irradiation and packaging to ensure and preserve the intended antimicrobial effects of irradiation (64 FR 72150)[6]. FSIS requires the labeling of irradiated meat and poultry products, including the radura symbol. These labeling requirements are outlined in the final rule, Irradiation of Meat Food Products, 64 FR 72150.

[6] Irradiation of Meat Food Products; Final rule. Dec 21, 1999. Federal Register. 64: 72150-72166.

Thayer (1991) used gamma irradiation at 0 to 3.6 kGy on sterile, mechanically deboned chicken meat inoculated with approximately log 9.9 cfu/g *Salmonella* Typhimurium. In this study, the higher the dose of gamma radiation used, the higher the kill rates of *Salmonella* (log reductions). Gamma irradiation was also more lethal for *S.* Typhimurium at higher temperatures and in the presence of air (as opposed to in a vacuum). The researchers found that using gamma irradiation resulted in a log reduction between 5.5-7 log. More details of the conditions used to achieve these log reductions are available in the research article.

In a different study, Thayer (1992) inoculated fresh, nonfrozen chicken wings with *Salmonella* Typhimurium and used five gamma irradiation doses: (0, 0.90, 1.80, 2.70, and 3.60 kGy) in air at 5°C. All *Salmonella* were killed on samples inoculated with 10 or 100 CFU/wing. Surviving *Salmonella* were detected on chicken wings inoculated with either 1,000 or 10,000 CFU/wing after irradiation with 1.8 kGy, but the numbers were very low (below enumeration limit). No *Salmonella* were detected following gamma radiation doses of 2.7 or 3.6 kGy. This study demonstrated that irradiating poultry could result in significant reductions in *Salmonella* on raw chicken wings.

Another study found that applying electron beam irradiation to boneless, skinless chicken breasts containing naturally occurring bacteria resulted in an approximately 5-log reduction in *Salmonella* and *Campylobacter*. The doses applied were 1.0 and 1.8 kGy at ambient temperature and both doses resulted in comparable reduction of *Salmonella* and *Campylobacter* (Lewis 2002).

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Attachment 1

Antimicrobial interventions for further processed poultry. Parameters are provided to guide establishments in choosing antimicrobial interventions that are appropriate to their processes. Values indicated are not critical operational parameters. Establishments need to identify the critical operational parameters used in their establishment and provide scientific support for the values they select.

Intervention	Pros	Cons	Typical parameters	Reference
Chlorine-Based Treatments	- Inexpensive - Broad spectrum - Quick acting	- Corrosive and outgases at low pH - Ineffective at high pH - Neutralized by high organic load - Formation of hazardous trihalomethanes	pH: 6.0 – 6.5 concentration: 20 – 50 ppm free chlorine temperature: 4°C Application: dip or spray	Buncic and Sofos, 2012 Oh, 2014
Organic Acids	- Low toxicity compared to some other chemicals - Broad spectrum - Not affected by hard water - Relatively stable in the presence of organic matter	- Can be expensive - Can be corrosive at high temperatures	pH range: 2.5 – 5.4 concentration: 1.5 – 5% temperature: 4°C application: dip or spray	Zhao, 2006
Acidified Sodium Chlorite (ASC)	-Inexpensive	- Can form hazardous halogenated organic compounds - Neutralized by organic matter	pH range: 2.3 – 2.9 concentration: 500 – 1200 ppm temperature: 4°C Application: dip or spray	Wang, 2014 Alonso-Hernando, 2013
Peroxyacetic Acid	- Broad pH range - Broad temperature range - Affected by organic matter to a lesser degree than chlorine - No rinse required	- Expensive	pH: 3.0-7.5 concentration: 100-1000 ppm temperature: 4°C Application: dip or spray	McKee, 2014 Chen, 2014

Intervention	Pros	Cons	Typical parameters	Reference
Trisodium Phosphate (TSP)	- Inexpensive	- High pH may affect poultry after prolonged contact	pH: 11 – 13 concentration: 8 – 12% temperature: 20 – 30°C Application: dip or spray	Capita, 2002 Del Rio, 2007
Electrolyzed Oxidizing (EO) Water Treatment	- Noncorrosive to equipment and personnel - Inexpensive to operate	- Solution rapidly loses antimicrobial activity if electrolysis is stopped - neutralized by organic matter - may be expensive to set up system	EO water has the following characteristics: pH: 2.1 – 2.7, oxidation-reduction potential (ORP): >1000 mV, free chlorine: 8 – >70 mg/L Application: dip	Huang, 2008 Park, 2002
High Pressure Pasteurization (HPP)	- No chemicals on food; no rinse required	- Expensive to install - Typically done at a separate establishment - Can alter appearance and texture of product	Operates at pressures >100 MPa Application: N/A	Liu, 2012 Simonin, 2012
Irradiation	- No chemicals on food; no rinse required	- Expensive to install - Typically done at a separate establishment - Labeling requirement	≤3.0 kGy packaging must be air permeable (21 CFR 179.26(b)(6))	Thayer 1991 and 1992