FSIS Guideline

for Controlling *Campylobacter* 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 *Campylobacter* 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 is the 2021 edition of the FSIS Guideline for Controlling *Campylobacter* in Raw Poultry. This edition separates the guideline into two separate documents in response to comments received on the 2015 edition: 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 *Salmonella* can be found in the FSIS Guideline for Controlling *Salmonella* 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 revised this guideline to respond to public comments on the *Draft Compliance Guideline For Controlling Salmonella and Campylobacter in Raw Poultry (4th Edition)* 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 *Campylobacter*. In addition, since the 2015 revision of this guideline, FSIS has implemented the more sensitive enrichment method for *Campylobacter* and is therefore revising *Campylobacter* pathogen performance standards for chicken parts, comminuted chicken and turkey products. This guideline can assist establishments in meeting *Campylobacter* performance standards and reducing illnesses associated with *Campylobacter*.

CDC estimates *Campylobacter* is the #1 cause of bacterial diarrheal illness in the United States; most *Campylobacter* infections are associated with eating raw or undercooked poultry or from contamination of other foods by these items (CDC, 2017).

This guideline describes concerns and controls for each step in the poultry slaughter process. 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 at a higher standard of pathogen control, including *Campylobacter*.

Again, the information in this guideline is provided as guidance to assist poultry slaughter and processing establishments 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 *Draft Compliance Guideline For Controlling Salmonella and Campylobacter in Raw Poultry (4th Edition):*

- Removed the word "compliance" from the document title and throughout the document to clarify that this document does not constitute regulatory requirements;
- Separated information specific to controlling *Campylobacter* into a separate guideline;
- 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 *Campylobacter*;
- Added information about antimicrobial carryover and considerations to mitigate its effect on microbiological sampling; and
- Updated data tables outlining the relative risk of various source materials used in further processed poultry products based on recent FSIS data.

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.

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 *Campylobacter*. This pathogen is a hazard that establishments producing raw poultry products can control through a Hazard Analysis and Critical Control Point (HACCP) plan or prevent in the processing environment through 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 *Campylobacter*) 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 *Campylobacter* in raw poultry products when considered together.

> ***Key Point***
>
> 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)).

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 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 can 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.

[1] 79 FR 49565 (p.49613)

Establishments must document the controls and procedures they use to reduce contamination in their HACCP plan, Sanitation SOP, or applicable prerequisite program in accordance with 9 CFR 417.5.

HACCP Plan to Control Hazards

If the establishment decides through its hazard analysis that *Campylobacter* is a food safety hazard that is 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 control can be applied, and, as a result, a food safety hazard can be prevented, eliminated, or reduced to acceptable levels. 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

More general considerations, including information on sanitation, sampling, hazard analysis, scheduled slaughter, and HACCP, relative to controlling pathogens during poultry production are covered in the FSIS Guideline for Controlling *Salmonella* in Raw Poultry. These principles apply to both the control of *Salmonella* and *Campylobacter*. Additional sampling guidance is available in The FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry.

Using Microbiological Sampling and Testing

Use of Microbiological Sampling Data

Following successful validation of its HACCP system, an establishment uses the validation data to implement its system. Establishments are required to support the monitoring and verification procedures selected and the frequency of those procedures (9 CFR 417.5(a)(2)). Microbiological verification data ideally includes samples collected at a number of points throughout the process (e.g., samples of starting materials, interim product, and finished product) for the same lot. Selecting samples in this way allows the establishment to determine whether the HACCP system is reducing contamination, and whether the HACCP system is working as designed, similar to process mapping. Samples at intermediate points provide additional information about intermediate process steps.

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. *Campylobacter* is not captured by commonly used indicator tests, including Aerobic Plate Count (APC) and Enterobacteriaceae (EB).

There are no identified indicator organisms that directly reflect the presence or absence of pathogens in poultry (e.g., *Campylobacter)*. 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. 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 *Campylobacter* sample per month (for example, 11 samples/52 weeks for 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.

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 *Campylobacter* can use the FSIS performance standards as indicators of process control.

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.

It is important for the establishment to be able to collect and ship samples properly. On-site assistance or information on proper sample collection (aseptic techniques) and prompt shipment of samples to the laboratory from the establishment are also important. The final result of the analysis will be neither accurate nor meaningful if a laboratory has not implemented procedures to prevent mishandling of samples or alteration of records. In particular, *Campylobacter* is sensitive to light (Ultraviolet exposure) and freezing, so it is critical that samples are maintained in a refrigerated, but not frozen, place until shipped or transported to the laboratory. Maintaining temperature of the sample above 0 °C but below 15 °C before and during transport protects sample integrity.

To effectively use data to evaluate process control, the collection, handling, storage, and transportation of samples must be 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.

Examples of non-destructive sample collection techniques that an establishment may choose to use to collect poultry carcass samples are included as attachments to the FSIS Compliance Guideline: Modernization of Poultry Slaughter Inspection - Microbiological Sampling of Raw Poultry. Non-destructive techniques do not result in

destruction of the product being sampled. A parts rinse sample collection is an example of a non-destructive sampling technique.

Antimicrobial Interventions and Drip Time

Using antimicrobial interventions 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).

Recommended Best Practices, Ongoing Verification Testing

1. Prevent samples being analyzed for *Campylobacter* from exposure to freezing temperatures and Ultraviolet light exposure.
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.

PRE-HARVEST

Pre-Harvest Interventions and Management Practices

Pre-harvest interventions and practices can prevent or reduce *Campylobacter* contamination in 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 *Campylobacter* 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 *Campylobacter*. 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 *Campylobacter* contamination on birds received by slaughter and processing establishments (Cox & Pavic, 2010). Establishments may include specifications in their grow-out contracts for growers to incorporate strategies that address the potential contamination of *Campylobacter* during hatching and grow-out. Reducing or eliminating *Campylobacter* 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 *Campylobacter*.

Alternately, if an establishment does not require *Campylobacter* to be 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. By using these test results, an establishment could decide to implement a scheduled slaughter and processing plan based on the presence or absence ("status") of *Campylobacter* (Katsma et al., 2007) as described in the FSIS Guideline for Controlling *Salmonella* in Raw Poultry. Other decisions could be to utilize additional chemical interventions or divert products from positive flocks to lethality treatment (such as cooking).

Pre-harvest Recommendations to Control *Campylobacter*

FSIS recommends that official establishments obtain birds produced from a system of breeder flocks, hatcheries, and grow-out houses that use the pre-harvest best practices and interventions described here.

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

- Exposure to contaminated water, feed, and bedding in the grow-out house; and
- Environmental exposures due to poor biosecurity practices and inadequate pest control.

Vertical transmission of *Campylobacter* (transmission via the egg from hen to chick) is not as well documented as that of *Salmonella*; however, contamination of the egg during laying by a colonized hen can lead to exposure during hatching, transferring the pathogen from parent to progeny (Cox et al., 2012).

Key Points

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

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

FSIS is not aware of a single pre-harvest intervention that eliminates *Campylobacter* 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 *Campylobacter* 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), the 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 *Campylobacter*: Breeder Flock & Hatchery, Grow-out House, Bedding, Feed, Water, and Transportation. Scheduled Slaughter is an additional approach, which is covered in the FSIS Guideline for Controlling *Salmonella* in Raw Poultry. 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 *Campylobacter* in poultry that may be exposed to this pathogen (Table 1). 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 are 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 live poultry and reducing *Campylobacter* in birds presented at slaughter. Evidence suggests that stress at pre-harvest can have adverse effects on food safety (Corry, 2001). 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 1. Pre-harvest products to reduce colonization and number (level) of *Campylobacter* in poultry.

Definition	Notes on Use
Vaccines: increase immunity to *Campylobacter* by exposing the immune	Several vaccines are currently in development for the prevention of *Campylobacter* in live poultry. Proposed targets include the flagellar antigens as well as the

system to a controlled preparation. Vaccine types include <u>live vaccines</u> (an attenuated strain of *Campylobacter*), <u>sub-unit vaccines</u> (a vaccine with minimal parts of the target for immune response), and <u>autogenous vaccines</u> (developed from bacteria isolated from the farm environment).	capsule of the bacteria (Poly et al., 2019). Special approvals from APHIS are required for long-term use of <u>autogenous vaccines</u> or for use of these vaccines with multiple flocks.
<u>Competitive Exclusion & Probiotics</u>: preparations of beneficial bacteria that compete with *Campylobacter* 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 a statistically significant reduction in colonization and shedding of *Campylobacter* (Smialek et al, 2018).
<u>Prebiotics</u>: specific nutrients that will allow beneficial bacterial species to more effectively compete against *Campylobacter*.	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 that some available prebiotics reduced *Campylobacter* by more than 1 log, and when combined with probiotics, reduced *Campylobacter* by more than 3 logs (Kim et al, 2019).
<u>Organic Acids</u>: increase the acidity of the gut, which can kill *Campylobacter*. Because each bacterial species has a different susceptibility to organic acids, this mechanism also increases the ability of beneficial bacteria to compete against pathogens.	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. Organic acids in the water will lower the pH in the crop and reduce pathogen colonization and growth. One study found that use of lauric acid products resulted in up to a 1 log reduction of *Campylobacter* (Zieger, 2017).

Breeder Flock & Hatchery

Breeder flocks and hatcheries can be the original source of *Campylobacter* 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 broiler and turkey chicks from breeder flocks free of *Campylobacter* onto grow-out farms (Cox et al., 2012). (Note that pathogen-free breeder stock is not a requirement for participation in NPIP.) Broiler breeders also demonstrate variability in innate immunity to *Campylobacter* — some chicken breeder stocks have been shown to be more resistant to colonization (Han et al., 2016; Connell et al., 2012). 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 1 to prevent or reduce colonization by *Campylobacter* 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.

Competitive exclusion and probiotics can be administered to chicks on the day of hatch to inoculate the gastrointestinal tract with beneficial bacteria (Table 1). 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 *Campylobacter.*
3. Consider using one or more of the products listed in Table 1.
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). 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 *Campylobacter* in birds presented for slaughter (Cox & Pavic 2010; Newell et al., 2011; Muenier et al., 2017):

- 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 Gibbens et al. (2001) found that correct use of a boot dip and house-specific boots and overalls reduced flock colonization of *Campylobacter* by 50%);
- 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 *Campylobacter* with the measures described above, consider the use of one or more of the products in Table 1 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.

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 the target pathogen into flocks presented for slaughter; the establishment can consider this possibility and develop their 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 1.

Bedding

Litter or bedding can be considered a reservoir for *Campylobacter* contamination (Montrose et al., Shane, Harrington, 1985). Downtime between flocks is ideally 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 (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 (Han, 2016). 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). Reducing litter pH to less than 4.5 can reduce *Campylobacter* to below detectable limits (Line, 2002). 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), *Campylobacter* colonization of birds from contaminated litter 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.

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 *Campylobacter*. Specifically, obtain feed from manufacturers that follow Good Manufacturing Practices (GMPs) 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 1).

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 (Hald et al., 2004). 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 decrease the acidity of the crop, increasing the likelihood that the bird will ingest pathogens and be contaminated at slaughter (Byrd et al., 1998). Consider providing water with organic acids (Table 1 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 (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 1).
4. Protect feed from contamination during transport and storage
5. Pelleted and acidified feed may be more resistant to contamination during storage.
6. 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 1 are available as water additives for young chickens. Of note are organic acids added to water, particularly during feed withdrawal (Byrd et al., 2001). 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 *Campylobacter* they may ingest when pecking at the litter.

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 1, particularly organic acids during feed withdrawal.

Transportation

The presence of *Campylobacter* on birds at receiving at slaughter has been linked to dirty transport cages (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 1 shows a chicken transport crate that is not washed after every load.

Figure 1

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.

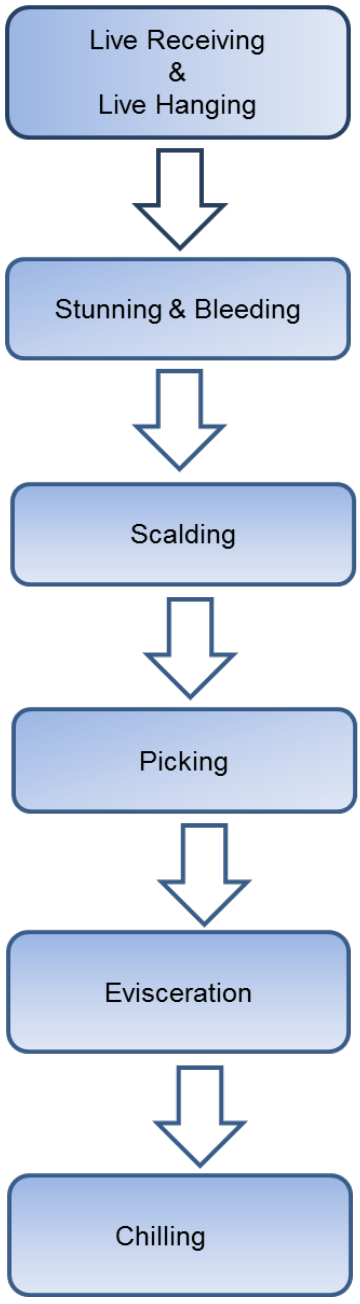
Recommended Best Practices, Transportation

1. Use clean containers and sanitize containers between loads.
2. Use new disposable paper liners when transporting chicks to the farm.
3. Minimize the 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

Live receiving 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 *Campylobacter.* The feathers, skin, crop, colon, ceca, and cloaca of birds brought to slaughter are often highly contaminated with *Campylobacter* (Kotula and 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 *Campylobacter* 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 *Campylobacter* at live receiving and later in the process (Fluckey, et al., 2003; Newell, et al., 2001). Establishments can consider how the frequency of cleaning transport cages might inform their lotting practices, since research has indicated *Campylobacter* positive birds were linked to dirty transport cages. If establishments lot product (to achieve microbiological independence) on a flock basis, they can clean and sanitize transport cages between each flock to maintain microbiological independence.

Key Points

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

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

Employee traffic patterns and air flow can be controlled to prevent cross contamination and reduce levels of *Campylobacter*. 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. One study found employee clothing to be a source of contamination for birds relative to *Campylobacter* (Herman, et al., 2003).

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 combinations of gases (e.g., carbon dioxide, argon, and nitrogen) to stun the birds before they are hung on the line. Any stunning method must be monitored and controlled to ensure effectiveness. A study by Musgrove, et al., (1997) showed that *Campylobacter* increased in carcass rinses collected after stunning. Good feed withdrawal practices can greatly reduce this problem. 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 *Campylobacter* carried forward into the next steps. Figure 2 shows young chickens entering the stunner with minimal external fecal contamination.

Figure 2

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

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 *Campylobacter* cells from positive carcasses to spread *Campylobacter* to negative carcasses. However, scalding can reduce levels of *Campylobacter* on the carcasses, since much of the dirt, litter, and feces on carcasses is removed at this step. *Campylobacter* contamination consistently decreases when scalding is well controlled (Slavik et al., 1994; Hinton et al, 2004).

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 3 shows an immersion scald tank with excessive fecal material contamination. Berrang and Dickens (2000) found 3.80 log10 CFU/g of *Campylobacter* in breast skin before entering the scald tank. *Campylobacter* may harbor in chicken skin, which may aid its survival through scalding (Lee et al.,

1998). 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 *Campylobacter* on carcasses.

Figure 3

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 stage tanks 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 *Campylobacter* in the water (Humphrey & Lanning, 1987).

Making the pH more acidic (3-4) is also effective at decreasing levels of *Campylobacter* (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 are able to maintain a desirable pH, less monitoring is needed.

Key Points

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

Water pH should be monitored carefully.

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). *Campylobacter* is most heat resistant at a pH of 7.0 (Humphrey & Lanning, 1987).

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 provide a list of approved chemicals that can be used in scalders. Additives to raise the pH during scald have shown to be effective at reducing *Campylobacter* (Berrang et al., 2006).

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 *Campylobacter* 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 FSIS inspectors for overscald per 9 CFR 381.92. If the temperature is too low, the tank becomes a breeding ground for bacteria. *Campylobacter* cannot grow at temperatures greater than 116.6 ºF (47ºC). Therefore, scalding temperatures higher than 116.6°F (47ºC) can be sufficient to control *Campylobacter* growth. Table 2 shows common scalding times and temperatures for various classes of poultry.

Table 2. 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

While scalding above 116.6 ºF (47 °C) controls *Campylobacter* growth and initiates inactivation, scalding at 132 ºF (56 °C) reduced *Campylobacter* counts most effectively (Slavik et al.,1995).

Some religious traditions forbid scalding. Under Kosher slaughter, carcasses are soaked in cold water to make feather removal easier. 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 *Campylobacter* growth (6.5-7.5).
5. Use pre-scald brush systems to clean birds prior to scald tank.
6. Maintain hard scald temperatures of 132 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 *Campylobacter* occurs during picking because of contact with contaminated rubber

picking fingers and contaminated reuse water (Georgnaras, et al., 1997, Wempe, et al., 1983). 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 *Campylobacter* increase during this step (Berrang & Dickens, 2001).

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 *Campylobacter*.

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

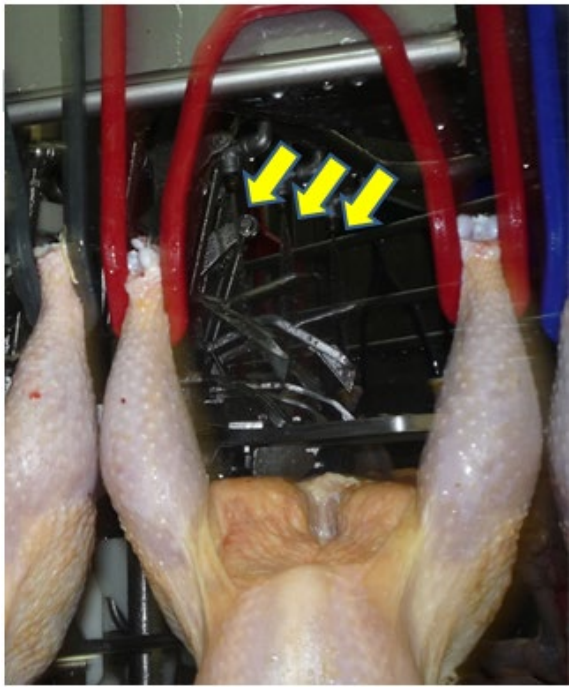
Evisceration begins at rehang and ends when the carcass enters the chiller.

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 4 shows an automated opener system that utilizes replaceable blades that are cleaned between each carcass.

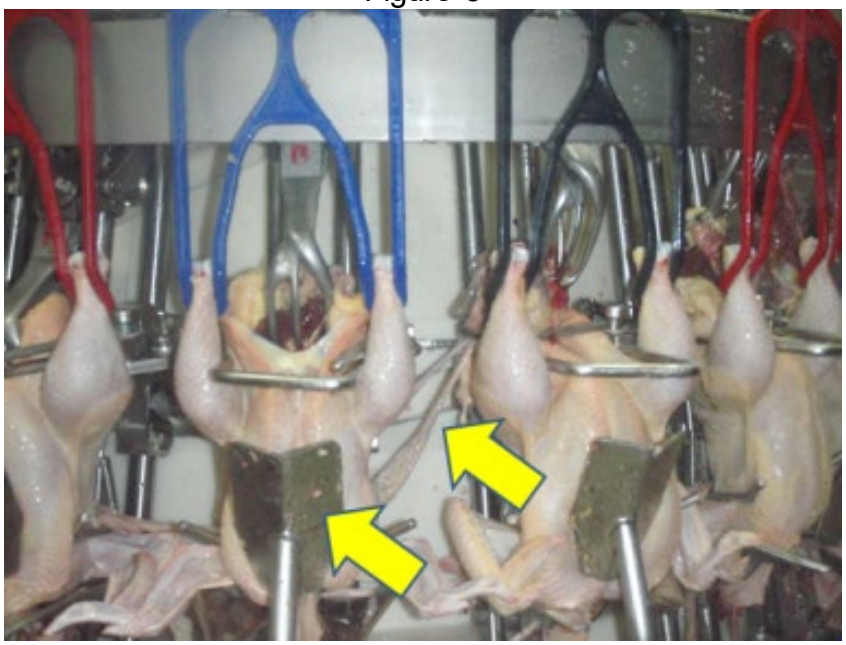
Figure 4



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 5 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 5



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 6 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 *Campylobacter,* causing carcasses to later become cross contaminated. In some operations, at least half of carcass surfaces are contaminated with crop and upper GI contents immediately before evisceration (Byrd et al., 2002). Retracting the viscera from the body cavity can transfer crop and upper GI contents to the interior body cavity (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 6

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

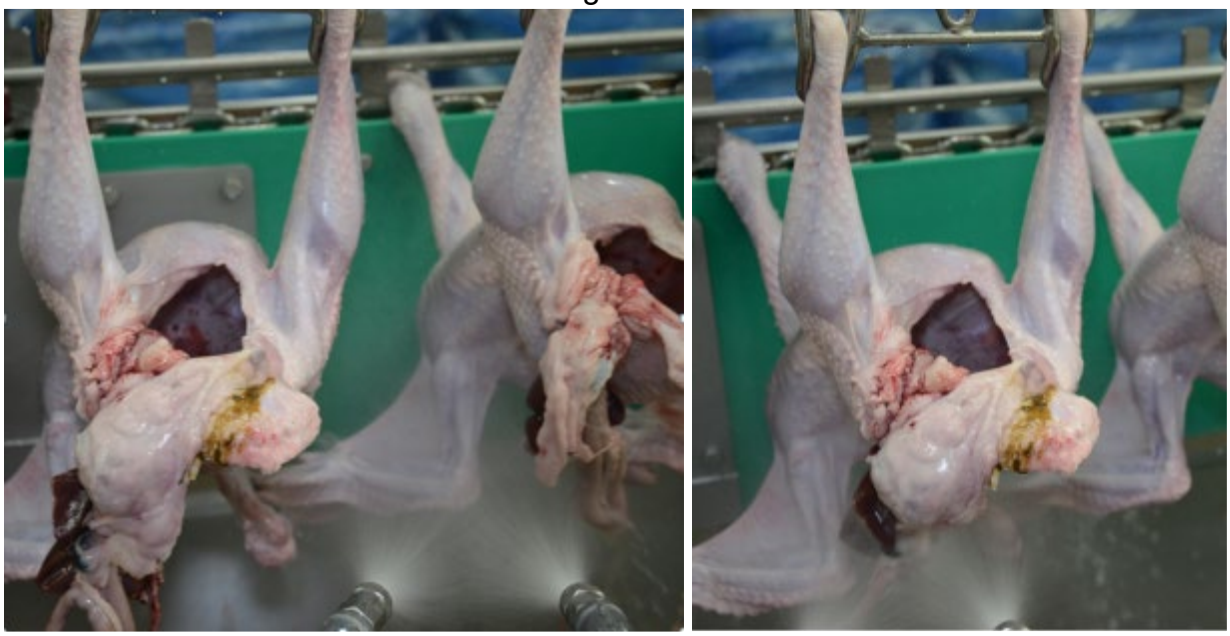
Carcass rinses or sprays can be effective interventions for removing incidental contamination from the carcass surface during evisceration. However, establishments can aim to consistently implement sanitary dressing procedures to control pathogens. Rinses with an antimicrobial have been shown to reduce *Campylobacter* by 1.5 log

(Bashor, et al., 2004). 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.

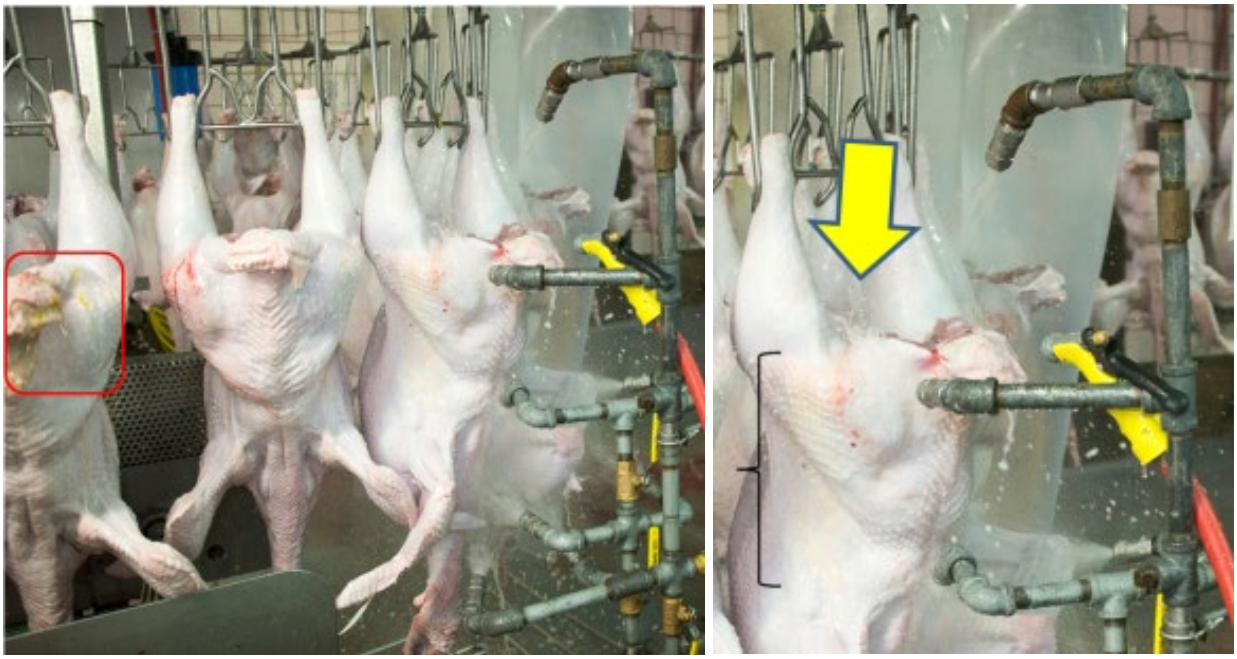
Note: This guideline uses the term "free available chlorine" when referring to parts per million (ppm) chlorine. Free available chlorine is the concentration of hypochlorous acid (HOCL) and hypochlorite ions (OCL) existing in chlorinated water. (Reference: Handbook of Chlorination and Alternative Disinfectants, 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 7 shows a rinse that is not calibrated to wash contamination. Figure 8 shows sprays that spread contamination onto other parts of the carcass.

Figure 7



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 were 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 8



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 *Campylobacter* 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 *Campylobacter* positive carcasses, while others produce carcasses that upon testing typically do not have detectable levels of *Campylobacter*. 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 *Campylobacter* control because crop tissue often contains *Campylobacter* (Byrd at al., 1998).

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.

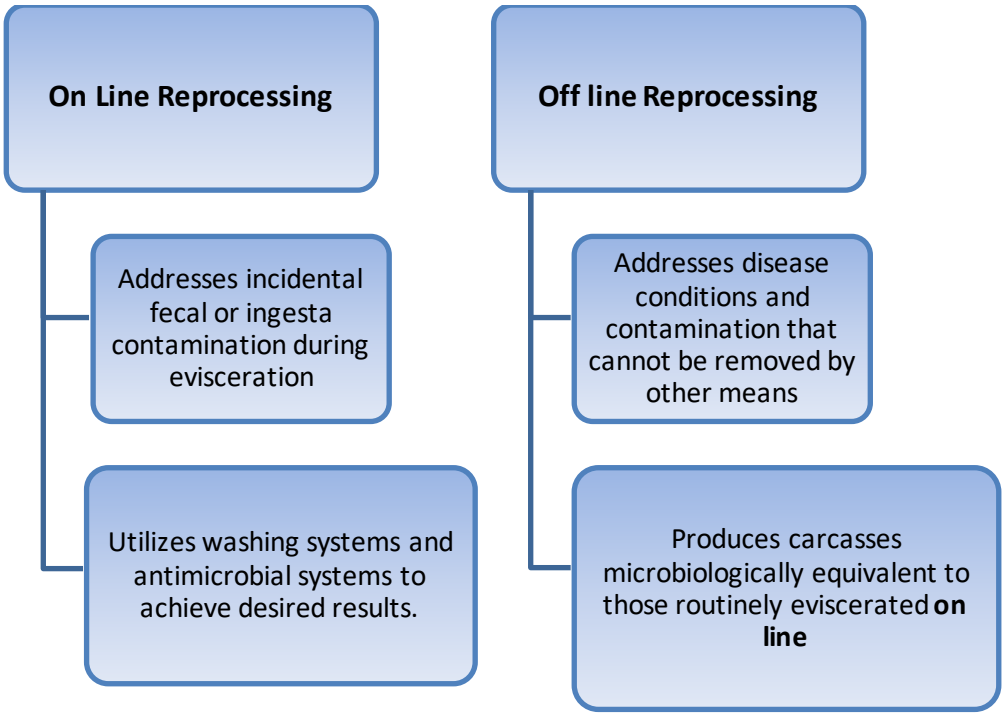
Chilling

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 *Campylobacter* on visibly contaminated carcasses. Both on-line (OLR) and off-line (OFLR) reprocessing systems can be used to remove incidental contamination during the 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 to FSIS 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, can 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.

Source Materials Can Affect Pathogen Status of Comminuted Product

Certain poultry parts may be more likely to be contaminated with pathogens and 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 *Campylobacter* (55%) than other parts, including breasts, legs, and wings (between 16-43% for *Campylobacter*). 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 *Campylobacter*. As previously discussed, skin can contain *Campylobacter* 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. Table 3 shows that ground and other raw comminuted chicken products (such as sausages and patties) sampled by FSIS that were produced using skin-on source materials were more likely to be contaminated with *Campylobacter*[2]. Table 4 shows the risk for use of bone-in source materials for comminuted turkey products.

[2] FSIS Not Ready-to-Eat Comminuted Poultry Exploratory Sampling Project results from samples collected June 1, 2013 through June 30, 2015.

Table 3. FSIS exploratory sampling testing results, raw comminuted chicken by source material composition (6/1/13-6/30/15, 2,688 samples)

Comminuted Chicken Products	*Campylobacter* prevalence in this source material	*Campylobacter* presence risk relative to the lowest prevalence source material (Deboned & skinless)[3]
Mechanically separated	20.2%	11.9-fold increase
Ground and Other Comminuted Chicken Products	*Campylobacter* prevalence in this source material	*Campylobacter* presence risk relative to the lowest prevalence source material (Deboned & skinless)[3]
Bone-in & Skin-on	12.1%	7.1
Bone-in & Skinless	4.4%	2.6
Deboned & Skin-on	3.6%	2.1
Deboned & Skinless	1.7%	N/A

The interior of poultry bones can contain pathogens as well. 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 indicates that both chicken and turkey raw comminuted products produced using bone-in source materials are more likely to be contaminated with *Campylobacter* than those produced using deboned source materials. Table 3 shows this for comminuted chicken products, and Table 4 shows this for comminuted turkey products.

Tables 3 and 4 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 *Campylobacter* when its source materials contain both bone and skin (12.1%). Comminuted chicken made from deboned and skinless source materials had the lowest prevalence for *Campylobacter* (1.7% for *Campylobacter*).

[3] For bone-in and skin-on source materials, *Campylobacter* prevalence in comminuted chicken was 12.1%. The lowest prevalence product, made from deboned and skinless source materials, was 1.7%. To calculate the relative risk, each source material type was divided by the lowest risk product: 12.1/1.7 = 7.1.

The tables also indicate how much more likely products made from different source materials are to contain *Campylobacter*, 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 more likely to be positive for *Campylobacter* compared to those made from deboned and skinless source materials.[3]

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

Table 4. FSIS exploratory sampling testing results, raw comminuted turkey by source material composition (6/1/13-6/30/15, 934 samples)

Comminuted Turkey Products	*Campylobacter* prevalence in this source material	*Campylobacter* presence risk relative to the lowest prevalence source material (Deboned)
Mechanically separated	2.4%	1.2-fold increase
Ground and Other Comminuted Products	*Campylobacter* prevalence in this source material	*Campylobacter* presence risk relative to the lowest prevalence source material (Deboned)
Bone-in	9.8%	4.9
Deboned	2.0%	N/A

It is important to keep in mind that the data in Tables 3 and 4 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, a chicken establishment can compare using bone-in and skin-on source materials (12.1% *Campylobacter* prevalence) with using deboned and skin-on source materials (3.6%) to determine that the relative risk is 3.36 (12.1/3.6). This means there is about a 3 times greater chance that the bone-in source material will result in *Campylobacter* being present in the finished product. Therefore, there is likely a benefit to using the deboned source materials instead of the bone-in source materials.

Additional guidance regarding the use of in-house source materials and incoming source materials purchased from supplying establishments, including the use of Certificates of Analysis or Letters of Guarantee, is available in the FSIS Guideline for Controlling *Salmonella* in Raw Poultry.

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 FSIS Compliance Guideline Procedures for New Technology Notifications and Protocols.

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 *Campylobacter* 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 *Campylobacter* levels on source materials. That consideration also applies 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 *Campylobacter* can be applied by spraying or dipping (immersion). Generally, immersion is more effective than spraying because it ensures better coverage and longer contact time (Loretz, 2010). 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 9 shows an antimicrobial dip being applied to boneless, skinless poultry parts prior to grinding.

Figure 9

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. Oyarzabal et al. (2004) reported ~ 1 log reduction of *Campylobacter* and Mehyar et al. (2005) reported a 1.5 log reduction in *Campylobacter* on inoculated drumsticks.

Trisodium Phosphate

Trisodium phosphate (TSP) is an inorganic, non-chlorine-containing compound with a high pH. Its pH is between 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 a wide pH range (3 to 7.5). PAA is affected by protein or other organic materials to a lesser degree than chlorine is. When added to the chiller at a concentration of 200 ppm for one hour of contact time, PAA demonstrated a 1.5 log reduction of *Campylobacter* (Bauermeister et al., 2008). Applied as a dip with 1000 ppm PAA and a 20 second contact time demonstrated a 2.0 log reduction of *Campylobacter* (Nagel et al., 2013). In contrast, when applied as a spray, PAA requires increased contact time/increased concentrations to achieve similar reductions (Bertram et al., 2019).

Studies Comparing Chemical Interventions

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

Another study by McKee et al. (2013) compared the pathogen reduction of antimicrobial interventions applied to chicken parts, including those used to produce ground product. Preliminary research shows that parts immersed/dipped into a tank containing antimicrobials had the greatest reductions. 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 bacteria (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 they can infect other susceptible bacteria. Phage preparations for *Campylobacter* have been developed, but have not yet been approved for use in FSIS-regulated products; inclusion in FSIS Directive 7120.1 for use in meat, poultry, egg, or fish products would require a New Technology submission for review of these phage applications.

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. 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).

In a study by Park and others (2002), EO water treatment with a contact time of only 10 seconds demonstrated an equal reduction of *Campylobacter* as chlorinated water (50 ppm) at about 3 log10 CFU/g.

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).

Liu (2012) investigated high pressure inactivation of *Campylobacter* in comminuted chicken breast meat (individual meat particle size of ≤1 mm^3) inoculated with *Campylobacter jejuni* at 6 log CFU/g. Polyethylene glycol was used as the pressure transmission fluid. Compression and decompression rates were 300 MPa/min. The temperature of the system was maintained by a water-jacketed unit. The temperature during compression and decompression did not exceed 2°C. Pressure at 400 MPa for 30 min reduced *Campylobacter* counts from 6 log to below the detection limit of 1.48 log CFU/g (reduction of approximately 4.5 log).

Cryogenic Freezing

Cryogenic freezing is defined as freezing at -74.2°F (-59°C) or below (Balasubramanian, 2012) using liquefied gases called cryogens. Two popular cryogens used are liquid carbon dioxide (CO2) and liquid nitrogen (N2). Cryogens are completely inert (non-reactive or flammable), colorless, odorless, tasteless, and have minimal environmental effects. Tunnel and spiral belt are the two common commercial designs (Shaikh & Prabhu, 2007). Cryogenic freezers are insulated enclosures or chambers surrounding a product conveyor with a method to introduce and regulate the amount of cryogen into the chamber. It is important to note that during cryogenic freezing, meat is not immersed into the cryogen, e.g., liquid carbon dioxide or liquid nitrogen. The meat is sent on a conveyor a short distance above the cryogen. It is the vapor of the cryogen that causes the meat to freeze.

Gunther (2015) studied the effect of cryogenic freezing (using liquid nitrogen vapor) on *Campylobacter*-inoculated ground turkey patties containing polyphosphates. It is important to note that polyphosphates are not part of the cryogenic freezing process. Rather, some establishments add polyphosphates during routine poultry processing to enhance the moisture absorbance, color, and flavor and to reduce product shrinkage of poultry. Gunther analyzed the patties for surviving *Campylobacter* after the patties were cryogenically frozen at -80°F (-62.2°C) for 4 minutes (using liquid nitrogen vapor) and stored at -20°F for 7 and 33 days.

This treatment achieved log reductions of *Campylobacter* in the frozen patties after 7 and 33 days at -20°C of 2.5 logs and 3.2 logs, respectively.

Cryogenic freezing is similar to individual quick freezing (IQF) in that the outcome results in poultry that is completely frozen solid. The way cryogenic freezing differs from IQF is the technology used to achieve the frozen state, including how it is applied to product and associated operational parameters. Establishments performing IQF typically use conventional compressor-type refrigeration units, e.g., blast freezing such as in spiral freezers. It would not be sufficient to indicate that IQF or other processing freezing procedures reduce pathogens without scientific support that such a procedure results in a pathogen reduction and identifies the associated critical operational parameters.

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)[4]. 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.

One 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 *Campylobacter* (Lewis, 2002).

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

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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	Bashor et al., 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
Crust Freezing	– No chemicals on food; no rinse required	– Expensive to install – Requires source of CO_2 or N_2	Operates at approximately -30° to -55°C Application: N/A	Georgsson, 2006 Boysen and Rosenquist, 2009
Cryogenic Freezing	– No chemicals on food; no rinse required – Odorless, colorless, tasteless	– Expensive to install and operate – CO_2 or N_2 are dangerous to handle	Operates at approximately -59°C Application: N/A	Shaikh and Prabhu, 2007
High Pressure Processing (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