GROWTH OF *ESCHERICHIA COLI* O157:H7 AND *SALMONELLA* SEROVARS ON RAW BEEF, PORK, CHICKEN, BRATWURST AND CURED CORNED BEEF: IMPLICATIONS FOR HACCP PLAN CRITICAL LIMITS

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ABSTRACT

Small amounts (10–25 g; 6.3–20.8 cm^2 inoculated area) of raw ground beef, intact beef, pork and chicken (dark and white meat),and bratwurst and cured corned beef were inoculated with Salmonella *serovars and* Escherichia coli *O157:H7, refrigerated 24 h at 5C, and then held either at 10C (± 1C) for up to 8 h or at room temperature (22C ± 2C) for up to 2 h. Except for a 0.2 log CFU increase in* Salmonella *serovars in ground beef during 2 h at room temperature, pathogens did not grow. Results of trials with commercial amounts of beef, pork, chicken, ground beef and bratwurst exposed to 10C for 8 h or 22C for 2 h also showed no pathogen growth. Potential critical limits for processing of previously refrigerated raw meat products are exposure temperatures between 5 and 10C for not more than 8 h or between 5 and 22C for not more than 2 h.*

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INTRODUCTION

Under the United States Department of Agriculture (USDA) regulations mandating the Hazard Analysis Critical Control Point (HACCP) system for ensuring safe meat and poultry products (USDA 1996), a Critical Control Point (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." The major CCP in HACCP plans for raw meat and poultry products is often the step in the process at which the product is warmest. For example, the stuffing step may be the CCP in a process for making uncooked bratwurst. At such a step, certain critical limits must be met to ensure control of significant hazards previously identified by the processor when doing a hazard analysis. Two significant microbiological hazards associated with raw meat and poultry products are *Salmonella* serovars and *Escherichia coli* O157:H7. Processors of raw products may have limited control over whether these pathogens are present in the raw meat they receive for processing. Therefore, processors must select a CCP and associated critical limits that will minimize the risk associated with contaminated raw ingredients. Regulatory officials expect processors of raw products to use CCP critical limits (time and temperature) that have been scientifically validated to not allow growth of *Salmonella* serovars and *E. coli* O157:H7. For processors of raw poultry products, the existing regulatory limit of 13C for maximum product temperature during processing (United States Department of Agriculture 2003) can be used as a critical limit, or a more restrictive critical limit may be chosen. Although validation of critical limits ideally should involve in-plant microbiological testing (Brashears *et al.* 2002), wide-scale microbiological testing is not feasible for most very small processors. The objective of this study was to provide initial, laboratory-based evidence supporting simple critical limits that could be validated for use in raw meat and poultry HACCP plans.

MATERIALS AND METHODS

Preparation of Inoculum

Although contamination of raw meat or poultry by a single pathogen strain is possible in a plant setting, the present study used multistrain "cocktails" of *E. coli* O157:H7 and *Salmonella* serovars to account for potential variation. The following *E. coli* O157:H7 strains were used: ATCC 43894, 51657, 51658 and 43895 (obtained from American Type Culture Collection, Manassas, VA; the first three strains were originally from infected patients and the fourth was from ground beef implicated in an out-

break), and USDA-FSIS-380-94 (obtained from Dr. John Luchansky, Food Research Institute, University of Wisconsin-Madison; originally from salami implicated in an outbreak). *Salmonella* serovars used were *S. hadar* S21, *S. typhimurium* S9, *S. infantis* S20, *S. enteritidis* E40, *S. anatum* S14 and *S. heidelberg* S13. All of the salmonellae were obtained from Dr. Eric Johnson, Food Research Institute, University of Wisconsin-Madison and had been used in previous challenge studies. The original source was unknown for strains S21 and S20, while strains S9, S13 and S14 were originally isolated from samples submitted to the Wisconsin State Laboratory of Hygiene. Strain E40 was a chicken ovary isolate. Frozen stock cultures were maintained in Brain Heart Infusion broth (BHIB; Difco, Becton Dickinson, Sparks, MD) with 10% (v/v) added glycerol (Fisher Scientific, Itasca, IL). Working cultures were prepared by growing each strain for two passages in BHIB and then streaking on Brain Heart Infusion Agar (BHIA; Difco). Following growth on BHIA for 24 h at 35C, the working cultures were stored at 5C. For each trial, a colony of each culture was transferred separately to 9 mL of BHIB and incubated for 24 h at 35C, and then centrifuged at $8000 \times g$ for 10 min. Each culture was then re-suspended in 9 mL of Butterfield's Phosphate Diluent (BPD, Nelson-Jameson, Marshfield, WI) and all of the cultures for each genus were combined. For bratwurst and corned beef experiments, and trials with commercial amounts of products, the cultures for each genus were combined in a sterile 50-mL plastic tube, centrifuged, decanted, re-suspended to the original volume in BPD and then the resulting cocktails for the two genera were combined, with an overall population for each genus of 8.1–8.8 log CFU/mL.

Meat and Poultry Products

For trials with small amounts (10–25 g; 6.3–20.8 cm^2 inoculated area) of meat, ground beef (20% fat), boneless beef round steak, boneless center cut pork chops, chicken leg quarters (connected drumstick and thigh, up to 6% retained water) and boneless skinless chicken breasts were purchased at a local grocery store (separate purchases for each trial), transported to the laboratory within 15 min and refrigerated $\leq$24 h until used. Uncooked bratwurst, from three different manufacturers, was purchased frozen from the same local grocery store, transported to the laboratory and thawed under refrigeration. None of these products contained ingredients added for the purpose of inhibiting microbial growth. Uncooked, cured, corned beef briskets with garnish spices added (proprietary mix) were shipped overnight from a local processor in cooler boxes with ice packs. The corned beef represented three production lots, with each lot being studied in an independent trial. The corned beef was vacuum-packaged and had been cured with up to 30% of a

mixture of water, salt, sodium phosphate, sugar, hydrolyzed corn protein, monosodium glutamate, sodium nitrite, sodium erythorbate, sodium nitrate, flavoring and dextrose. Although some of these ingredients could potentially inhibit *Salmonella* and *E. coli* O157:H7, their addition was done primarily to obtain desired color and flavor, and to inhibit endospore germination and outgrowth. The corned beef was refrigerated 4 days before use. To prepare samples, products were divided or cut into smaller portions (10–25 g; 6.3–20.8 cm^2 inoculation area) and stored at 5C until inoculation. The ground beef was subdivided and shaped into small "mini-patties" (25 g), and the beef and pork were cut into small pieces (2.5 cm × 2.5 cm surface area, 1.2 cm thick). For chicken, the skin was removed from the chicken parts and small pieces (2.5 cm × 2.5 cm surface area, 1.2 cm thick) were cut from the surface muscle. Bratwursts (4–5 links per lot) were cut into 16 equal-sized pieces. The pieces were left intact for external (casing surface) inoculation. For internal inoculation, each link was cut in half longitudinally, and then the resulting half-links were subdivided into 16 equal-sized pieces. The outer layer of each corned beef brisket was aseptically removed and cut into 6.3 cm × 6.3 cm × 0.6 cm thick pieces.

For trials with commercial amounts of meat products, two beef rounds (average weight 26.4 kg), two beef briskets (average weight 4.0 kg), two boneless pork loins (average weight 4.2 kg), 12 boneless skinless chicken breasts (average weight 615 g), six 1.4 kg chubs of ground beef round and 18 fresh pork bratwursts with natural casing (average weight 100 g) were purchased from local grocery stores and transported within 15 min to a controlled environment chamber at the University of Wisconsin-Madison where the products were stored at 5C.

Inoculation of Meat Pieces

Each mini-patty or piece of meat was inoculated with 0.1 mL of a 1:1000 dilution (BPD) of the *E. coli* O157:H7 cocktail and 0.1 mL of a 1:1000 dilution of the *Salmonella* spp. cocktail. For bratwurst and corned beef pieces, the inoculation was done with a 1:10 dilution of the combined two-genus cocktail, 0.1 mL for bratwurst and 0.3 mL for corned beef. Each inoculated piece was aseptically transferred to a sterile sample bag and refrigerated for 24 h at 5C to ensure that inoculum cells were not actively reproducing, thus simulating the situation on meat shipped and stored under refrigeration. After this 24 h refrigeration period, enumeration of inoculum organisms was done for three patties/pieces per storage treatment for each trial of each product type, as described below.

In trials with commercial amounts of products, the package of product was aseptically opened, and the packaging material either folded back (beef,

pork, ground beef) or removed (chicken, bratwurst). Products were inoculated with a 1:10 dilution of the combined two-species cocktail as follows: each of two beef rounds was inoculated at four sites with 0.5 mL spread over each 10×10 cm site; each of two beef briskets was inoculated at four sites with 0.5 mL spread over each 7.5×7.5 cm site; each of two boneless pork loins was inoculated at four sites with 0.5 mL spread over each 6.3×7.5 cm site; each of 12 boneless skinless chicken breasts was inoculated with 0.5 mL spread over one half of the exposed surface; each of two chubs of ground beef round was inoculated over the entire upper surface with 1.0 mL; the exterior of each of four fresh pork bratwursts was inoculated with 0.25 mL spread over the entire upper surface; and four bratwursts were sliced open and for each bratwurst 0.25 mL was spread evenly inside the cut. After a 30-min wait to allow bacterial attachment, the packaging material was placed back over the inoculated surface of beef, pork and ground beef. Inoculated chicken breasts and bratwursts were individually placed into commercial zip-lock food storage bags. Inoculated meat products then remained in the 5C environmental chamber for 24 h until exposure to potential growth conditions.

Exposure of Inoculated Meat Products to Potential Growth Conditions

After refrigeration, the inoculated mini-patties and small meat pieces were analyzed for initial inoculum levels or exposed to either room temperature (22C ± 2C) for 1 or 2 h, or 10C (± 1C, in a refrigerated incubator) for 2, 4, 6 or 8 h. Because of the small amounts of meat/poultry studied, environment temperature was monitored, instead of product temperature, using a thermocouple probe (K-type) with an attached data-logger (Model SP-150, Dickson Instruments, Addison, IL). Inoculated commercial amounts of meat products were exposed to a temperature of either 10C for 8 h or 22C for 2 h. In trials with commercial amounts of products, the environmental chamber temperature was then returned to 5C. Thermocouple probes (K-type) were inserted just under the surface of a beef round and bratwurst during the 10 and 22C trials. An attached data-logger recorded the time and temperature at 5-min intervals.

Enumeration of Inoculum Organisms

After the mini-patties or small meat pieces had been exposed to refrigeration and/or the various temperature/time combinations, surviving pathogens were enumerated. Enumeration was done for three samples following each storage treatment in each trial. Initially, 99 mL of BPD was added to a sample bag and the contents were stomached for 2 min using a Stomacher 400 lab blender (Fisher Scientific, Itasca, IL). Subsequent dilutions were made

in BPD and spread-plates were prepared (one plate per dilution) on Sorbitol MacConkey agar (SMAC; Oxoid, Inc., Ogdensburg, NY) and XLD agar (Oxoid) for enumeration of *E. coli* O157:H7 and *Salmonella* serovars, respectively. Plates were incubated at 35C for 24 h, typical colonies (white/colorless on SMAC, black on XLD) were counted and log CFU was calculated for each mini-patty or piece. To confirm that colonies counted were the inoculum organisms, each of five typical colonies per plating medium (trials with ground beef, intact beef, pork, chicken) or one colony per trial (trials with bratwurst and corned beef) was transferred to BHIA and incubated for 24 h at 35C. A presumptive *E. coli* O157:H7 colony from each BHIA plate was then tested for Gram reaction, cell morphology, oxidase reaction, presence of O157 antigen (DrySpot latex agglutination kit; Oxoid), and, for trials with ground beef, intact beef, pork and chicken, appearance of growth on Levine's EMB agar (Difco). A presumptive *Salmonella* colony from each BHIA plate was tested for Gram reaction, cell morphology, oxidase reaction and biochemical characteristics (API 20E kit; bioMerieux, Inc., Hazelwood, MO). Throughout the study, all presumptive colonies were confirmed as the appropriate inoculum species.

For trials with commercial amounts of product, samples were analyzed after 24 h at 5C and then after 4 and 8 h exposure to 10C or after 1 and 2 h exposure to 22C; samples were also analyzed 24 h after the 10C trials. Each sample was obtained by excising the inoculated area with a sanitized (70% ethanol) knife. The sample was transferred to a stomacher filter bag and analyzed as described above. Confirmation tests confirmed presumptive colonies also as described above.

Statistical Analysis

For trials with small amounts (10–25 g; 6.3–20.8 cm^2 inoculated area) of meat, the log CFU/piece values for each sample after a given storage treatment in a trial were averaged. Then, the three resulting values (three trials) for a given storage treatment were averaged. The resulting value was compared with the value obtained after 24 h at 5C using the two-sample *t*-test (Minitab, release 12.22, Minitab, Inc., State College, PA) with a significance level of 0.05. No statistical analysis was done for trials with commercial amounts of meat.

RESULTS AND DISCUSSION

Initially, small amounts of ground beef, intact beef, pork, chicken dark meat and chicken white meat, and cured corned beef and bratwurst were inoculated with multistrain cocktails of *Salmonella* serovars and *E. coli*

O157:H7. Small amounts of product were used because they would warm up much faster than the large amounts of meat used in meat processing plants, thus increasing the likelihood of pathogen growth. Samples were inoculated with approximately 5 log CFU of *E. coli* O157:H7 and *Salmonella* spp., refrigerated at 5C for 24 h (to be sure that the inoculum organisms were not reproducing, simulating their condition in previously refrigerated meat) and then exposed to either 10C (± 1C) for up to 8 h, or room temperature (22C ± 2C) for up to 2 h. In these initial trials, changes in log CFU/piece were small after all storage treatments tested, ranging from an increase of 0.2 to a decrease of 0.2 (Table 1). No value obtained after any storage treatment was significantly different ($P < 0.05$) from the initial value, with the exception of that for *Salmonella* on the ground beef mini-patties after 2 h at 22C (panel A); however, the latter 0.2 increase in log CFU/piece is probably not of practical significance. It was clear from these results that short-term increases in raw meat temperature would have little effect on numbers of *E. coli* O157:H7 and *Salmonella* serovars present on meat and poultry products. Interestingly, the results suggested that short-term exposure of poultry pieces to temperatures above the 13C regulatory limit would not result in dangerous pathogen growth. The lack of growth observed in laboratory experiments was consistent with that predicted for *E. coli* O157:H7 and *Salmonella* by the United States Department of Agriculture, Agricultural Research Service PMP 6.1 computer-generated predictive model (USDA-ARS, Eastern Regional Research Center, Wyndmoor, PA). For a pH 6.5 broth system with 0.5% water-phase salt and no added sodium nitrite (least restrictive conditions in the model), the model predicted that *E. coli* O157:H7 would remain in lag phase for 54.0, 6.6 and 3.6 h at 10, 20 and 24C, respectively. Generation times for *E. coli* O157:H7 at these temperatures were predicted to be 5.3, 1.1 and 0.7 h, respectively. For *Salmonella* under the same broth culture conditions, the model predicted lag times of 63.4, 6.9 and 4.5 h and generation times of 9.4, 1.0 and 0.6 h, respectively.

The surface temperature for small pieces of meat would rapidly increase to at or near the storage temperature, with the interior temperature also increasing rapidly. In intact whole muscle product (beef, pork and chicken pieces), pathogenic bacteria are only expected to be on the surface, because the interior of muscle tissue is virtually free of microbes. The surface is the first part of the samples to warm or cool when exposed to changing temperatures. Within practical limits, temperature changes within intact muscle have little effect on surface microbial growth. Ground meat (mini-patties and bratwurst) represents a different case as microbes are distributed throughout, and the slowest-cooling part of the ground meat mass is the key area when evaluating microbial growth. Compared with the samples used in our

TABLE 1.
LOG CFU/G OF *SALMONELLA* SEROVARS AND *ESCHERICHIA COLI* O157:H7 ON SMALL AMOUNTS (10–25 G; 6.3–20.8 CM^2 INOCULATED AREA) OF MEAT AND POULTRY PRODUCTS STORED AT 5C FOR 24 H AND THEN AT EITHER 10C OR ROOM TEMPERATURE (RT; 22C ± 2C). PRODUCTS ARE GROUND BEEF MINI-PATTY (PANEL A), INTACT BEEF (B), INTACT PORK (C), CHICKEN WHITE MEAT (D), CHICKEN DARK MEAT (E), BRATWURST EXTERIOR (F), BRATWURST INTERIOR (G) AND CURED CORNED BEEF (H)

	Storage treatment conditions	Log CFU per piece*	
		E. coli O157:H7	*Salmonella* serovars
A = ground beef mini-patty	Initial (24 h, 5C)	4.7 (0.1)	4.5 (0.1)
	1 h at RT	4.7 (0.1)	4.5 (0)
	2 h at RT	4.8 (0.1)	4.7 (0.1)†
	2 h at 10C	4.7 (0)	4.5 (0)
	4 h at 10C	4.7 (0.1)	4.5 (0)
B = beef piece	Initial (24 h, 5C)	4.6 (0.1)	4.6 (0.1)
	1 h at RT	4.7 (0.1)	4.6 (0.1)
	2 h at RT	4.8 (0.1)	4.6 (0.1)
	2 h at 10C	4.7 (0)	4.5 (0.1)
	4 h at 10C	4.8 (0.1)	4.6 (0)
C = pork piece	Initial (24 h, 5C)	4.6 (0)	4.5 (0.1)
	1 h at RT	4.5 (0)	4.5 (0.1)
	2 h at RT	4.5 (0.1)	4.5 (0.1)
	2 h at 10C	4.6 (0.1)	4.5 (0.1)
	4 h at 10C	4.5 (0.1)	4.5 (0.1)
D = chicken white meat piece	Initial (24 h, 5C)	4.7 (0.2)	4.3 (0.2)
	1 h at RT	4.6 (0.1)	4.2 (0.2)
	2 h at RT	4.7 (0.2)	4.3 (0.1)
	2 h at 10C	4.8 (0.1)	4.3 (0.1)
	4 h at 10C	4.7 (0.1)	4.2 (0.1)
E = chicken dark meat piece	Initial (24 h, 5C)	4.7 (0)	4.3 (0.1)
	1 h at RT	4.7 (0.2)	4.4 (0.1)
	2 h at RT	4.8 (0.1)	4.3 (0.1)
	2 h at 10C	4.6 (0.1)	4.3 (0.1)
	4 h at 10C	4.7 (0.1)	4.4 (0.1)
F = exterior of bratwurst	Initial (24 h, 5C)	5.3 (0.1)	5.2 (0.1)
	4 h at 10C	5.1 (0.2)	5.0 (0.2)
	6 h at 10C	5.2 (0.1)	5.1 (0.1)
	8 h at 10C	5.2 (0.1)	5.1 (0.2)
G = interior of bratwurst	Initial (24 h, 5C)	5.5 (0.1)	5.4 (0.1)
	4 h at 10C	5.5 (0)	5.4 (0.1)
	6 h at 10C	5.5 (0.1)	5.3 (0.2)
	8 h at 10C	5.5 (0.1)	5.3 (0)
H = corned beef piece	Initial (24 h, 5C)	5.9 (0.1)	5.8 (0.1)
	4 h at 10C	5.9 (0.1)	5.8 (0)
	6 h at 10C	5.9 (0.2)	5.8 (0.1)
	8 h at 10C	5.8 (0.2)	5.7 (0.2)

* Values are means ($n = 3$) with standard deviations in parentheses. Absence of a superscript indicates no significant difference ($P \geq 0.05$) from initial value).

† Value is significantly different ($P < 0.05$) from initial value.

study, larger masses of meat would take considerably longer to increase in temperature, thus there would be a smaller likelihood of pathogen growth. In addition, though, large masses of ground meat would take a longer time to cool once they did increase in temperature. Ideally, meat and poultry processors should determine actual processing plant and product temperatures at various times during the processing day, over an extended time, to fully understand their product temperature history. Additionally, processors should obtain microbiological testing data for indigenous microorganisms, e.g., coliform count, Aerobic Plate Count, for use in validating critical limits. If no increase in numbers of these indigenous microbes occurs when the proposed critical limits are followed, then the critical limits could be considered fully validated. Such an approach was taken by Brashears *et al*. (2002) to validate a beef fabrication critical limit of processing room temperature at 14C or lower for no more than 4 h.

Results of subsequent trials with commercial amounts of meat (Table 2) confirmed the findings of trials with small meat pieces. There was no evidence of growth on any of the products during exposure to either 10C for 8 h or 22C for 2 h. In 10C trials the temperatures just below the surface of the beef round (largest piece of meat) and the bratwurst (smallest piece) did not exceed 8.3C during the 8-h exposure time and were back to 5C within 5.5 and 0.5 h, respectively, after the room was re-cooled. In 22C trials, the beef round temperature did not exceed 13C during the 2- h exposure time, and had cooled to 5C in 1.5 h after the room was recooled. The bratwurst surface temperature rose to 19C during the 2-h exposure time at 22C, but had cooled to 5C within 1.25 h after the room was recooled. Samples analyzed 24 h after the end of the 10C exposure showed no evidence of pathogen growth. These findings suggest that pathogen growth is unlikely in recooling raw meat and poultry products after short-term exposure to 10–22C temperatures.

Given that 5C is widely regarded as a safe temperature for preventing growth of nonpsychrotrophic pathogenic bacteria in potentially hazardous foods (United States Food & Drug Administration 2001), critical limits for a specific HACCP plan could address the time that the relevant temperature (product or processing room) is above this temperature. With temperature and microbiological data in hand, processors could establish scientifically valid critical limits involving processing plant or product temperature and times, and design their monitoring programs accordingly. Our results suggest that the following times and temperatures should be considered potential critical limits for preventing the growth of *Salmonella* serovars and *E. coli* O157:H7 on raw meat and poultry: products can be exposed to temperatures between 5 and 10C for not more than 8 h or to temperatures between 5 and 22C for not more than 2 h. The existing regulatory limit for raw poultry temperature during processing is supported by our results. Furthermore, our poultry results

TABLE 2.
LOG CFU/G OF *SALMONELLA* SEROVARS AND *ESCHERICHIA COLI* O157:H7 ON COMMERCIAL AMOUNTS OF MEAT AND POULTRY PRODUCTS STORED AT 5C FOR 24 H AND THEN AT EITHER 10C OR ROOM TEMPERATURE (RT; 22C ± 2C). PRODUCTS ARE BEEF ROUND (A), BEEF BRISKET (B), PORK LOIN (C), CHICKEN BREAST (D), GROUND BEEF (E), BRATWURST EXTERIOR (F) AND BRATWURST INTERIOR (G)

	Storage treatment conditions	Log CFU per piece	
		E. coli O157:H7	*Salmonella* serovars
A = beef round	Initial (24 h, 5C)	4.8	4.7
	1 h at RT	5.3	5.3
	2 h at RT	4.7	4.5
	Initial (24 h, 5C)	5.3	5.1
	4 h at 10C	5.5	5.4
	8 h at 10C	5.3	5.1
B = beef brisket	Initial (24 h, 5C)	5.1	5.1
	1 h at RT	4.7	4.5
	2 h at RT	4.6	4.4
	Initial (24 h, 5C)	5.3	4.8
	4 h at 10C	5.5	5.1
	8 h at 10C	4.6	4.4
C = Pork loin	Initial (24 h, 5C)	4.8	4.7
	1 h at RT	4.5	4.1
	2 h at RT	4.2	3.9
	Initial (24 h, 5C)	4.7	4.7
	4 h at 10C	4.8	4.6
	8 h at 10C	4.5	4.4
D = Chicken breast	Initial (24 h, 5C)	4.9	4.8
	1 h at RT	4.8	4.7
	2 h at RT	4.8	4.6
	Initial (24 h, 5C)	4.6	4.1
	4 h at 10C	4.6	4.3
	8 h at 10C	4.9	4.7
E = Ground beef	Initial (24 h, 5C)	4.9	4.8
	1 h at RT	4.6	4.5
	2 h at RT	4.7	4.6
	Initial (24 h, 5C)	4.6	5.3
	4 h at 10C	5.2	4.9
	8 h at 10C	5.0	4.8
F = Bratwurst exterior	Initial (24 h, 5C)	4.6	4.3
	1 h at RT	4.8	4.4
	2 h at RT	4.7	4.4
	Initial (24 h, 5C)	4.7	4.3
	4 h at 10C	4.7	4.5
	8 h at 10C	4.7	4.4
G = Bratwurst interior	Initial (24 h, 5C)	5.4	5.1
	1 h at RT	4.9	4.8
	2 h at RT	5.3	5.0
	Initial (24 h, 5C)	5.5	5.2
	4 h at 10C	5.1	5.1
	8 h at 10C	5.0	5.2

could be useful in evaluating poultry processing deviations involving short-temperature elevation.

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