DEVELOPING TIME-TEMPERATURE THERMAL PROCESSING GUIDELINES FOR READY-TO-EAT MEAT AND POULTRY PRODUCTS

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Abstract - USDA, FSIS Appendix A is widely used as validation support for thermal processes of processed meats, but its time-temperature tables were developed only for *Salmonella* in roast, cooked, and corned beef. The objective of this study was to develop pathogen- and product-specific time-temperature tables to improve validation of thermal processes. Ground roast beef, turkey breast, or ham was inoculated with 8 log CFU/g *Listeria monocytogenes* or *Salmonella* (5-strain mix) or STEC (7-strain mix). D- and z-values were generated for each product and pathogen combination using ground, inoculated, one-gram portions heated to one of four temperatures (54.4, 60, 65.6, and 71.1°C) in a water bath. To validate thermal death times, roast beef, turkey breast, and ham were manufactured, inoculated, stuffed into 4" (10.16 cm) diameter casings, and cooked to one of three final temperatures (54.4, 62.8, or 71.1°C) according to commercial thermal processes. Samples were removed from core, midpoint, and surface to enumerate surviving pathogens at pre-determined time-points during cooking. Results confirm that the cooking temperatures and times in Appendix A are sufficient to inactivate pathogens when temperatures meet or exceed 62.8°C. This study will provide new thermal processing guidance to appropriately address pathogenic bacteria in RTE meat products.

Key Words –Food safety, Lethality, Validation

- INTRODUCTION

Thermal treatments are critical in controlling foodborne pathogens in ready-to-eat (RTE) meat and poultry products. Currently, U.S. meat industry establishments manufacturing RTE meat and poultry products have limited science-based supporting documentation to ensure and validate the thermal destruction of pathogenic microorganisms during cooking. One lethality tool that has gained widespread adoption is the USDA, FSIS Appendix A "Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat And Poultry Products," which is used extensively by the meat industry to establish validated thermal processes [1]. Appendix A is based on research conducted by Goodfellow and Brown [2] on the fate of *Salmonella* inoculated in beef for cooking, but is applied to a wide array of products including hams, hot dogs, luncheon meats, and jerky, to name a few.

Heat resistance of microorganisms is affected by several factors, including bacterial properties such as the pathogen of interest, cell concentration, phase of growth, strain, and exposure to stressors such as acid or salt [3]. The intrinsic properties of food, such as fat content, water activity, or meat species, also influence the heat resistance of pathogens [4, 5, 6].

Pathogen- and product-specific time-temperature tables are needed to improve validation of thermal processes. The objective of this study was to determine the temperature-death times of *Listeria monocytogenes*, *Salmonella*, and shiga-toxin producing *E. coli* (STEC) in RTE roast beef, ham and turkey breast, and develop validated time-temperature tables for destruction of these pathogens in a wide array of RTE meat products.

- MATERIALS AND METHODS

This research was completed in two phases. In Phase I, ground turkey breast (containing 1.5% salt, 1.5% dextrose, 20% water), ground roast beef (containing 1.0% salt, 0.35% sodium phosphates, 0.75% sugar, 20% water), and ground ham (containing 2.5% salt, 1.65% sugar, 0.35% sodium phosphates, 547 ppm sodium erythorbate, 200 ppm sodium nitrite, 20% water) were inoculated with 8 log CFU/g *L. monocytogenes* or *Salmonella* (5-strain mixes) or STEC (7-strain mix). One-g portions (0.5-1.0 mm in moisture-impermeable vacuum pouches) were heated at one of four temperatures (54.4, 60, 65.6, or 71.1°C) by submerging in a water bath. Triplicate samples were removed and immediately chilled to ≤4°C when meat reached target temperature (ca. 6-12 sec) and at seven additional times. Surviving *L. monocytogenes, Salmonella,* or STEC were enumerated using Modified Oxford, XLD, or Sorbitol MacConkey agar base, respectively, with thin layer overlay of nonselective media to enhance recovery of injured cells. Each study was replicated twice. Linear regressions of the data were used to calculate D- and z-values for each treatment combination (3 product types x 3 pathogens x 4 temperatures). From this data, treatment combinations were selected for validation using commercial production processes. Table 1 shows the treatment combinations used for validation in Phase II.

Table 1 Treatment combinations used for Phase II validation.

Product	Pathogen	Final Temperature (° C)
Turkey	*Salmonella*	71.1
Roast beef	*Salmonella*	54.4
Roast beef	*Salmonella*	62.8
Roast beef	*Salmonella*	71.1
Roast beef	STEC	54.4
Roast beef	STEC	62.8
Roast beef	STEC	71.1
Ham	*Listeria*	62.8
Ham	*Listeria*	71.1

In Phase II, turkey breast, roast beef, and ham were manufactured according to the same formulations used in the first phase, inoculated with 8 log CFU/g of the designated pathogen cocktail, and stuffed into 4" (10.61cm) diameter casings. Treatments were cooked to one of three target temperatures (54.4, 62.8, or 71.1°C) using either a step-up steam (turkey breast, roast beef) or wet bulb/dry bulb (ham) thermal process. Triplicate 25-g samples were removed from the core, midpoint, and surface of each chub for enumeration of surviving pathogens at 3 pre-determined time-points during each thermal process (54.4°C - sampled at 54.4, 54.4 +1 h, and 54.4°C +2 h; 62.8°C - sampled at 54.4, 62.8, and 62.8°C +5 min; 71.1°C - sampled at 54.4, 62.8, and 71.1°C). Additional samples were processed after chilling to ≤4°C to account for integrated lethality during cooling. Surviving *L. monocytogenes, Salmonella* or STEC were enumerated using Modified Oxford, XLD or Sorbitol MacConkey agar, respectively, with thin layer overlay of nonselective media to enhance recovery of injured cells. Each treatment combination was replicated twice.

- RESULTS AND DISCUSSION

Table 2 displays the D-values, in minutes, for each treatment combination.

Table 2 D-values (minutes) for *Salmonella, L. monocytogenes,* and STEC in roast beef, turkey breast, and boneless ham.

	54.4°C	60.0°C	65.6°C	71.1°C

Salmonella				
Beef	11.90*	0.72	0.18	0.02
Turkey	20.83	2.42	0.24	0.03
Ham	16.67	1.50	0.25	0.02
Listeria				
Beef	55.56	7.25	1.98	0.41
Turkey	55.56	5.95	0.62	0.07
Ham	55.56	9.26	1.33	0.33
STEC				
Beef	33.33*	1.63	0.21	0.02
Turkey	33.33	2.22	0.19	0.02
Ham	33.33	1.09	0.12	0.03

- Although this D-value was repeatable in a meat wafer system, it was not validated in a commercial process and may underrepresent true D-value. Low D-value may be due to differences in heat-stress response during short come-up time.

In all product types, inactivation rates for STEC were similar to *Salmonella* at 60, 65.6, or 71.1°C, and were comparable to or less than times reported in Appendix A. In contrast, *L. monocytogenes* showed greater thermotolerance than *Salmonella* and STEC under all conditions. For example, a >5 log reduction of *Salmonella* and STEC in turkey was achieved instantaneously at 71.1°C, whereas *L. monocytogenes* was inactivated within 10 seconds. At 60°C, >5 log reduction of *L. monocytogenes* required 30 and 50 minutes in turkey and ham, respectively, as compared to <12 minutes for *Salmonella* and STEC. At the lowest temperature tested (54.4°C), >5-log reduction of *Salmonella,* STEC, and *L. monocytogenes* in all product types was achieved in <2, 2.8, and 4.6 hours, respectively. Preliminary results from Phase I support Appendix A as an acceptable tool for *Salmonella* and STEC lethality, and as expected, *L. monocytogenes* was more thermotolerant than *Salmonella* or STEC. Since Phase I data were generated using model systems and one gram meat samples, only immediate lethality was measured, while integrated lethality was not accounted for to determine expected total lethality in a commercial process.

Validation during Phase II confirmed that cooking to 71.1°C was sufficient to kill >6 log of the 3 pathogens in all the products tested. STEC and *Salmonella* were similarly inactivated in roast beef when cooked to 62.8°C, but the additional lethality contributed during cooling was necessary to inactivate >6 log *L. monocytogenes* in ham cooked to a final temperature of 62.8°C. Less than 4 log of *Salmonella* or STEC were inactivated in the core samples of beef heated to 54.4°C and held for 2 hours. Additional investigation is needed to identify hold times or other modifications necessary to achieve >6 log reductions of *Salmonella* and STEC when utilizing 54.4°C as the final cook temperature for roast beef.

- CONCLUSION

Results from this study confirm that cooking temperatures and times identified in Appendix A are sufficient to kill pathogens when temperatures meet or exceed 62.8°C. Results also provide new thermal processing guidance to appropriately address pathogenic bacteria in RTE meat products. Project results from generating D- and Z- values as well as understanding additional lethality effects from integrated validation will be important for establishing new data for use in pathogen modeling programs.

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