PS5.06 Ensuring Compliance with Lethality Microbiological Performance Standards for Meat Products Using Alternative Cooking Procedures for Large, Intact Meat Products 333.00

Kerri Harris (1) kharris@tamu.edu, Ashley Haneklaus(1), Mayra Marquez-Gonzalez 2, Lisa Lucia 1 Alejandro Castillo 1 Margaret Hardin 1 Wesley Osburn 1 Jeffrey Savell 1
(1)Texas A&M University
(2)University of Gualajara

***Abstract*—The United States Department of Agriculture - Food Safety and Inspection Service (USDA-FSIS) has specific microbiological performance standards for fully cooked, ready-to-eat products. To assist establishments in meeting the performance standards, FSIS developed guidelines for cooking temperatures, times, and relative humidity. Producers of large products often find these guidelines too restrictive and would prefer to utilize alternative cooking temperatures, times, and relative humidities to comply with the performance standard. This project was designed to determine if alternative cooking parameters would comply with the USDA-FSIS performance standard. Large (10.43 to 12.25 kg), cured bone-in hams (n = 80) and large (≥ 9.07 kg), uncured beef inside rounds (n = 80) were obtained and subjected to ten different treatments. The effect of alternative lethality parameters on log reductions of *Salmonella* Typhimurium and coliforms, and the toxin production of *Staphylococcus aureus* was evaluated. Products were subjected to 1 of 10 treatments defined by varying final internal product temperatures (48.9ºC, 54.5ºC, 60.0ºC, 65.6ºC, or 71.1ºC) and relative humidities (50 or 90%). For all treatments, at least a 6.5 log reduction in *S.* Typhimurium was achieved and coliform counts also were significantly reduced for both hams and roast beef. *S. aureus* toxin kits returned negative results for toxin production across all treatments for both products. Relative humidity did not alter lethality effectiveness for any of the treatments. In conclusion, the results of this study demonstrate that alternative cooking temperatures, times, and humidities can achieve the performance standard established by USDA-FSIS for fully cooked, ready-to-eat products.**

A. N. Haneklaus is with Texas A&M University, College Station, TX 77843 USA; (1+979-845-3935; fax: 1+979-845-9454; e-mail: ahaneklaus@tamu.edu).

M. Marquez-Gonzalez was with Texas A&M University, College Station, TX 77843 USA. She is now with the Department of Biology and Pharmacy, University of Guadalajara, Guadalajara, Jalisco 44430 Mexico (e-mail: maymago@hotmail.com).

L. M. Lucia is with Texas A&M University, College Station, TX 77843 USA (e-mail: llucia@tamu.edu).

A. Castillo is with Texas A&M University, College Station, TX 77843 USA (e-mail: a-castillo@tamu.edu).

M. D. Hardin is with Texas A&M University, College Station, TX 77843 USA (e-mail: margaret.hardin@tamu.edu).

W. N. Osburn is with Texas A&M University, College Station, TX 77843 USA (e-mail: osburnw@tamu.edu).

K. B. Harris is with Texas A&M University, College Station, TX 77843 USA (e-mail: kharris@tamu.edu).

J. W. Savell is with Texas A&M University, College Station, TX 77843 USA (e-mail: j-savell@tamu.edu).

***Index Terms*— lethality, meat, performance standards, *Salmonella*.**

I. INTRODUCTION

During the production of ready-to-eat and partially cooked meat and poultry products, establishments must meet microbiological performance standards set in place by the United States Department of Agriculture, Food Safety Inspection Service (USDA-FSIS). These standards, found in Chapter 9 of the Code of Federal Regulations (CFR), "set forth levels of pathogen reduction and limits on pathogen growth that official meat and poultry establishments must achieve in order to produce unadulterated products" [5]. More specifically, 6.5-$\log_{10}$ reduction of *Salmonella* in ready-to-eat beef products and 7-$\log_{10}$ reduction in ready-to-eat poultry must be achieved in ready-to-eat products to achieve the required lethality. [5].

USDA-FSIS published a compliance guideline entitled, "Appendix A Compliance Guidelines for Meeting Lethality Performance Standards for Certain Meat and Poultry Products." [3]. The guideline provided cooking parameters that provides temperatures and times that have been validated to comply with the lethality performance standards. Establishments that produce large hams and roast beef products may desire to use different cooking parameters than those provided in the guidelines; however, they must have sufficient data to demonstrate that the microbiological performance standard is met.

In addition to temperature and time requirements, the relative humidity is also important. Several studies suggest that maintaining a high relative humidity during the cooking process is needed to

achieve adequate lethality. Injecting steam during the cooking process has been used to destroy *Salmonella* on the surface of beef [1, 2]. The importance of maintaining a high relative humidity during thermal processing in order to ensure sufficient destruction of *Salmonella* is addressed in the USDA-FSIS compliance guidelines for lethality [3]. These guidelines recommend using a sealed oven or steam injection to raise the relative humidity above 90% during the cooking process.

Establishments producing fully-cooked, ready-to-eat products often identify *Salmonella* as a food safety hazard and establish critical control points in their HACCP (Hazard Analysis and Critical Control Point) systems to eliminate it. Many establishments utilize the compliance guidelines as support for their critical limits. Therefore, failure to meet the compliance guidelines results in a deviation from a critical limit that requires them to take corrective actions to address the safety of the product. The identification of additional cooking parameters that comply with the performance standard would allow establishments more flexibility when setting critical limits that ensure the safety of the products.

II. MATERIALS AND METHODS

A. Raw materials

Eighty bone-in hams (IMPS # 401A) [4], weighing between 10.43 and 12.25 kg, and eighty boneless beef inside rounds (IMPS # 168) [4], weighing greater than 9.07 kg, were purchased from a commercial processing facility and shipped frozen to the Rosenthal Meat Science and Technology Center at Texas A&M University.

B. Treatment structure

Eight hams and eight inside rounds were assigned randomly to each of the ten cooking treatments. For both ham and roast beef, each lethality treatment (n = 8) was conducted twice, with each run (n = 4) taking place on separate days. Treatments are outlined in Table 1.

Table 1. Final internal temperature (°C) and relative humidity (%) parameters by treatment for lethality

Treatment Number	Temperature	Humidity
1	48.9	90
2	54.4	90
3	60.0	90
4	65.6	90
5	71.1	90
6	48.9	50
7	54.4	50
8	60.0	50
9	65.6	50
10	71.1	50

C. Raw material preparation

Minor processing of each ham and roast took place before treatment application. For each treatment group, frozen hams and roasts were removed from the freezer (-40ºC) and were allowed to thaw at approximately 1.1ºC. Each thawed ham or roast was weighed and trimmed free of intermuscular fat and connective tissue required to expose the *M. gracilis* and *M. semimembranosus* muscles. Trimming of the product allowed increased uniformity between products and a fresh lean surface for microorganism attachment during inoculation. During the weighing and trimming process, each ham and roast were assigned an individual identification number and an associated treatment group (run). Following trimming, each ham and roast were re-weighed to assess compliance with the weight parameters set forth in the proposal for this experiment; this weight is referred to as the "trimmed weight." After initial product preparation, hams were cured. Using a curing pump with a four-needle hand-valve injector, hams were stitch pumped to 20% of their raw, trimmed weights with a brine solution consisting of 2% sodium chloride, 2% sucrose, 200 ppm sodium nitrite, 540 ppm sodium erythorbate, and 5000 ppm of sodium tripolyphosphate. Pumped hams were weighed to verify initial brine retention (≥ 20% of initial raw trimmed ham weight), placed in gondolas (by run), covered with plastic, and allowed to equilibrate at approximately 1.1°C for 12 to 15 h prior to thermal processing. Post-equilibration, each ham was re-weighed to determine final brine retention.

D. Inoculation procedures

Surfaces of either hams or beef were delineated with metal pins to differentiate areas for individual organism inoculation. Approximately 100 cm^2 was inoculated with the bacterial suspension of either *S.* Typhimurium or the coliform cocktail with a sterile disposable spreader (VWR). Approximately 200

cm^2 was inoculated with the bacterial suspension of *S. aureus* using a sterile disposable spreader. The initial inoculum concentration of each organism on the ham surface was approximately 5.8, 8.0, 7.8-log_{10} CFU/cm^2 for *S. aureus*, coliforms and *S.* Typhimurium, respectively. The initial inoculum concentration of each organism on the roast beef was approximately 6.1, 8.2, and 8.5-log_{10} CFU/cm^2 for *S. aureus*, coliforms and *S.* Typhimurium, respectively. The inoculation area was contained well within the boundaries established with the pins (> 3 cm) to prevent run off. Each inoculated ham or roast beef was allowed a 15 to 30 min dwell time for proper attachment of the microorganisms. An initial sample was taken to provide a baseline data point for which post-treatment lethality could be compared.

Prior to thermal processing, representative samples were removed from each of the inoculated areas before cooking by excising one 10-cm^2 (2 mm in depth) area, and placing the sample into a sterile stomacher bag. The uncooked samples were packed in an insulated cooler with refrigerant packs and transported from the smokehouse to the Food Microbiology Laboratory located in the adjacent building for analysis.

E. Thermal processing

Both hams and roast beef were placed in a smokehouse and subjected to thermal processing schedules with varying final internal temperatures. The treatments consisted of cooking hams and roast beef at either 50% or 90% relative humidity. Steam humidity was injected into the smokehouse to achieve and maintain the appropriate levels of relative humidity. Hams and roasts were removed from the smokehouse for sampling when the internal product temperatures reached 48.9ºC, 54.4ºC, 60.0ºC, 65.6ºC, or 71.1ºC, as determined by treatment designation. The ten treatments for each product type were derived from cooking the product to one of five internal temperatures at either 50% or 90% humidity, as previously outlined in Table 1.

F. Microbiological analysis

Post thermal processing, after the designated final internal product temperature was achieved, the hams or roast beef were removed from the smokehouse and a 10-cm^2 area (2 mm in depth) was immediately excised from each inoculated area, placed into a sterile bag, and immersed in an ice slurry to prevent continued rise in product temperature. Post-lethality samples were transported from the smokehouse area to the Food Microbiology Laboratory located in the adjacent building for analysis. For staphylococcal enterotoxin production assay, approximately 50 g of lean was excised from the surface of either the ham or roast beef, placed in a sterile bag, and immersed in an ice slurry. These samples were transported to the Food Microbiology Lab for further analysis.

The microbiological analyses taken after each cooking treatment demonstrated which treatments met the USDA-FSIS lethality microbiological performance standards by producing at least a 6.5-log_{10} reduction of *Salmonella.*

G. Statistical analysis

Data were analyzed using PROC GLM of SAS (SAS Institute, Inc., Cary, NC). Least squares means were generated for main effects and separated using PDIFF option when appropriate with an alpha-level ($P < 0.05$).

III. RESULTS AND DISCUSSION

The initial log_{10} CFU/cm^2 concentration of *S.* Typhimurium for all treatments was sufficient to produce a 6.5-log_{10} reduction as shown by Tables 2 and 3.

Table 2. Least squares means of initial log_{10} (CFU/ cm^2) concentration of inoculum by organism for ham lethality treatments

	Ham		
	Salmonella	Coliforms	*S. aureus*
Mean Initial concentration	7.8	8.0	5.8
Minimum initial concentration	6.6	6.9	4.9
Maximum initial concentration	8.6	8.7	6.7
SEM[1]	0.04	0.04	0.03

[1]SEM = is the standard error of the least squares means.

Table 3. Least squares means of initial log_{10} (CFU/ cm^2) concentration of inoculum by organism for roast beef lethality treatments

	Roast Beef		
	Salmonella	Coliforms	*S. aureus*
Mean Initial concentration	8.5	8.2	6.1
Minimum initial concentration	7.5	7.7	5.2
Maximum initial concentration	9.4	9.4	6.8
SEM[1]	0.04	0.03	0.04

[1]SEM = is the standard error of the least squares means.

All lethality treatments applied to ham and roast beef produced post-lethality samples with < 1 CFU/cm^2 of *S.* Typhimurium, *S. aureus* vegetative cells, and coliforms (Tables 4 and 5). Therefore, all internal temperature and relative humidity combinations yielded product that met USDA-FSIS lethality performance standards. Further, all toxin test kits returned negative results for *S. aureus* toxin

production. In some cases, it may appear that a 6.5-$\log_{10}$ reduction in *S.* Typhimurium was not achieved. For purposes of statistical analysis, raw plate counts of < 1 CFU/cm^2 were represented as a log value of 0.7. Therefore, a minimum reduction value of 5.9-$\log_{10}$ CFU/cm^2 for *S.* Typhimurium appears misleading, as shown in Tables 3 and 4. If 0.7-$\log_{10}$ CFU/ cm^2 is added to 5.9-$\log_{10}$ CFU/cm^2, a net reduction of 6.6-$\log_{10}$ CFU/cm^2 of *S.* Typhimurium is observed.

Table 4. Least squares means of $\log_{10}$ (CFU/ cm^2) reduction by organism for ham lethality treatments

	Ham		
	Salmonella	Coliforms	*S. aureus*
Mean reduction	7.1	6.4	5.7
Minimum reduction	5.9	5.4	4.7
Maximum reduction	7.9	7.2	6.5
SEM[1]	0.04	0.04	0.04

[1]SEM = is the standard error of the least squares means.

Table 5. Least squares means of $\log_{10}$ (CFU/ cm^2) reduction by organism for roast beef lethality treatments

	Roast Beef		
	Salmonella	Coliforms	*S. aureus*
Mean reduction	7.8	7.5	5.4
Minimum reduction	6.8	7.0	4.5
Maximum reduction	8.7	8.7	6.1
SEM[1]	0.04	0.03	0.04

[1]SEM = is the standard error of the least squares means.

IV. CONCLUSION

Temperature, times, and humidities for cooking other than those defined in USDA-FSIS's compliance guideline can be used to comply with the required lethality microbiological performance standards. The identification of alternative cooking parameters for large hams and roast beef will allow establishments additional choices for processing these products. The increased flexibility associated with cooking large, whole-muscle cuts, while still complying with the required performance standards, will also help establishments ensure product safety and meet HACCP requirements.

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