The Effects of Chilling Temperature of Bone-in Fully-Cooked Hams on Microbial Growth and Shelf Life [1]

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Clostridium perfringens is bacteria commonly found in soil, water, and air that cross contaminates the external surface of carcasses during processing (McClung, 1945; Dische and Elek, 1957). The inside of a whole-muscle product is essentially sterile, but bacteria, can be introduced from the outside surface during needle injection. Cooking meat products to a proper endpoint temperature (≥ 158ºF) kills the vegetative bacterial cells. However, *C. perfringens* spores can survive, germinate, and grow if the proper environment exists (Kalinowski et al., 2003). *C. perfringens* spores grow in the absence of oxygen and growth is maximized at temperatures from 60°F to 130°F. Therefore, *C. perfringens* is the primary pathogen of concern during cooling of red meat products (USDA, 2005). A person must consume approximately 10^6 -10^7 or 1 to 10 million *C. perfringens* spores to result in food-borne illness (McClung, 1945; Dische and Elek, 1957; Kalinowski et al., 2003).

In 1999, the Food Safety Inspection Service (FSIS) branch of USDA published a performance standard requiring that cooked meat and poultry products must have less than a 1 log growth of spore-forming bacteria, such as *C. perfringens*, during cooling or stabilization (USDA, 1999) http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/95-033F.pdf. From this, the USDA developed "Appendix B, Guidelines for Cooling Heat-Treated Meat and Poultry Products (Stabilization)" (USDA, 2005) http://www.fsis.usda.gov/PDF/CPerfringens_Risk_Assess_ExecSumm_Sep2005.pdf. These guidelines were suggested to be followed to prevent bacterial growth and ultimately food-borne illness. Appendix B recommends cured meat should be chilled from 130°F to 80°F within five hours and then from 80°F to 45°F in an additional ten hours for a total chilling time of fifteen hours.

Objectives

Many processors find it difficult to meet the time-temperature requirements in USDA's Appendix B particularly with large bone-in hams. Therefore, the objective of this study was to determine the effect of not meeting the USDA's suggested Appendix B standard for chilling on the microbial growth and retail acceptability of bone-in, fully-cooked hams.

Methods and Materials

Hams (n = 27) were separated from carcass sides then processed in three groups (n = 9) by being pumped to 117% of initial weight with a solution containing 1.5% sodium chloride, 0.5% sodium tripolyphosphate (STPP), 0.75% sugar and 100 ppm sodium nitrite with a multi needle injector. Hams were allowed to equilibrate for one

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hour prior to cooking. A digital thermocouple was placed in the thickest portion of the three largest hams. All hams were cooked in a commercial smokehouse to an internal temperature of 155°F. After leaving the smokehouse, hams were placed in room at 70°F for four hours to simulate a chilling rate that might occur with a full smokehouse truck. Three hams from each group were randomly assigned to be chilled at ambient temperatures of 29°F, 34°F, or 40°F—to exceed, meet, or not meet the USDA's recommended procedure for stabilization, respectively. The zero hour measurement was recorded when the temperature of each probed ham reached 130°F.

For microbiological analysis, the ham surface and deep muscle was swabbed using the USDA Cattle/Swine Kit sponge, then placed in stomacher bags. Serial dilutions were prepared from the sponge swabs, plated onto Petrifilm for aerobic plate counts (APC) and counts of *Escherichia coli* (EC) and total coliforms (TC), and reported as a logarithmic function of the colony forming units (CFU) per square inch. Generally, APC measures bacteria that grow in the presence of oxygen, serving as an indicator of the presence of spoilage organisms as well as possible human pathogens, and EC and TC counts are indicators of the presence of fecal bacteria contamination. To assess retail acceptability, ham center slices from each test ham were packaged in individual styrofoam trays wrapped with oxygen-permeable polyvinyl chloride film. Ham slices were placed in an open-topped, coffin-chest display case for seven days where they were subjectively evaluated on a daily basis for retail acceptability by six trained retail panelists.

Results and Discussion

The general processing characteristics (Table 1) of hams in this study are similar to those from the National Pork Benchmarking Study (Scanga et al., 2003), relative to percent pump (117%) and percent cooking loss (20%).

Table 1. Simple averages for processing characteristics.

	Ham weights, lb		
Ambient chilling temperature	**Initial**	**Pumped**	**Cooked**
29°F	21.4	24.9	20.1
34°F	20.2	23.8	19.1
40°F	19.8	23.3	18.8

As stated previously, Appendix B (USDA, 2005) recommends that cured meat be chilled from 130°F to 80°F within five hours of the initiation of chilling and from 80°F to 45°F in an additional ten hours. As per the design of the study, hams chilled at an ambient temperature of 40°F, did not meet the USDA's recommended procedure for stabilization, after five or fifteen hours of chilling (Table 2). Hams chilled at 29° and 34°F met the USDA recommendation for stabilization. The hams chilled at an ambient temperature of 40°F took six hours to reach the internal temperature of 80°F and over twelve hours to reach 45°F.

Table 2. Average deep muscle temperature of hams during chilling.

	Hours of chilling			
Ambient chilling temperature	**0**	**5**	**15**	**24**
29°F	130°F	70°F	34°F	28°F
34°F	130°F	72°F	41°F	36°F
40°F	130°F	85°F	50°F	43°F

As expected, ambient chilling temperature did not affect ham surface TC or EC counts after 24 hours of chilling (Table 3). The APC values from the surface of the ham where higher than expected, regardless of treatment. Additionally, hams chilled at 29°F had lower APC values than hams chilled at 34°F or 40°F (Table 3). Hams chilled at 29°F were in a cooler with no worker traffic or possibility for cross-contamination, while the hams chilled at 34°F, or 40°F were placed in coolers with extensive worker traffic, potentially leading to the differences between treatments.

Table 3. Effect of ambient temperature on ham surface bacterial load after 24 hours of chilling.

	Log_{10} CFU per in^2		
Ambient chilling temperature	**TC**	**EC**	**APC**
29°F	0.0	0.0	3.2
34°F	0.0	0.6	5.3
40°F	0.0	0.0	5.3

The deep muscle did not statistically differ for TC and EC counts or APC values after 24 hours of chilling, regardless of ambient temperature (Table 4). These results were comparable to results for surface bacteria. However, TC counts and APC values numerically increased with ambient chilling temperature. *E. coli O157:H7* was not present on either the surface or interior muscle of hams which supports USDA's theory that *E. coli O157:H7* is not likely to occur in pork products.

Table 4. Effect of ambient temperature on deep muscle bacterial load after 24 hours of chilling.

	Log_{10} CFU/ gram		
Ambient chilling temperature	**TC**	**EC**	**APC**
29°F	0.0	0.0	.19
34°F	.3	0.0	1.9
40°F	1.5	0.0	2.8

Ambient chilling temperature did not affect any of the evaluated characteristic by day seven of retail display (Table 5).

Table 5. Effect of ambient temperature during chilling on the shelf life characteristics of ham center slices on day 7 of retail display

	Ambient chilling temperature		
Shelf life characteristic	**29°F**	**34°F**	**40°F**
Overall Appearance[1]	5.9	6.2	6.3
Color[2]	6.4	6.3	6.4
Discoloration[3]	6.6	6.9	6.9
Purge[4]	5.0	5.1	5.1
Odor[5]	5.2	5.2	5.1

[1]8 = extremely desirable overall appearance; 1 = extremely undesirable
[2]8 = bright pink; 1 = dark red
[3]8 = no discoloration; 1 = 100% discoloration
[4]6 = no purge; 1 = abundant pure
[5]6 = no off odor; 1 = extreme off odor

Anaerobic bacteria were not accounted for in this study. However, Taormina et al., (2003) found processed meat products cured with sodium nitrite exhibited limited growth of *C. perfringens*, the primary anaerobic bacteria of concern, during extended chilling and cold storage. Additionally, Zaika (2003) found hams chilled to 47°F within 15 hours met the USDA's requirement of < 1 log10 increase in *C. perfringens*. This suggests that products chilled similarly to those of Zaika (2003) and Taormina et al., (2003) pose a very low public health risk.

Conclusions

Hams which did not meet USDA's Appendix B guidelines did not differ from hams which met the guidelines for aerobic plate counts, total coliform or *E. coli* counts on either the surface or within the deep muscle of hams. Additionally, meeting the Appendix B guideline did not affect any acceptability during seven days of retail display. Collectively, these findings complement findings of other researchers that hams containing sodium nitrite which are chilled to 45°F–50°F within 15 hours pose a low risk to the public relative to food-borne illness.

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