Escherichia coli O157:H7 Risk Mitigation for Blade-Tenderized and Enhanced Nonintact Beef Muscle

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Introduction

Escherichia coli O157:H7 was declared an adulterant in raw ground beef in 1994. The definition was expanded to include nonintact muscle in 1999, and a requirement for reassessment was issued in 2002. "Ten thousand ten" is the common reference to Food Safety and Inspection Service Directive 10,010.1, Revision 1, dated March 31, 2004. This Directive is titled "Microbiological Testing Program and Other Verification Activities for *Escherichia coli* O157:H7 in Raw Ground Beef Products and Raw Ground Beef Components and Beef Patty Components." This revision expands the definition of "adulterated" to include nonintact raw beef and intact muscle intended for nonintact processing. Beef that has been mechanically tenderized by needling, cubing, frenching, or pounding devices and beef that has been reconstructed into formed entrees are included. After 2 more outbreaks related to nonintact product, an additional reassessment was mandated in 2005 (USDA-Food Safety and Inspection Service, 2005). We (Standard Meat Company) have reassessed our hazard analysis and Hazard Analysis and Critical Control Point plan and have concluded that *E. coli* O157:H7 is a hazard *not* reasonably likely to occur for the following reasons:

- Smith et al. (2005) concluded that certain lactic acid bacteria serve as an intervention in controlling O157:H7.
- The incidence of O157:H7 is rare, at <0.083% (Kennedy et al., 2006)
- A single pass through the needles has been shown to transfer only 3 to 4% of the population into the interior of the meat, with most at the surface (Sporing, 1996)
- In addition to the hazard analysis reassessment, we have added routine cleaning and sanitation of needles at each break. Because the needles are the only piece of equipment that contributes to the nonintact status (everything else is surface), this addition of cleaning and sanitizing to the cleanup definition would create sublots within the cleanup.
- Our finished product is supplied to a food service organization that ensures proper cooking.
- Nonintact blade-tenderized meat is no greater risk than intact meat when cooked to an internal temperature of 140°F (rare) or above (Sporing, 1996).

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Blade Tenderization

The importance of tenderness to beef products has been well documented over time. Huffman et al. (1996) reported consumer data stating that tenderness as the most desired attribute when eating a steak at home or in a restaurant. Blade tenderization has been shown to have a great impact on the overall tenderness of beef products. In a report to Standard Meat Company, the USDA-Agricultural Research Service, US Meat Animal Research Center (2006) reported findings stating that blade tenderization decreased slice shear force values (increased tenderness) of top sirloin and strip loin steaks and at a rate greater than that of increased aging times or aging temperatures (Figure 1).

At Standard Meat Company, we have identified numerous hurdles before and within our processing system that can reduce the risk of translocation of harmful bacteria into otherwise sterile muscle tissue. Purchasing programs are in place to ensure that product arriving at our facility has been subjected to multiple documented intervention steps throughout the slaughter and fabrication process. A review by Koohmaraie et al. (2007) discusses some of the more significant preharvest and postharvest interventions. Another variable common to our raw material is that the product has been trimmed beyond the "commodity" level. During fabrication, the highest bacterial counts should

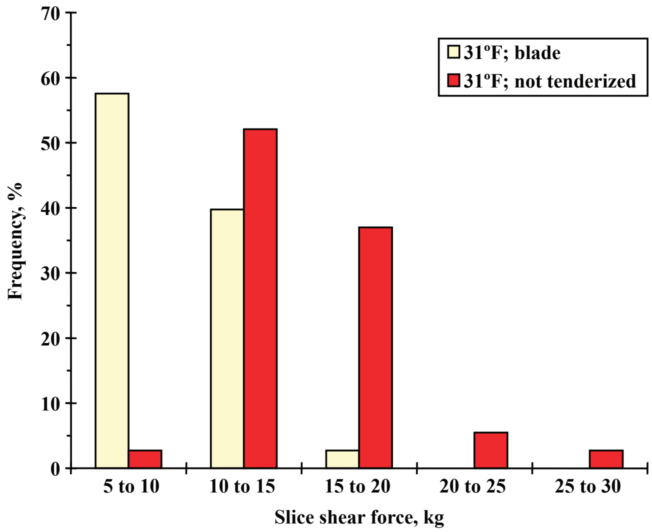


Figure 1. Slice shear force (kg) of strip loin steaks aged at 31°C.

be found on the external-lateral surface of the subprimal. In many cases, this is the fat surface of the subprimal that is subjected to trimming specifications. Because of this, surface trimming can be considered to be as effective as chemical treatments for reducing bacterial populations (American Meat Institute, National Meat Association, National Cattleman's Beef Association, Southwest Meat Association, 2006). Once in our facility, the product is aged for extended periods of time under vacuum-packaged conditions in which lactic acid bacteria have been shown to compete with and possibly inhibit the growth of pathogenic bacteria (Smith et al., 2005). Within the processing environment, internal data collected have suggested that removing the subprimal from the primary packaging material can reduce the general bacterial populations by 40 to 60%. The actual blade-tenderization process is conducted by penetration from the internal-medial surface of the subprimal. The blades used in the process are shaped to provide a cutting or displacement of muscle tissue, in contrast to a blunt force object, which has more potential to push material into the interior of the product. Gill and McGinnis (2005) reported that "contamination of deep tissue as a result of tenderizing by piercing with thin blades can be minimized if the blades are designed to limit the number of bacteria carried into the meat" (Figure 2). Blades are cleaned and sanitized at each break (3 times in an 8-h shift) to create sublots within the production day.

Integrated lethality is the concept that lethality not only occurs at a specific time and temperature (e.g., 155°F for 15 s for *E. coli* O157:H7, as specified in the 2005 Food Code for nonintact beef; US Department of Health and Human Services, Public Health Service, Food and Drug Administration, 2005), but also builds throughout portions of the cooking and cooling process (cook-up and cool-down). Figure 3 shows a model used to describe the concept. This particular sample was removed from the heat source at 130°F and continued to be cooked up to a maximum internal temperature of 145.9°F. The calculated total lethality of the cooking process was a 4.95-log reduction for *E. coli* O157:H7 (Scott and Weddig, 1998). When analyzing cooking models, it becomes apparent that the core temperature curve is greatly dependent on several factors, including product type, steak thickness, cooking surface, and moisture and fat content. Numerous variables with a high level of sensitivity create a scenario in which individual product- and process-specific data are required to validate findings.

As with all processes, best practices include good sanitation, manufacturing, and maintenance practices. Best practices specific to blade tenderization of beef products include

- Purchasing specifications that include validated intervention steps and surface trimming,
- Precise cold-chain management,
- Aging under a vacuum environment,
- Removal of packaging film,
- Blade penetration from the medial surface of the subprimal, and
- Cleaning and sanitation of blades for sublotting of product.

Brine Injection

Brine injection is an established industry practice used to increase the overall palatability of beef products. Salt-phosphate blends are typically used, sometimes in conjunction with an enzymatic tenderizer, to increase tenderness, flavor, and moisture retention of enhanced beef products. Vote et al. (2000) reported increased tenderness, juiciness, and beef flavor when subprimals were enhanced with solutions containing phosphate, lactate, and chloride.

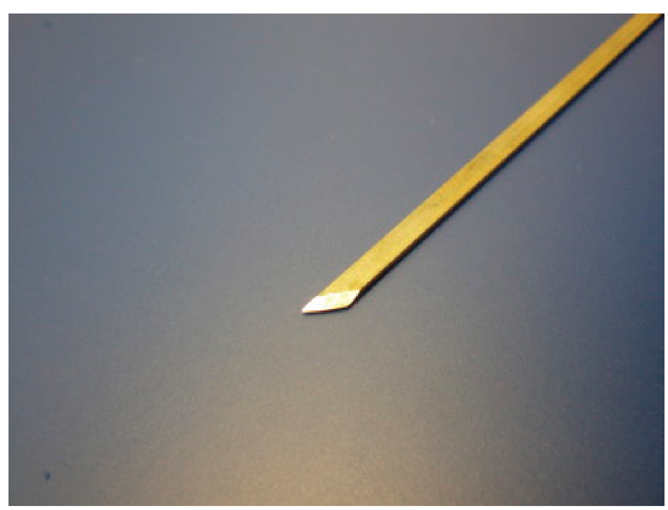


Figure 2. Typical blade used in blade-tenderization equipment.

PROCESS LETHALITY DETERMINATION

z = 10 °F   T ref = 145 °F   **Product name: _12 0z Top Butt _______**   **Date: _9 May 2007 _______**

Data Table

Time (min)	Core Temp (°F)	F-value (min)
0	37.9	0
1	39.6	0.00
2	42.1	0.00
3	45.9	0.00
4	50.2	0.00
5	55.1	0.00
6	65.5	0.00
7	71.9	0.00
8	78.3	0.00
9	83.4	0.00
10	92.5	0.00
11	100.2	0.00
12	106.4	0.00
13	112.6	0.00
14	118.7	0.00
15	125.1	0.01
16	135.4	0.07
17	142.2	0.39
18	145.4	1.20
19	145.9	2.36
20	145	3.47

Instructions:

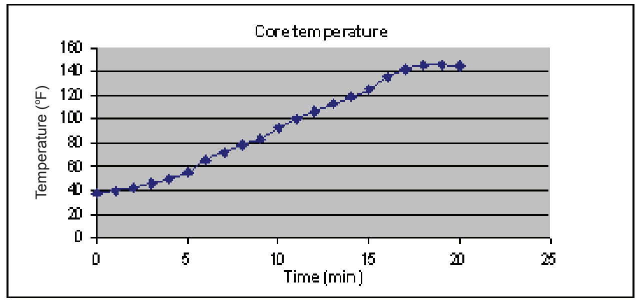
1. Enter proper z and T ref, (i.e. reference temperature).
2. Enter in-process times and temperatures in col. B and C (overwrite example data).
3. Total lethality will be the final computed cumulative F-value.

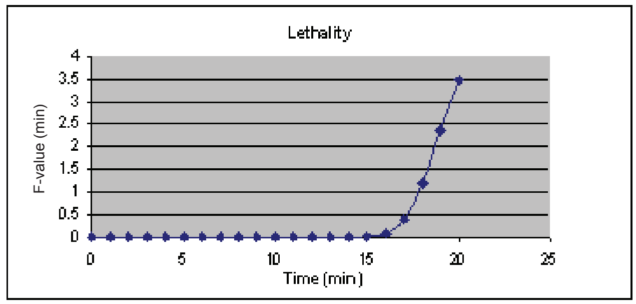
Definitions:

D-value: The time (in minutes) at an associated T ref required to kill 90% of the selected microorganism; a one log reduction.

z-value: The number of degrees F to change the D-value by a factor of ten.

F-value: The process lethality. The equivalent time of heating at a reference temperature.





3.47/.7=4.96

Organism	T ref (°F)	z (°F)	D (min)	Log reduction	Required F-value
	Microbial Heat Tolerence				
Salmonella	145	10	0.7	7	4.9
E. coli O157:H7	145	10	0.7	7	4.9
Listeria monocytogenes	145	10	1.2	4	4.8
Lactobacillus plantarum	145	10	11.1	4	44.4
Group D *Streptococcus*	158	18	3.0	4	12

Note: This model is a tool for calculating F-values. To ensure correct results, the proper z, T ref, and D-values for each product and organism must be used.

Figure 3. Integrated lethality model.

Since 2000, 6 reported *E. coli* O157:H7 outbreaks have been associated with nonintact beef, the latter 5 having been specifically linked to brine-injected product (Conference for Food Protection, 2008). In many processes involving brine injection, the brine solution is recirculated within the system (closed-loop system) so that the solution itself acts as a surface rinse before being injected. Recirculation is a method of minimizing waste, and considering that many brine solutions contain seasonings and tenderizing agents, this is also a means of reducing costs. With more complexities in equipment, processing, and ingredients as compared with blade tenderization, sanitation becomes paramount. Without proper steps taken throughout the process, the brine itself can become the mode of bacterial translocation.

Best practices for brine injection of beef products include the very same actions as described for blade tenderization along with other considerations, including

- Use of a chemical intervention before injection (acidified sodium chlorite, lactic acid, and peroxyacetic acid are some of the more common solutions used),
- Monitoring of water quality,
- COAs for brine ingredients,
- Use of antimicrobial interventions or filtering techniques when recirculating brine,
- Temperature control of brine solutions,
- Uniform distribution of brine (no hot pockets),
- Maximum age of brine with definitive breaks in the process, and

- Daily breakdown, cleaning, and sanitation of equipment (including injection needles and the brine makeup system).

In conclusion, blade-tenderized and brine-enhanced nonintact steaks destined for food service and retail should present no greater risk from *E. coli* O157:H7 than intact steaks. Low incidence levels coupled with adherence to best practices should successfully mitigate the risks identified in previous outbreaks. It should be clear that blade tenderization is a very different process from brine enhancement and the 2 should not be treated the same in regulatory or best practices discussions.

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