EFFECTS OF POSTMORTEM AGING ON BEEF TENDERNESS AND AGING GUIDELINES TO MAXIMIZE TENDERNESS OF DIFFERENT BEEF SUBPRIMAL CUTS

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Introduction

The 1991 National Beef Tenderness Survey determined that 17.5 percent of rib and loin cuts, 40.8 percent of chuck cuts, and 35.8 percent of round cuts were unacceptable to consumers in tenderness characteristics (Morgan et al., 1991). Results of that survey fortified industry speculation that beef was inconsistent in tenderness, and suggested that inconsistency in beef tenderness could be attributed to variability in cooking methods, USDA quality grade, live animal handling techniques, genetics, diet and length of postmortem aging period.

Advances in scientific knowledge of the factors influencing tenderness have led to the development of technologies to reduce inconsistency and improve the tenderness of beef. High-voltage electrical stimulation, calcium chloride infusion, mechanical tenderization and control of postmortem aging time have been employed to try to improve the tenderness of beef (George et al., 1997). Many of these techniques also have been combined to increase the rate and extent of myofibrillar fragmentation during postmortem storage of beef.

This review of literature was conducted to assess the current state of scientific knowledge concerning the effects of postmortem aging on the tenderness of muscles in different beef subprimal cuts and to develop—based on the scientific literature—recommendations for aging different beef subprimals to maximize consumer acceptability of beef. It is imperative that the industry deliver to the ultimate beef consumer a consistent, safe and highly palatable beef product.

Effects of postmortem aging on beef chuck subprimal cuts

Smith et al. (1978) performed a study using 126 USDA Choice carcasses. Carcasses were aged for 5, 8, 11, 14, 21 or 28 days (21 carcasses per aging period). After reaching the appropriate postmortem aging time, the carcasses were fabricated into subprimals and evaluated for tenderness. The researchers extracted blade steaks, blade roasts and arm steaks, and evaluated the effects of postmortem aging time on tenderness of the steaks. Steak tenderness was evaluated using a trained sensory panel and Warner-Bratzler shear force. Warner-Bratzler shear force is a method developed to measure the pounds of pressure required to cut through a 1/2 inch core of cooked meat product. They reported that for most of the cuts from the chuck, aging past 11 days did not significantly increase tenderness as measured by sensory panel ratings, but that tenderness measured using Warner-Bratzler shear force for the *infraspinatus* muscle in the chuck increased with up to 14 days of aging and tenderness of the *superficial pectoral* muscle increased with up to 28 days of aging (Smith et al., 1978).

Weatherly et al. (1998) used 10 USDA Select and 10 USDA Choice carcasses to evaluate the effects of aging on the tenderness of shoulder clods and chuck rolls. All subprimals were fabricated into 1-inch thick steaks and vacuum packaged. They aged the shoulder clod and chuck roll for 4, 8, 12, 16, 20 or 24 days. Tenderness of the steaks was determined using Warner-Bratzler shear force techniques. The researchers found that chuck rolls should be aged for 12 days to achieve optimum Warner-Bratzler shear force values and that shoulder clod steaks displayed a linear response in tenderness to aging, but that the response was not statistically significant (Weatherly et al., 1998).

Effects of postmortem aging on subprimal rib cuts

Xie et al. (1996) studied 27 Wagyu-sired steers to evaluate the effects of postmortem aging on the palatability of ribeye steaks. After 48 hours of postmortem chilling, the ribeye roll was fabricated from the left side of each carcass, cut into six steaks, vacuum-packaged and aged for 2, 4 or 10 days. Tenderness was determined using a 10-member trained sensory panel and Warner-Bratzler shear force. Shear force values and sensory tenderness ratings were significantly improved following 10 days of postmortem aging compared with 2 days postmortem aging (Xie et al., 1996).

In the Smith et al. (1978) study, rib portions of carcasses were dry-aged for 5, 8, 11, 14, 21 or 28 days (21 carcasses per aging period). After reaching the appropriate postmortem aging time, the carcasses were fabricated to obtain rib steaks which were then evaluated for tenderness. Tenderness for rib steaks was determined as follows: (a) the first rib steak was evaluated for tenderness using an eight-member trained sensory panel, and (b) the second rib steak was evaluated for tenderness with a Warner-Bratzler shear force device. The researchers reported that steaks from the rib portion of the carcass achieved maximum tenderness after 11 days of postmortem aging according to sensory panel ratings and Warner-Bratzler shear values (Smith et al., 1978).

Weatherly et al. (1998) fabricated subprimal ribeyes into 1-inch thick steaks, vacuum packaged and aged for 4, 7, 10, 13, 16, 19, 22, 25, 28, 31 or 34 days. Tenderness of the steaks was determined using Warner-Bratzler shear force techniques. The researchers reported that optimal tenderness was achieved at 13 days of postmortem aging (Weatherly et al., 1998).

Minks and Stringer (1972) fabricated 12 USDA Choice ribs into 1-inch thick steaks and aged them for 0, 7 or 15 days. Tenderness was characterized using a six-member trained taste panel and Warner-Bratzler shear force evaluation. In their study, results displayed a significant increase in tenderness between day 0 to day 15 (Minks and Stringer, 1972).

Effects of postmortem aging on subprimal loin cuts

In the Smith et al. (1978) study, loin portions in the carcasses were dry-aged for 5, 8, 11, 14, 21 or 28 days (21 carcasses per aging period). After reaching the appropriate postmortem aging time, the carcasses were fabricated to obtain loin steaks that were then evaluated for tenderness. The researchers reported that steaks from the loin portion of the carcass achieved maximum tenderness after 11 days of postmortem aging according to sensory panel ratings (Smith et al., 1978).

In an Australian study, Mitchell et al. (1991) evaluated aging effects on the sensory properties of *longissimus dorsi* muscle steaks. These researchers used 36 carcasses for evaluation with a 16- to 20-member trained sensory panel and Warner-Bratzler shear force techniques. They electrically stimulated 18 of the carcasses using high voltage (800 volts, 14.3 pulses/sec); the remaining 18 carcasses were subjected to the "tender stretch" process. *Longissimus dorsi* muscle steaks from these carcasses were aged for 3, 10 or 21 days. The scientists found that there was no advantage to aging steaks beyond 10 days because of the weight losses that occurred in a vacuum bag, even though the data illustrated a slight increase in tenderness through the 21st day of postmortem aging and in spite of the fact that the carcasses were subjected to postmortem tenderization via high voltage electrical stimulation or "tender stretch" (Mitchell et al., 1991).

Calkins and Seideman (1988) evaluated the response to aging of the *longissimus* muscle of 8 Charolais bulls and 7 Charolais steers (both genders were 15 months of age at slaughter). They removed 1-inch thick loin steaks from the left side of each carcass at 1 or 3 days of aging and loin steaks posterior to the 13th rib of the right side of each carcass at 6, 9 or 14 days of postmortem aging. Steak tenderness was assessed using a 10-member trained taste panel and Warner-Bratzler shear force evaluation. Results suggested that aging steaks beyond 14 days did not increase tenderness (Calkins and Seideman, 1988).

Eilers et al. (1996) fabricated a total of 256 strip loins and top sirloins into 1-inch thick steaks and aged them for 6, 12, 18 or 24 days. The steaks from these cuts were evaluated for tenderness by a six-member trained taste panel and using Warner-Bratzler shear force evaluation. Findings suggested that strip loins should be aged for a minimum of 12 days for "acceptable" tenderness. "Acceptable" tenderness was used to describe steaks that had Warner-Bratzler shear force values below 8.6 pounds. In order to achieve "superior" tenderness, results suggested that strip loin steaks should be aged for 24 days. "Superior" tenderness was used to describe steaks that had Warner-Bratzler shear force values of less than 7 pounds. Top sirloin butts required long aging periods to reach the "acceptable" level of Warner-Bratzler shear force. After 24 days of aging, only 16 percent of top sirloin steaks had shear force values above 8.6 pounds (Eilers et al., 1996).

Carpenter et al. (1976) conducted an experiment to evaluate the tenderness of 120 top sirloin butts grading USDA Good (now USDA Select) and USDA Choice that were aged for 7, 14, 21, 28 or 35 days. The cuts were then evaluated for tenderness using an eight-member trained sensory panel and a Warner-Bratzler shear force device. Results indicated that 11 days of postmortem aging was optimal for top sirloin butts as the sensory panel tenderness scores did not significantly increase after 11 days. Warner-Bratzler shear force results indicated a significant decrease in tenderness from day 7 to day 35 (Carpenter et al., 1976).

Davis et al. (1975), using 12 steers of mixed breeding, evaluated tenderness of strip loin steaks extracted and aged for 4, 12 or16 days postmortem. A six-member sensory panel and a Warner-Bratzler shear device were used to characterize tenderness of the strip loin steaks after reaching the desired length of aging time. Tenderness increased significantly through day 12 of aging, but there were nonsignificant differences in tenderness between 12 and 16 days of aging (7.26 pounds at 12 days *versus* 6.82 pounds at 16 days; Davis et al., 1975).

Weatherly et al. (1998) fabricated Shortloins and top sirloin butts into 1-inch thick steaks and vacuum packaged. They aged the top sirloin butt steaks for 4, 7, 10, 13, 16, 19, 22, 25, 28, 31 or 34 days. Shortloin steaks were aged for 4, 7, 10, 13, 16, 19, 22, 25, 28 or 31 days postmortem. They found that the optimal aging time for shortloins was 13 days. In addition, it was determined that top sirloin butt steaks did not display a significant response to aging, but did show a slight, linear increase in tenderness from the 4^{th} to 34^{th} days of postmortem aging (Weatherly et al., 1998).

Miller et al. (1997) performed a study in which they fabricated 320 strip loins from USDA Choice and Select carcasses. Tenderness was determined using a Warner-Bratzler shear force instrument and an eight-member trained sensory panel. The researchers found that strip loins aged for 14 days were significantly improved in tenderness as measured by both sensory panel ratings and Warner-Bratzler shear force values. These scientists concluded that aging should be a processing control point to improve palatability and consumer satisfaction with the consistency of beef (Miller et al., 1997).

Savell et al. (1981) conducted two studies, using 23 USDA Good (now USDA Select) and USDA Standard carcasses in the first study, and 20 USDA Choice and USDA Good carcasses in the second study. The right side of carcasses in the first study was high-voltage electrically stimulated (550volts, 2-6 amps, 17 impulses) and the left side of carcasses was used as the control (not electrically stimulated). One boneless steak was extracted from the 13^{th} rib of each side after 2 days of postmortem aging. Loin steaks were extracted from carcasses at 6, 10 or 14 day aging periods, vacuum packaged, and frozen. Tenderness was determined using Warner-Bratzler shear force. In the second study, electrically stimulated carcasses were managed and prepared in the same manner as were those in the first study. The shortloin was removed at 1 day postmortem from each side and fabricated into strip loins. Each strip loin was then cut into six 1.5-inch thick steaks, vacuum packaged and aged for 1, 2, 5, 8, 11, or 14 days. Warner-Bratzler shear force and an eight-member experienced sensory panel were used to evaluate tenderness. In the first study, researchers found significant decreases in Warner-Bratzler shear values up to day 10 of postmortem aging for electrically stimulated and non-electrically stimulated beef. In the second study, Warner-Bratzler shear values decreased significantly through day 14 for the non-electrically stimulated beef, while the electrically stimulated beef achieved maximum tenderness at 11 days postmortem aging. Sensory panel results were the same as Warner-Bratzler shear force results for non-electrically stimulated beef, but the panel found that maximum tenderness for electrically stimulated beef was achieved after only eight days of postmortem aging (Savell et al., 1981).

Diles et al. (1994) conducted a study using carcasses from 10 mature crossbred cows. The strip loin from the left side of each carcass was hot-boned from the carcasses (within .5 hours after slaughter) and cut into three sections of which one was subsequently treated with 150 m*M* $CaCl_2$ infusion, the second section was treated with 200 m*M*, and the third section was not treated. The right side of each carcass was chilled for 24 hr before the strip loin was removed; the strip loin was then treated in the same manner as was the strip loin from the left side of the carcass. Steaks from both sets of strip loins were aged for 7 or 14 days. The non-infused control group and the injected groups had lower shear force values when aged for a 14-day period compared to those aged for only 7 days (Diles et al., 1994).

O'Connor et al. (1997) found results similar to those of Wulf et al. (1996). They used 575 steers and heifers from a variety of *Bos taurus* and *Bos indicus* cattle. At 24 hr postmortem, the strip loin was fabricated from a randomly chosen side of each carcass, cut into seven 1-inch thick steaks and aged for 1, 4, 7, 14, 21 or 35 days. Tenderness was measured with a Warner-Bratzler shear force device, and a steak from each strip loin was aged for 14 days to be evaluated by an eight-member trained sensory panel to determine differences in tenderness between steaks from *Bos indicus* vs. *Bos taurus* cattle. These scientists agreed with Wulf et al. (1996) that tenderness increased from day 1 to day 35 of postmortem aging. In addition, it was found that from day 1 to day 14 of postmortem aging, the percentage of steaks that were “unacceptable” in tenderness in *Bos indicus* breed-type cattle dropped from 47 percent to 10 percent. In the *Bos taurus* breed-type cattle, the percentage of steaks that were “unacceptable” in tenderness dropped from 30 percent to 1 percent after 14 days of postmortem aging (O’Connor et al., 1997).

Effects of postmortem aging on subprimal round cuts

In the Smith et al. (1978) study discussed previously, 126 USDA Choice carcasses were dry-aged for 5, 8, 11, 14, 21 or 28 days (21 carcasses per aging period). After reaching the appropriate postmortem aging time, carcasses were fabricated to obtain round steaks that were evaluated for tenderness. Tenderness of the steaks was determined as follows: (a) the first round steak was evaluated for tenderness with a Warner-Bratzler shear device and (b) the second round steak was evaluated for tenderness using an eight-member trained sensory panel. These researchers found that aging of the round cuts past 11 days postmortem resulted in no statistically significant increases in tenderness based upon both sensory panel and Warner-Bratzler shear force evaluation. However, there were small, nonsignificant linear responses to increased days of aging (Smith et al., 1978).

Parrish et al. (1969) reported results that did not agree with those of Smith et al. (1978). In that study, 8 USDA Choice carcasses from Hereford cattle were used to determine the impact of postmortem aging on tenderness using the Warner-Bratzler shear force technique and a sensory panel. *Semimembranosus* steaks were aged for 4, 7 or 11 days. The researchers found that no significant increase in tenderness could be attributed to postmortem aging of round steaks (Parrish et al., 1969).

Mitchell et al. (1991) found similar results to those of Smith et al. (1978) when they aged *semimembranosus* steaks for 3, 10 or 21 days. From 36 carcasses selected for evaluation in Australia, *semimembranosus* steaks were subjected to assessment by a 16 to 20-member trained sensory panel and Warner-Bratzler shear force evaluation. They electrically stimulated 18 of the carcasses using high voltage (800 volts, 14.3 pulses/sec); the remaining 18 carcasses were subjected to the "tender stretch" process. Mitchell et al. (1991) found no advantage due to aging *semimembranosus* steaks subjected to high-voltage electrical stimulation or "tender stretch" beyond 10 days; but did find a slight nonsignificant increase in tenderness through 21 days of postmortem aging (Mitchell et al., 1991).

Eilers et al. (1996) fabricated a total of 256 top rounds into 1-inch thick steaks and aged them for 6, 12, 18 or 24 days. The steaks from these cuts were evaluated for tenderness using a six-member trained taste panel and Warner-Bratzler shear force techniques. The scientists reported that the tenderness of the *gluteus medius* from beef carcasses improved with 24 days of postmortem aging. The researchers reported that the *semimembranosus* muscle should be aged at least 12 days to increase tenderness. Additionally, *semimembranosus* muscle cuts should be aged 24 days to elicit a "superior" tenderness response. "Superior" tenderness was used to describe steaks that had Warner-Bratzler shear force values of less than 7 pounds (Eilers et al., 1996).

Weatherly et al. (1998) aged top round and bottom round steaks from 10 select and to choice carcasses for 4, 8, 12, 16, 20 or 24 days. Those scientists found that the optimal aging time for a bottom round steak was 12 days, while tenderness of top rounds could be improved if aged for up to 16 days (Weatherly et al. 1998).

Recommendations

There is a definite need for a standard set of aging time recommendations for different types of beef subprimal cuts to help assure consistency in tenderness and palatability for the ultimate consumer. Based on the scientific literature, common minimum aging times for the cuts from the chuck, rib, loin and round were identified (Table 1).

The minimum recommended postmortem aging time for steaks from the rib section, based on the scientific literature, was 11 to 15 days; the chuck roll and shoulder clod cuts from the chuck should be aged a minimum of 12 and 11 days respectively; strip loin and top sirloin should be aged for at least 14 days and 21 days, respectively; and top round and bottom round cuts should be aged for a minimum of 16 and 12 days respectively.

TABLE 1. Aging recommendations for beef subprimal cuts

~~Study~~	n	Chuck		Rib	Loin		Round	
		Chuck roll	Shoulder clod	Ribeye roll	Strip	Top sirloin	Bottom	Top
Smith et al. (1978)	126	11	11	11	11		11	
Weatherly et al. (1998)	20	12	0	13	13	0	12	16
Xie et al. (1996)	27			10				
Parrish et. al (1969)	8						0	
Mitchell et al. (1991)	36				10		10	
Calkins and Seideman (1988)	15				14			
Minks and Stringer (1972)	12			15				
O'Connor et al. (1997)	575				14			
Eilers et al. (1996)	256				12	24	12	
Carpenter et al. (1976)	120					11		
Davis et al. (1975)	12				12			
Miller et al. (1997)	320				14			
Savell et al. (1981)	43				14			
Diles et al. (1994)	10				14			
Recommendations		**12**	**11**	**11-15**	**14**	**21**	**12**	**16**

Recommended aging times were contrived through the evaluation of different models and sample sizes of reviewed scientific journal articles.

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