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Comparison of Postmortem Handling Methods for Effects on Quality Characteristics of Mature Beef

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ABSTRACT

The longissimus, semitendinosus and semimembranosus muscles from 60 U.S. Utility beef carcasses were used to investigate the effects of electrical stimulation (ES), different postmortem boning times, blade tenderization coupled with enzyme dip, and storage conditions on the quality, appearance, cooking and sensory properties of cooked beef muscle. Muscles were removed from stimulated and nonstimulated sides at 1, 3 or 24-h postmortem, wrapped in PVC film and either immediately frozen at -40°C or stored at 2 to 3 C for 24 h and then frozen at -40°C. Before freezing, part of the muscles was allocated to blade tenderization and/or enzyme dip treatments while the remainder served as controls. Electrical stimulation increased tenderness in muscles excised at 1 h postmortem; however, as boning time increased, the effects of ES on tenderness decreased. It was concluded that electrical stimulation increased tenderness sufficiently to allow boning at 1 or 3-h postmortem. Blade tenderization and/or enzyme dip treatments did not significantly improve tenderness of any of the muscles over the effects of ES. With the exception of the semitendinosus, muscles chilled 24 h before freezing were significantly ($P<.05$) more tender than those frozen immediately.

Many researchers have reported the benefits of hot-processing (*9,12,13,14,15*). Advantages include savings in energy, space, labor, time and improvements in product quality. Much of the hot-processing research has been reported on young cattle (A maturity) rather than on mature beef. Cross and Tennent (*9*) demonstrated certain advantages of electrical stimulation before hot-processing U.S. Good and Choice carcasses. Results indicated that electrically stimulated, hot-processed primal cuts were more tender than unstimulated cold-boned cuts. Berry et al (*4*) compared mechanical and enzymatic systems as a means of tenderization for hot-processed strip loins and top rounds from mature cows. They concluded that even with mechanical and enzymatic treatments, cold-boned cuts were usually more tender than hot-boned cuts. Carcasses in this study (*4*) were not stimulated since they were concerned that with electrical stimulation, the rapid postmortem pH decline might cause increased cooking loss and decreased juiciness ratings of ground beef produced from the same carcasses. Cross and Tennet (*10*) demonstrated that palatability and cooking properties of hot-processed ground beef were not significantly affected by electrical stimulation. Therefore, the objective of this study was to evaluate the effects of electrical stimulation, both singularly and in combination with blade tenderization, enzymatic and storage treatments, on sensory and cooking properties of hot-processed mature beef primals.

MATERIALS AND METHOD

Processing

Sixty U.S. Utility (C to E maturity) carcasses that were similar in subcutaneous fat thickness (approximately 1 cm), as determined via a fat probe on the unchilled carcass, were selected for this experiment. One side of each carcass was electrically stimulated (1.5 amp, 250-350 volts, AC, 60 Hz) for 3 min, with four 10-s duration impulses per min within 45 min of slaughter (ES). The other side of each carcass remained unstimulated (non ES).

The ribeye (longissimus), eye of round (semitendinosus) and top round (semimembranosus) muscles were removed from the carcass at 1, 3 or 24 h. The paired muscles from each carcass (ES vs. non ES) remained within each muscle excision group. Immediately after removal of muscles from the carcass, each muscle was weighed (no fat trimming was required), its temperature was recorded and they were subjectively scored by a panel of two experienced evaluators for: lean color (8 = light greyish-red; 1 = very dark red or purple), fat color (5 = white; 1 = yellow), and shape (8 = normal; 1 = extremely abnormal). Samples for pH determination were removed from each muscle, frozen in liquid nitrogen and values were determined using iodoacetate as outlined by Nichols and Cross (*16*). Each boneless primal cut was wrapped in PVC (polyvinyl chloride) film and stored according to one of the following treatments: (*a*) frozen immediately at -40°C, (*b*) chilled for 24 h at 2°C and then frozen at -40°C. All cuts (chilled or frozen) were stored 24 h on racks before being placed in boxes.

After freezing, cuts were stored in boxes for 20 d at -10°C. At the end of the storage period, each cut was tempered to -2°C for 24 h. Muscles (LD and ST) allocated to each mechanical tenderization/enzyme dip treatment (MT:ED) were passed through a Ross blade tenderizer, sliced into 1.9-cm thick steaks using a Bettcher cleaver, passed (1-2 s) through a 2°C solution of enzyme (papain) and individually wrapped in PVC film.

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Steaks were allowed to drain 5 min before being wrapped in the PVC film. Steaks were subsequently boxed and frozen at -40°C. Top round cuts (semimembranosus) were treated in a similar manner except they were not sliced into steaks and were not subjected to enzyme dipping. Control cuts were treated in a similar manner except they were not ED or MT. All steaks and roasts were stored for 1 to 3 months at -10°C before being presented to the sensory panel.

Cookery or presentation of sensory panel

Thawed ribeye steaks (24 h at 3°C) from each hot-processing treatment were weighed and cooked on Farberware Open Hearth broilers (Model 450-A) to determine cooking characteristics. Steaks were broiled to a final internal temperature of 70°C. Additionally, top round roasts were roasted in a 177°C electric oven to an internal temperature of 70°C and eye of round steaks were grilled on a flat surface grill at 225°C to a final internal temperature of 70°C. Internal temperatures were monitored during each cooking procedure by Teflon-coated iron/constantan thermocouples. Total cooking losses were calculated as a percentage of differences between frozen and cooked weights. Each cooked steak and roast slice was sectioned and scored for degree of doneness (1 = extremely well done; 8 = rare) by a trained laboratory technician using photographic standards. Three steaks or roast slices from each treatment were prepared per taste panel session by sectioning each into eight pieces and randomly assigning two of the 24 pieces to each panelist. Samples were served to panelists as described by AMSA (*1*).

In a total of 40 sessions, a 10-member descriptive attribute panel, trained by the procedures of Cross et al. (*6*) and AMSA (*1*), evaluated samples from each treatment. Each steak or roast was evaluated at different sessions by the panel. Samples from six of the 12 cell treatments (Table 1) were evaluated per session and each cell treatment was replicated five times. The panel rated each sample for differences in tenderness, juiciness, connective tissue amount and beef flavor intensity (8 = extremely tender, juicy, no detectable connective tissue, and intense in beef flavor; 1 = extremely tough, dry, abundant in connective tissue and bland in beef flavor).

Shear force

Five steaks from each experimental design cell were used for determination of cooked Instron shear force by the single-blade procedure of Cross et al. (*7*). Four 1.3-cm diameter cores were cut from each steak, so each mean for method/batch represents 20 observations.

Chemical

Percent fat and moisture were determined on two raw steaks from each treatment by AOAC procedures.

Statistical analysis

Data for each main effect and all possible interactions were reduced by analysis of variance as outlined by Snedecor and Cochran (*17*), and by the mean separation technique of Duncan (*11*).

RESULTS AND DISCUSSION

Analysis of variance showed several significant interactions which include boning time × stimulation treatment (Table 1) interactions, postmortem tenderness treatment × stimulation treatment interactions and storage treatment (Table 2) main effects.

The effect of postmortem boning time and electrical stimulation on quality and appearance traits and cooking and sensory traits are presented in Table 1. Irrespective of muscle, electrical stimulation significantly lowered pH values at 1 and 3 h postmortem as compared to control sides (nonstimulated). After 24 h, all muscles had reached their ultimate pH value and no significant difference could be attributed to elelctrical stimulation. Cross and Tennent (*9*) reported pH values of 5.7 in ES longissimus boned at 4 h; however, these results on mature cows indicate a considerably higher pH at 3 h. Bendall (*2*) indicated rapid cooling of muscles to 2°C can begin when the pH has reached 6.0 or less without danger of cold shortening. Based on that guideline, ES carcasses from this study should not be rapidly chilled until sometime after 3 h postmortem.

Early boning had significant effects on initial visual muscle color score. Cuts boned at 24 h were significantly brighter in color than those boned at 1 or 3 h (data not presented). These results are similar to those found by Cross and Tennent (*8*), who reported that the visual color scores at 1 and 4 h were significantly darker than those evaluated at 48 h, but no differences were detected after 20 d of storage. Cross and Tennent (*8*) evaluated the shape of hot-and cold-boned beef primal cuts for young beef. They indicated that a rating of six or above for shape was considered by industry to be acceptable and would not normally be discriminated against during marketing. Based on these guidelines, the mean shape rating for all treatments was acceptable (data not presented).

Postmortem boning time and electrical stimulation had no significant effect on percent cooking loss, degree of doneness or juiciness irrespective of muscle (Table 1). Cross and Tennent (*9,10*) showed that cooking losses increased as postmortem boning time increased. A possible explanation for lack of effects in this study might be that the carcasses used in the aforementioned studies were from younger animals and had more intramuscular fat.

Tenderness as evaluated by the sensory panel and the Instron shear-force values revealed that SM and ST muscles boned at 1 and 3 h postmortem were borderline in tenderness (Table 1). Instron shear-force values indicated that, in all muscles, ES tended to improve tenderness at the 1 h boning time. As boning time increased, the effects of ES decreased. This would suggest that cold-shortening might be involved in muscle toughening in early boned muscle. This is supported by pH values above 6.0 at the time of excision (Table 1). Bendall and Rhodes (*3*) indicated that rapid cooling of muscles to 2°C can begin when the pH has reached 6.0 or less without danger of cold shortening. Even though all muscles studied were borderline in tenderness, these data imply that ES of carcasses improved tenderness sufficiently to perhaps allow hot-boning at 1 or 3 h postmortem.

The effect of electrical stimulation and postmortem tenderness treatment (blade tenderization + enzyme dip) had no significant effect ($P>.05$) on cooking losses, tenderness (ST and SM), juiciness, flavor and connective tissue amount (data not presented). Electrical stimulation appeared to have little effect on cooking losses. Electrical stimulation had significant positive effects on tenderness in the LD (Table 2) but not the SM or ST muscles (data not presented). Blade tenderization and enzyme dip treatments did not significantly improve tenderness of any of the muscles over and above the effects of ES. This is in agreement with work reported by Berry et al. (*4*). Generally, juiciness, flavor and connective tissue ratings were not influenced by blade tenderization or enzyme treatments.

TABLE 1. *Effect of electrical stimulation and postmortem boning time on cooking and sensory traits of beef primal cuts.*

	Muscles																	
	SM						ST						LD					
	Boning time (h)						Boning time (h)						Boning time (h)					
	1		3		24		1		3		24		1		3		24	
Traits	ES	NS	ES	NS	ES	NS	ES	NS	ES	NS	ES	NS	ES	NS	ES	NS	ES	NS
Initial pH	6.47^{e}	6.76^{d}	6.18^{f}	6.56^{e}	5.77^{g}	5.85^{g}	6.48^{e}	6.66^{d}	6.24^{f}	6.54^{e}	5.75^{g}	5.80^{g}	6.48^{e}	6.72^{d}	6.22^{f}	6.54^{e}	5.76^{g}	5.89^{g}
Thaw loss, %	9.5^{d}	7.6^{d}	7.6^{d}	6.9^{d}	8.3^{d}	9.3^{d}	6.0^{d}	5.4^{de}	4.8^{de}	5.0^{de}	4.7^{de}	3.6^{e}	1.3^{d}	1.0^{de}	0.6^{e}	0.8^{de}	0.8^{de}	0.7^{e}
Cooking loss, %	35.2^{d}	38.1^{d}	37.8^{d}	36.0^{d}	37.8^{d}	37.8^{d}	37.3^{d}	38.5^{d}	37.3^{d}	37.2^{d}	35.4^{d}	36.1^{d}	36.6^{d}	36.4^{d}	37.0^{d}	36.1^{d}	37.0^{d}	36.2^{d}
Tenderness[b]	3.9^{de}	3.5^{ef}	3.2^{f}	3.3^{f}	4.3^{d}	4.0^{d}	3.5^{e}	3.2^{e}	3.7^{de}	3.6^{de}	4.0^{d}	4.1^{d}	4.9^{de}	4.1^{g}	4.9^{de}	4.4^{ef}	5.2^{d}	5.0^{de}
Juiciness[b]	4.1^{d}	4.2^{d}	3.8^{d}	4.2^{d}	3.8^{d}	3.7^{d}	4.6^{d}	4.6^{d}	4.7^{d}	4.7^{d}	4.7^{d}	4.6^{d}	5.3^{d}	5.5^{d}	5.2^{d}	5.2^{d}	5.1^{d}	5.4^{d}
Flavor[b]	4.4^{de}	4.2^{e}	4.3^{e}	4.2^{e}	4.6^{e}	4.5^{de}	4.8^{d}	4.9^{d}	4.8^{d}	4.8^{d}	5.0^{d}	5.0^{d}	5.3^{d}	5.1^{d}	5.1^{d}	5.2^{d}	5.1^{d}	5.1^{d}
Connective tissue amount[c]	5.7^{de}	5.6^{ef}	5.6^{def}	5.2^{f}	6.1^{d}	5.8^{de}	5.0^{ef}	4.9^{f}	5.0^{ef}	5.1^{ef}	5.4^{de}	5.5^{d}	6.2^{d}	5.7^{e}	6.1^{de}	5.8^{de}	6.1^{de}	6.1^{de}
Shear force, kg	6.5^{f}	7.4^{de}	6.8^{ef}	7.5^{d}	5.5^{g}	6.3^{f}	6.2^{e}	7.0^{d}	6.3^{e}	6.5^{de}	6.3^{e}	6.1^{e}	5.0^{ef}	5.9^{d}	4.9^{f}	6.4^{d}	4.0^{g}	5.1^{ef}

[a]Degree of doneness: 8 = rare and 1 = extremely well done.

[b]Tenderness, juiciness and flavor: 8 = extremely tender, juicy and intense and 1 = extremely tough, dry and bland.

[c]Connective tissue amount: 8 = none and 1 = an abundant amount of panel detectable connective tissue.

[d-g]Means within a row, within muscle groupings with different superscripts are significantly different ($P<.05$).

TABLE 2. *Effects of postmortem tenderness treatments on the cooking and sensory traits of the beef longissimus.*

	Postmortem tenderness treatments			
	Blade tenderization		Control	
Traits	ES[a]	NS[a]	ES	NS
Thaw loss, %	0.8[b]	1.0[b]	0.9[b]	0.7[b]
Cooking loss, %	24.2[b]	24.9[b]	25.7[b]	25.0[b]
Tenderness	5.1[b]	4.6[c]	4.9[b]	4.3[c]
Juiciness	5.2[b]	5.3[b]	5.2[b]	5.4[b]
Flavor	5.2[b]	5.1[b]	5.1[b]	5.2[b]
Connective tissue amount	6.3[b]	6.1[b]	6.0[b]	5.6[c]
Shear force, kg	4.7[c]	5.6[b]	4.6[c]	6.0[b]

[a]ES = electrical shock and NS = no electrical shock.
[b,c]Means in the same row with different superscripts are different (P<.05).

TABLE 3. *Effect of postmortem storage treatments on the cooking and sensory traits of beef primal cuts.*

	Muscles					
	SM		ST		LD	
Traits	Freeze	Chill and freeze	Freeze	Chill and freeze	Freeze	Chill and freeze
Thaw loss, %	8.9[a]	7.5[a]	4.3[b]	5.6[a]	0.8[a]	0.7[a]
Cooking loss, %	37.2[a]	36.7[a]	37.2[a]	36.5[a]	29.8[a]	27.8[a]
Degree of doneness	2.0[a]	2.2[a]	2.5[a]	2.6[a]	3.8[a]	3.8[a]
Tenderness	3.4[b]	3.9[a]	3.6[a]	3.8[a]	4.5[b]	5.0[a]
Juiciness	3.9[a]	3.9[a]	4.6[a]	4.7[a]	5.2[a]	5.3[a]
Flavor	4.3[a]	4.4[a]	4.9[a]	4.9[a]	5.1[a]	5.1[a]
Connective tissue amount	5.6[a]	5.7[a]	5.0[a]	5.2[a]	5.9[a]	6.1[a]
Shear force, kg	6.9[a]	6.4[b]	6.6[a]	6.2[a]	5.7[a]	4.7[b]

[ab]Means within a row, within muscle groupings with different superscripts are significantly different (P<.05).

The effect of postmortem storage treatments on the cooking and sensory traits of beef primal cuts is presented in Table 3. Thaw loss, cooking loss, degree of doneness ratings, juiciness, flavor and connective tissue amount were not significantly affected by storage method (P>.05). With the exception of the ST muscle, samples frozen after 24 h (chill and freeze) were significantly (P<.05) more tender (panel and Instron shear) than those frozen immediately.

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