Effects of a Unique Application of Electrical Stimulation on Tenderness, Color and Quality Attributes of the Beef L*ongissimus* Muscle[1]

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SUMMARY

This study evaluated effects of four uniquely applied beef carcass electrical stimulation (ES) treatments on USDA grade factors, muscle color, and tenderness. One side of each beef carcass was subjected to ES using one of four treatments (medium voltage for medium duration, MVMD; medium voltage for long duration, MVLD; high voltage for medium duration, HVMD or high voltage for long duration, HVLD) and was compared to its corresponding non-ES control side. Electrical stimulation of beef sides was applied focusing on middle meats while preventing severe contraction of the round and chuck. Mean marbling scores (n = 284) for stimulated sides did not differ (P = .923) from those for control sides within ES treatment classes. Mean values for CIE L*, a* and b* of lean color (n = 284) were higher (P < .05) for all treated sides than for the respective control sides. When WBS values for steaks were adjusted to a common visual degree of doneness, WBS values (n = 122) were lower (P < .05) for ES treated sides than for control sides for all four ES application treatments. Treatment responses were not influenced by USDA Quality Grade group. For those carcasses where the control sides had shear force values greater than 10 lbs, matching sides treated with MVMD, MVLD, HVMD, or HVLD had WBS values less than 10 lbs 50, 88, 60 and 75% of the time, respectively.

Key Words: Beef, Electrical Stimulation, Tenderness, Lean Color

INTRODUCTION

Inadequate tenderness and low overall palatability were among the "Top 10 Quality Concerns" in the 1995 National Beef Quality Audit. Additionally, tenderness and taste have been identified as the two primary drivers of consumer purchases of beef (Savell et al., 1987; Miller et al., 1995).

Use of high-voltage electrical stimulation (ES) increases the tenderness of beef *longissimus* steaks (Tatum et al., 1997; Eilers et al., 1996). This study determined the effects of using high-voltage or medium-voltage electrical stimulation (ES) of beef carcasses that was applied for either medium duration or long duration by excluding the round and chuck from the electrical stimulation circuit, on: (1) tenderness of the *longissimus* muscle, and (2) USDA Quality Grade factors and lean color attributes of the *longissimus* muscle at the $12^{th}/13^{th}$ rib interface.

MATERIALS AND METHODS

Carcass Selection and Stimulation Procedure. On each of three days, five scientists selected 80 to 100 beef carcasses from the normal commercial production population of the Monfort packing plant in Greeley, CO. One side of each carcass was subjected to one of four ES treatments on the transfer chain leading from the carcass wash cabinets to the chilling coolers, approximately 50 minutes after exsanguination.

Electrical stimulation (ES) was performed at either medium voltage (MV) or high voltage (HV) and for either medium duration (MD) or long duration (LD)using the Stimulator 350 (Britt Rice Co., College Station, TX). The four ES treatment applications applied to carcasses were: (a) 11 impulse cycles of 100 volts (MVMD), (b) 16 impulse cycles of 100 volts (MVLD), (c) 6 impulse cycles of 100 volts plus 5 impulse cycles of 300 volts (HVMD) or (d) 6 impulses of 100 volts plus 10 impulse cycles of 300 volts (HVLD). An impulse cycle consisted of 1 second on and 1 second off. For all treatments, the frequency of the electrical current was 60Hz. Test carcass sides were identified with individually numbered tags; however, no indication of the treatment administered or notation of which side served as the negative control vs. which side served as the ES treated unit was placed on the tags. Carcasses were then placed in chill coolers for 36 h.

Data Collection Procedures. After the carcasses were chilled, ribbed and officially graded, they were retained in an area with adequate working space and lighting for evaluation. Carcass yield and quality grade factors for each carcass side (treated and control) were evaluated by a trained Colorado State University scientist. Carcass grade factors collected included hot carcass weight; preliminary yield grade; ribeye area; percent kidney, pelvic and heart fat; skeletal and lean maturity; marbling score; lean firmness scores and lean texture scores. Marbling score, lean maturity, lean firmness, lean texture, lean color, ribeye area, preliminary yield grade and notation of dark cutting condition were determined for each side of each carcass while skeletal maturity, hot carcass weight, adjusted yield grade and percent kidney, pelvic and heart fat were determined for each whole carcass.

Lean color was evaluated for each carcass side using a portable spectrophotometer equipped with a 6mm aperture (MiniScan XE; HunterLab Associates Laboratory, Inc., Reston, VA) following the standardization procedures as outlined for the spectrophotometer using black glass and instrument white tile. Color was measured in CIE L* (lightness: 100 represents white and 0 represents black), a* (redness-greenness: positive represents red and negative represents green) and b* (yellowness-blueness: positive represents yellow and negative represents blue) reflectance values.

Steak Selection, Preparation and Tenderness Determination. From

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matched carcass sides, carcasses were selected to represent each of three quality grade groups; Select (SE), low Choice (LC) or upper two-thirds Choice (UC). Ten carcasses from each of the USDA Quality Grade groups (SE, LC, UC) by ES treatment groups (MVMD, MVLD, HVMD, HVLD) were selected randomly to provide steaks for evaluation of tenderness using Warner-Bratzler shear force analysis. Steaks (approximately 1 in thick) from the *longissimus* muscle of 120 carcasses (240 total samples) were obtained at the 12th/13th rib interface.

Shear force values were determined for *longissimus* muscles obtained from each carcass side. Shear force was determined for steaks following a total postmortem aging period of seven days under refrigerated conditions (5°C). Each steak was turned at 4, 8, 12, and, if necessary, 16 min until reaching an internal temperature of 160°F, measured using a thermocouple. When each steak reached the desired temperature endpoint, it was cut in half and evaluated visually for degree of doneness. Shear force values were subsequently adjusted using visual degree of doneness as a covariate.

Following cooking, steaks were allowed to cool to ambient room temperature (~ 68°F) and six to ten 0.5 in cores were removed from each steak parallel to the muscle fiber orientation using a mechanical coring device. A single peak shear force measurement was obtained for each core using the Warner-Bratzler shear force machine and mean peak shear force was the average of the values required to shear the cores from each steak.

Statistical Analysis. Simple descriptive statistics (means and standard deviations) were computed for all carcass traits collected from control sides and stratified by ES treatment and quality grade group to characterize sample population. Preliminary analyses showed that quality grade group and gender of carcass as well as interactions of these traits with ES treatment class had no effect (P > .05); therefore data for steers and heifers as well as for SE, LC and UC were pooled into ES treatment class for all analyses. Data were analyzed as a split plot design in a model with the whole carcass representing the whole plot and the treated carcass side and control side representing the split plots. The model was tested using the least squares, mixed model procedure of SAS (1996) and included carcass identification as a random variable. Data were analyzed to assess differences between the treated vs. control sides of carcasses as well as differences between treatments. Additionally, ES treatment was nested within the carcass identification to account for the random effect of individual carcasses. To correct for the effects of visual degree of doneness, a covariate analysis was conducted using visual degree of doneness as a covariate in the analysis of Warner-Bratzler shear force (SAS, 1996). Visual degree of doneness was a significant (P < .05) covariate for WBS values. Least squares means were separated using a pairwise t-test procedure of SAS (1996).

RESULTS

Carcass Population. Sample carcasses were divided into three USDA Quality Grade groups; SE, LC or UC. The sample population was comprised of approximately equal numbers of steers and heifers. Additionally, the sample population possessed preliminary yield grades between 2.6 and 3.4. The carcass population also had consistent marbling scores within each USDA Quality Grade subgroup with the Select subgroups having average marbling scores between Slight^{30} and Slight^{40}, while low Choice subgroup marbling scores ranged from Small^{20} to Small^{40} and the upper two-thirds Choice subgroup had marbling scores between Modest^{50} and Modest^{80}.

Carcass Quality Grade Attributes. Mean scores for marbling, lean maturity and final quality grade by treatment subclass and differences between treated vs. control carcass sides for marbling, lean maturity and final USDA Quality Grade in each ES treatment group are presented in Table 1. Lean maturity scores were lower as a result of ES application (P < .05). Lean maturity scores, while improved with all ES treatments, were not improved more within one treatment versus the other treatments (P > .05).

Carcasses also were evaluated for lean firmness and lean texture of the *longissimus* muscle at the 12th/13th rib interface. Lean firmness and lean texture did not differ between treated and control carcass sides (P > .05).

Longissimus Muscle Color Attributes. Mean CIE L*, a* and b* values for ES sides and the differences between treated and control sides by treatment are presented in Table 2. The *longissimus* muscles of ES-treated sides were brighter, redder and less blue in color than the *longissimus* muscles of control sides (P < .05). Treatment comparisons for L*, a* or b* were not significant (P > .05).

Tenderness. The mean shear force value for each steak was adjusted to a common visual cooked degree of doneness using analysis of covariance. With only one exception (MVMD treated carcasses in the SE quality subclass), mean visual degree of doneness scores reflected a cooking endpoint of 70°C or below and there was no apparent bias in degree of doneness between steaks from treated vs. control sides. Adjusted shear force values for steaks from ES sides were lower (P < .05) than those for steaks from control sides (Table 3). The interaction between ES treatment and USDA Quality Grade subgroup on differences between control and ES shear force values was not significant (P > .05). Additionally, while the treatments resulted in lower shear force values when compared to the controls, these treatment effects did not differ when comparing the four ES treatments (P > .05).

Based on threshold values of 8.5 and 10 lbs, the percentage improvement in the frequency distribution within each ES treatment subclass was computed (Figure 1). Figure 1 indicates the number of control steaks and ES-treated steaks greater than 8.5 lbs and 10 lbs of Warner-Bratzler shear force beneath the threshold values. MVMD, MVLD, HVMD, and HVLD had WBS force values less than 10 lbs 50, 88, 60, and 75% of the time, respectively. These percentages indicated that beef became more acceptable in tenderness with the use of ES in comparison to the control steaks within each treatment.

DISCUSSION

Numerous studies have been conducted on the effects of electrical stimulation on carcass quality characteristics as well as tenderness attributes. Results from this study indicated that ES generated carcasses with more youthful lean maturity scores and more desirable lean color (P < .05). These findings were supported by other studies (Tatum et al., 1997) which reported that application of ES resulted in more youthful lean, more desirable overall maturity scores and improved lean color than in control sides. Electrical stimulation also resulted in improved tenderness or improved Warner-Bratzler shear force values as supported by other studies (Eilers et al., 1996; Tatum et al., 1997)

IMPLICATIONS

The unique application of ES resulted in similar results as contemporary application of ES with improved quality grade attributes and shear force values. Electrical stimulation improved lean color as stimulated sides, on average, became brighter, redder and less blue. Treated sides also had, on average, more desirable lean maturity scores than control sides in all ES treatments. Warner-Bratzler shear force values were improved with use of ES. Using the unique application of ES, there was no negative effect on cooking loss or purge loss as a result of using medium voltage or high voltage ES. The high voltage, long duration treatment resulted in the largest improvement in color between control and treated sides, the largest improvement in lean maturity scores, and had comparable improvements in tenderness to that of the other treatments and would be the treatment of choice to be used by packers.

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Table 1.
Mean Quality Grade Attributes for Treated Sides and Mean Differences for Quality Attributes Between Treated and Control Carcass Sides (n=284)

ES TRT[a]	Marbling Score			Lean Maturity			Quality Grade		
	ES Mean	Diff[b]	sem[c]	ES Mean	Diff[b]	sem[c]	ES Mean	Diff[b]	sem[c]
LVMD	Sm^{44}	7.6	8.3	A^{58}	-8.82[d]	2.2	$Select^{80}$	.1	.1
LVLD	Sm^{41}	1.3	8.4	A^{59}	-6.33[d]	2.2	$Select^{70}$	-.1	.1
HVMD	Sm^{41}	.6	8.3	A^{57}	-6.42[d]	2.2	$Select^{70}$	.0	.1
HVLD	Sm^{42}	5.3	8.4	A^{52}	-10.00[d]	2.2	$Select^{80}$	.1	.1

[a] Electrical Stimulation Treatment: LVMD=Low voltage, medium duration; LVLD=Low voltage, long duration; HVMD=high voltage, medium duration; HVLD=high voltage, long duration.
[b] Difference for given trait: Treated side minus control side.
[c] s.e.m.: Standard Error of the Mean for the given trait.
[d] Treatment means differ from control means (P < .05).

Table 2.
Mean Values for Color Attributes L*, a* and b* and Mean Differences for Color Attributes by ES Treatment

ES TRT[a]		LVMD	LVLD	HVMD	HVLD
L*[b]	ES Mean	35.63	35.53	35.56	36.40
	sem[c]	.29	.29	.29	.30
	Diff[d]	1.18[e]	1.09[e]	1.03[e]	1.56[e]
	sem[c]	.28	.28	.28	.28
a*[b]	ES Mean	11.68	11.56	11.73	11.58
	sem[c]	.19	.19	.19	.19
	Diff[d]	.20[e]	.44[e]	.51[e]	.48[e]
	sem[c]	.12	.12	.12	.12
b*[b]	ES Mean	12.03	11.95	12.03	12.30
	sem[c]	.15	.15	.15	.15
	Diff[d]	.30[e]	.55[e]	.55[e]	.70[e]
	sem[c]	.14	.14	.14	.14

[a] Electrical Stimulation Treatment: LVMD=Low voltage, medium duration; LVLD=Low voltage, long duration; HVMD=high voltage, medium duration; HVLD=high voltage, long duration.
[b] L* = lightness (100=white, 0=black), a* = redness/greenness (positive=red, negative=green), b* = yellowness/blueness (positive=yellow, negative=blue).
[c] s.e.m.: Standard Error of the Mean for the given trait.
[d] Difference for given trait: Treated side minus control side.
[e] Treatment means differ from control means, for each color attribute column (P > .05).

Table 3.
Least Squares Means for Warner-Bratzler Shear Force Adjusted to an Equal Visual Degree of Doneness Cooking Endpoint and Differences between Treated and Control Mean Shear Force Values by ES Treatment Subclass (n=122)

	Shear Force Value (lb)				
ES TRT[a]	ES Mean	ES sem[b]	Diff[c]	sem[b]	Probability of Significance
LVMD	8.69	.26	-.93	.31	.0035
LVLD	8.25	.26	-.86	.31	.0071
HVMD	8.42	.26	-1.46	.31	.0001
HVLD	8.33	.26	-1.01	.31	.0016

[a] Electrical Stimulation Treatment: LVMD=Low voltage, medium duration; LVLD=Low voltage, long duration; HVMD=high voltage, medium duration; HVLD=high voltage, long duration.
[b] s.e.m.: Standard Error of the Mean for the given trait.
[c] Diff.: Difference for the given trait: Treated side minus control side.

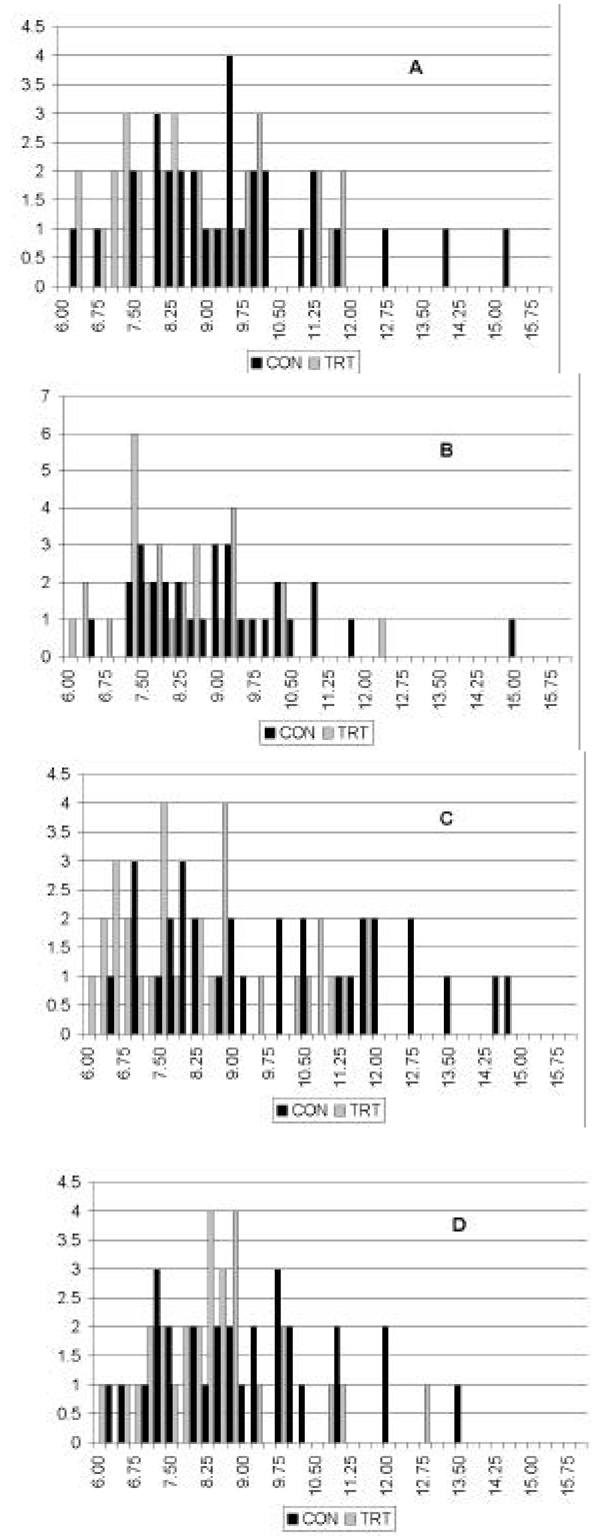

Figure 1. A: Adjusted shear force values for Low Voltage Medium Duration. B: Adjusted shear force values for Low Voltage Long Duration. C: Adjusted shear force values for High Voltage Medium Duration. D: Adjusted shear force values for High Voltage Long Duration. Graphs indicate the measured shear force value on the x-axis and the frequency of that shear force value on the y-axis.