Low voltage electrical stimulation of beef carcasses slows carcass chilling rate and improves steak color

C. E. Bakker, K. R. Underwood, J. K. Grubbs, A. D. Blair

Objective

The objective of this study was to evaluate the influence of two levels of low voltage electrical stimulation (ES) on temperature decline, pH, and meat quality.

Study Description

Forty-two carcasses selected from a commercial packing facility were utilized for this study. Three collections were conducted throughout the course of the production day. Prior to chilling, paired sides were identified to compare the influence of 2 levels of ES. One side was subjected to one of two ES treatments 1) 80 volts (ES80; n = 20) and 2) 40 volts (ES40; n = 22) 45 min after exsanguination. For both ES40 and ES80 treatments the ES was applied over a 60 second period where the carcasses received a 4 second pulse of electricity with approximately 2 seconds between each pulse. The remaining side of each carcass served as a negative control and did not receive ES (Control; n = 42). Carcass temperature decline, pH decline, Warner-Bratzler shear force, cook loss, and steak color were measured.

Take home points

Low voltage ES can be an effective means to improve tenderness and objective color scores of beef carcasses and slow the rate of carcass temperature decline postmortem. With the exception of early postmortem pH levels, no differences were observed between the ES40 and ES80 treatments. Therefore, beef processing facilities that implement low voltage ES as part of their carcass processing procedures may be able to reduce the ES voltage levels to 40 volts without impacting the meat quality characteristics expected with 80 volts of ES.

Keywords: beef, electrical stimulation, quality, temperature decline

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Abstract

The objective of this study was to evaluate the influence of two levels of low voltage electrical stimulation (ES) on temperature decline, pH, and meat quality. Forty-two A maturity beef carcasses were chosen from a commercial packing facility. One side of each carcass received either 40 (ES40) or 80 (ES80) volts of ES for 60 seconds. The paired side of each carcass did not receive ES (Control). Temperature loggers were placed in a sub-sample of 12 carcasses to record temperature decline over a 24 hour period. *Longissimus* muscle pH was measured at 1, 12, and 24 h postmortem in addition to ultimate pH. Strip steaks were fabricated for determination of shear force, cook loss, and objective color. Data were analyzed as a completely randomized design. Contrast statements were used to compare Control vs ES40 and ES80 sides, and ES40 vs ES80. A time by treatment interaction was observed for carcass temperature decline ($P < 0.001$) where ES sides stayed warmer for a longer period than Control sides. A treatment by time interaction was observed for pH decline with Control sides having a greater pH at 1 hour postmortem ($P < 0.001$). No difference was observed in ultimate pH between treatments ($P > 0.05$). Objective L*, a*, and b* values were increased for ES sides compared to Control sides ($P < 0.001$). No treatment effects were observed for shear force or cook loss ($P > 0.05$). The results of this study indicate ES slows the rate of carcass temperature decline, increases the rate of initial pH decline, and improves objective color scores. Similar results were observed between the two ES treatments indicating lower levels of ES may be used to achieve similar quality characteristics.

Introduction

In 1749, Benjamin Franklin first discovered the potential benefits of applying electrical stimulation (ES) to turkey carcasses and noted the improvement in meat quality and tenderness (Lopez and Hurbert, 1975). However, research on the impact of ES on meat quality did not accelerate until the 1950's when Harshram and Deatherage (1951) patented a method of ES for meat. Electrical stimulation used in the meat industry can be categorized as: extra low voltage ES, low voltage ES, or high voltage ES (Adeyemi and Sazili, 2014). Extra low voltage ES is used to facilitate the removal of blood from carcasses shortly after exsanguination, while high voltage ES is used to improve tenderness and color (McKeith et al., 1981; Roeber et al., 2000). However, there are discrepancies among reports regarding the influence of varying low levels of ES on meat quality traits (Savell et al., 1978; Roeber et al., 2000; Adeyemi and Sazili, 2014). Therefore, the objective of this study was to evaluate the influence of two levels of low voltage electrical stimulation on temperature decline, muscle pH, objective color, and objective tenderness. We hypothesized the ES treatments would increase carcass temperature, decrease muscle pH, improve tenderness, and increase objective L* and a* values with the 80 volt ES treatment having greater impact on these traits than the 40 volt ES treatment.

Experimental Procedures

Forty-two carcasses selected from a commercial packing facility were utilized for this study. Three collections were conducted throughout the course of the production day. Prior to chilling, paired sides were identified to compare the influence of 2 levels of ES. One side was subjected to one of two ES treatments 1) 80 volts (ES80; n = 20) and 2) 40 volts (ES40; n = 22) 45 min after exsanguination. For both ES40 and ES80 treatments the ES was applied over a 60 second period where the carcasses received a 4 second pulse of electricity with approximately 2 seconds between each pulse. The remaining side of each carcass served as a negative control and did not receive ES (Control; n = 42).

Following application of ES treatments, carcasses were chilled for 48 hours. Carcass temperature decline was monitored from the timepoint the carcasses entered the blast chiller on paired sides by inserting a temperature probe into the sirloin of both sides of the first 4 carcasses selected at each of the 3 collection time points. Standard carcass measurements were collected by SDSU personnel. Boneless striploins were collected, transported to SDSU, and fabricated into 1 inch steaks.

Steaks utilized for WBSF cooked on a clamshell to an internal temperature of 160 °F (medium degree of doneness). Six cores were taken parallel to the direction of the muscle fibers and then sheared once using a Warner-Bratzler shear machine and peak shear force was recorded for each core. An average shear force value was calculated and recorded for each steak.

Cook loss was determined on steaks designated for WBSF. Raw steak weight was recorded with a balance and after cooking, steaks were allowed to equilibrate to room temperature and weighed again. Cook loss was determined using the following equation.

Steaks designated for color determination were allowed to bloom for 30 minutes prior to evaluation. L*, a*, and b* values were recorded at two locations using a handheld colorimeter and averaged between both locations for each steak.

The experiment utilized both sides of 42 carcasses in a completely randomized design. The data analysis for this paper was conducted using the MIXED model of SAS software with fixed effect of treatment, random effect of carcass, and Toeplitz covariate structure. As hot carcass weight from both sides are needed to calculate USDA yield grades, carcass data were analyzed by ES treatment with data reported as ES40 or ES80 treatments. Contrast statements were used to compare Control vs ES40 and ES80 sides (No ES vs ES), and ES40 vs ES80 (ES Level). Peak internal cooking temperature was used as a covariate for cook loss and WBSF data. Temperature decline, WBSF, cook loss, and pH were considered repeated measures. Significance was determined at $P > 0.05$.

Results and Discussion

Carcass characteristics did not differ ($P > 0.05$; data not shown) between carcasses used for ES40 and ES80 treatments. A treatment by time interaction was observed for temperature decline ($P < 0.0001$; Figure 1). Sides treated with ES prior to chilling were warmer than sides that did not received ES and this difference persisted at 24 hours postmortem when temperature data loggers were removed from the carcasses.

A treatment effect was observed for WBSF with ES treated sides exhibiting more tender shear force values compared to the control sides ($P < 0.0220$; Table 1). The percentage of weight lost during cooking was not impacted by ES treatment ($P > 0.05$; Table 1).

A time by treatment interaction was observed for pH decline ($P < 0.0001$; Table 1). At 1 h postmortem, differences were observed for both the No ES vs ES contrast ($P < 0.0001$; Table 1) and the ES Level contrast ($P = 0.0167$; Table 1) with ES80 carcasses achieving the most reduced pH, ES40 intermediate, and Control reporting the greatest pH value.

A treatment effect for color was observed between the No ES vs ES sides with ES sides producing lighter (L*; $P < 0.0001$; Table 1), redder (a*; $P < 0.0001$; Table 1), and more yellow (b*; $P < 0.0001$; Table 1), steaks compared to the Control sides.

Implications

Low voltage ES can be an effective means to improve tenderness and objective color scores of beef carcasses and slow the rate of carcass temperature decline postmortem. With the exception of early postmortem pH levels, no differences were observed between the ES40 and ES80 treatments. Therefore, beef processing facilities that implement low voltage ES as part of their carcass processing procedures may be able to reduce the ES voltage levels to 40 volts without impacting the meat quality characteristics expected with 80 volts of ES.

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Table 1. Warner Bratzler Shear Force (WBSF), cook loss, pH decline, and objective color of beef carcasses subjected to low voltage electrical stimulation for 60 seconds in 4 seconds on, 2 seconds off intervals prior to initial chilling[1]					
Item	Control[2]	ES40[2]	ES80[2]	No ES vs ES P-value[3]	ES Level P-value[3]
WBSF, lb	8.47 ± 0.18[a]	8.14 ± 0.22[b]	8.02 ± 0.24[b]	**0.0220**	0.7332
Cook loss, %	17.94 ± 0.28	18.34 ± 0.38	18.24 ± 0.39	0.3753	0.8536
1 h pH	6.34 ± 0.03[a]	6.22 ± 0.04[b]	6.10 ± 0.04[c]	**< 0.0001**	**0.0167**
12 h pH	6.01 ± 0.03	5.94 ± 0.04	5.99 ± 0.04	0.2423	0.2388
24 h pH	5.86 ± 0.03	5.79 ± 0.04	5.83 ± 0.04	0.1251	0.3704
Ultimate pH[4]	5.60 ± 0.03	5.61 ± 0.04	5.64 ± 0.04	0.4861	0.6247
L*	40.38 ± 0.34[a]	42.28 ± 0.46[b]	42.77 ± 0.48[b]	**< 0.0001**	0.4582
a*	24.94 ± 0.30[a]	26.08 ± 0.33[b]	26.06 ± 0.38[b]	**< 0.0001**	0.9460
b*	10.14 ± 0.27[a]	11.30 ± 0.29[b]	11.19 ± 0.34[b]	**< 0.0001**	0.7079

[1] Least square means ± standard error of means

[2] Carcasses subjected to 0 (Control), 40 (ES40), or 80 (ES80) volts of electrical stimulation

[3] No ES vs ES contrast statement compares Control carcasses vs. 40 and 80 voltage treatments; ES Level contrast statement compares 40 vs. 80 voltage treatments

[4] Ultimate pH recorded upon the thawing of steaks aged 3 d and frozen

[abc] Means with different subscripts indicate a difference within row ($P < 0.05$)

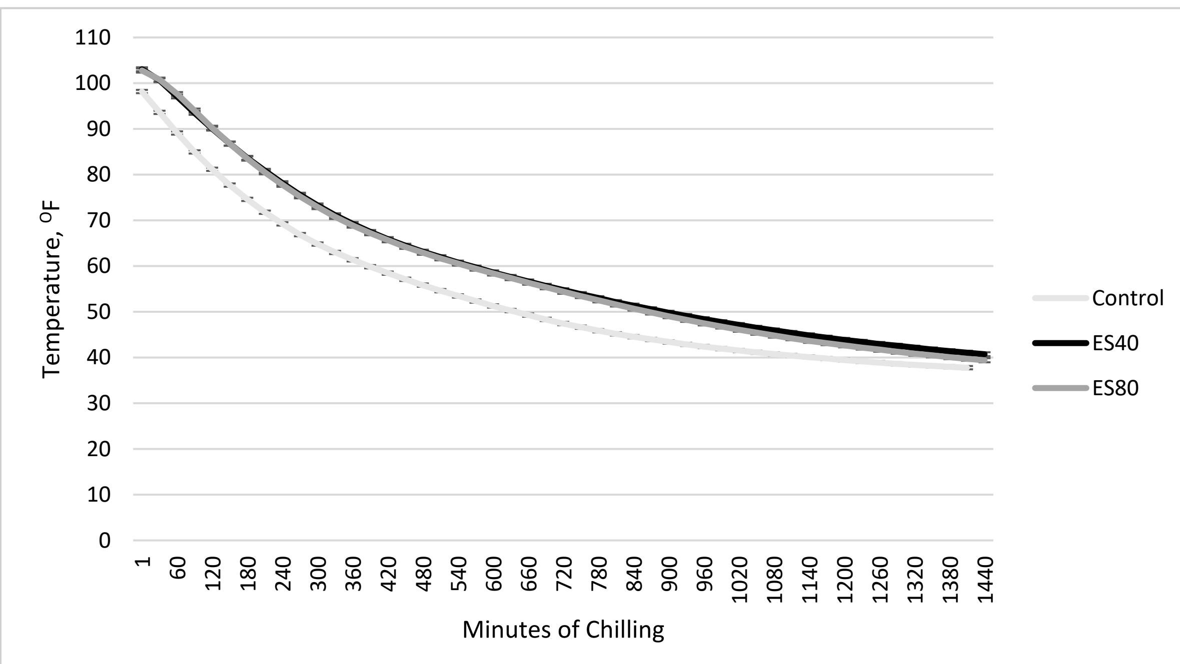

Figure 1. Temperature decline of carcass submitted to low voltage electrical stimulation (ES) prior to chilling. Data are depicted as least square means ± SEM. Treatments are as follows: Control = No ES, ES40 = 40 volts of ES, ES80 = 80 volts of ES. Electrical stimulation was applied for 60 seconds in 4 second on, 2 second off intervals