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Effects of High Voltage Electrical Stimulation on Meat Quality of Beef Carcasses

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Abstract: A total of 40 beef were used to determine the effects of High Voltage Electrical Stimulation (HVES; 500-800 V) on improving meat quality. ES was applied to the right half carcasses and the left halves were kept as control group. Meat quality was evaluated on *M. longissimus dorsi* and *M. semimembranosus* by examining pH at 0, 3, 6 and 24 h; Shear Force (SF), colour (L*, a*, b*) and sensory values at 2 and 7 days of post-slaughter period. As a result, ES introduced faster decrease and lower values of pH decline compared to the control group ($p<0.001$). The lowest SF values were demonstrated from the ES applied samples. Significant differences of redness (a*) and sensorial values were measured between ES and control groups. It was observed that HVES is a useful method for improving quality criteria of beef meat.

Key words: Electrical stimulation, carcass, colour, texture, sensorial properties

INTRODUCTION

In each stage of meat production, a great diversity of factors may affect the meat quality. Characteristics such as tenderness colour and taste affects directly consumer's preferences. They can be influenced by various physical, chemical and microbiological methods. One of these applications is Electrical Stimulation (ES), which is applied to the carcasses immediately after the slaughter (Hwang *et al*., 2003; Strydom *et al*., 2005).

ES involves transmitting an electrical current through the carcasses of freshly slaughtered animals. This electrical current accelerates post-mortem glycolysis and causes pH decline by the depletion of the energy reserves in the muscle (Eikelenboom *et al*., 1985; Stiffler *et al*., 1982). ES has received considerable attention for improving the meat quality; including tenderness, colour and palatability attributes in beef (McKenna *et al*., 2003; Hwang and Thompson, 2001), lamb (Polidori *et al*., 1999; Kahraman and Ergun, 2009), goat (Biswas *et al*., 2007; Cetin and Topcu, 2009), chicken (Birkhold and Sams, 1993), deer (Wiklund *et al*., 2002) and pigs (Taylor *et al*., 1995).

At ES applications, voltage is the major parameter of electric current. Due to the installation costs and safety for the operators, Low Voltage Electrical Stimulation (LVES; voltage <100 V) is frequently used in many countries instead of High Voltage Electrical Stimulation (HVES; voltage >100 V). But, LVES has been reported to be less effective for tenderness improvement when compared to HVES (Hwang and Thompson, 2001; Janz *et al*., 2001). The objective of this investigation study is to evaluate the effects of HVES on meat quality of beef carcasses.

MATERIALS AND METHODS

Stimulation procedure: A total of 40 beef weighting between 400-500 kg and 3 years age or older from Istanbul University Veterinary Faculty farm were used as material. Beef were transported to the slaughterhouse from nearby farm within 15 min for 1 day prior to slaughter. During this period, they were provided with *ad libitum* water and kept without feed for 24 h before slaughter. Beef were slaughtered by Halal method. Following exsanguinations and evisceration, all the carcasses were halved by splitting through the vertebral column approximately in 45 min post-slaughter period. Beef groups were allocated to five experimental groups according to HVES: 500 V, 50 Hz, 60 sec, 500 V, 50 Hz, 120 sec, 800 V, 50 Hz, 60 sec and 800 V, 50 Hz, 120 sec. HVES was applied to the right sides of each carcass and the corresponding left carcasses were used as Nonstimulated (NES) controls. After electrical stimulation, the electrical connections were removed and the carcasses were transported to a chiller at 0-4°C air flow 1-1.5 ms^{-2}.

Sampling and measurements: Meat quality measurements were assessed on the back (*M. longissimus* dorsi; LD) and thigh (*M. semimembranosus*; SM) muscles. pH was measured immediately at 0, 3, 6 and 24 h, respectively using a portable pH-meter (WTW pH 340i

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with a probe SenTix, Weilheim, Germany). The mean of three measures in each muscle were evaluated as pH value. At 24 h at postmortem, the carcasses were transferred to the cutting room for removing LD and SM. The samples were vacuum packaged in Cryovac barrier bags then held in the same cold room and were stored for 6 days prior to the evaluating the Shear Force (SF), colour (L*, a*, b*) and sensory values at 2 and 7 days of post-slaughter period.

SF values were determined for meat following a total postmortem aging period of 2 and 7 days under refrigerated conditions. After aging, steaks were thawed at 10-15°C for 3 h. Chops 2.5 cm thick were cut from each steak parallel to the muscle fiber orientation. Tenderness was measured using an Instron Texture Analyzer Machine model 3343 equipped with a Warner Bratzler device. Five replicates of each sample were made.

Colour as L* lightness, a* redness, b* yellowness values was measured using Colorflex HunterLab Spectrophotometer (Hunter Associates Laboratory Inc., Reston, VA, USA). Colour was evaluated using a diffuse illumination (D65 2° observer) with 8 mm viewing aperture and a 25 mm port size with the specular component excluded and readings were averaged. The unit was calibrated using a white, black and reference standard respectively. Colour values were obtained considering the average of five readings, performed in different location of the surface.

Five members trained sensory panel score the colour and overall (general appearance colour and wetness or dryness and odour) acceptability on the basis of nine point hedonic rating scales (Kerth *et al*., 1999).

Statistical analyses: The trial was performed triplicate. The General Linear Model procedure (PROC GLM) of SPSS 10.0 was used to analyze the data and to determine the Least Squares Means (LSM), Standard Errors (SE) and the significant differences among means. Significance of differences was defined as $p<0.05$ (Anonymous, 1999). Least squares procedures were used to analyze data for pH, textural, colour and sensory characteristics. The model used in the analyses of these characteristics included the fixed effects of electrical stimulation, muscle types, storage periods and also significant two-way interactions between these main effects.

RESULTS AND DISCUSSION

Analysis of the value of pH obtained from carcass halves through the measurements at 0, 3, 6 and 24 h are given in Table 1. According to the results, it was found that the pH values were lower than the control group. Differences among the results of the groups at 0, 3 and 24 h were statistically significant ($p<0.001$). ES accelerates the ATP and glycogen break down and causes a rapid pH decrease. Similar results in pH were reported by Polidori *et al.* (1999) and Soares *et al.* (1995). In another study, Morton *et al.* (1999) applied HVES (1130V, 1.8-2A) for 90 sec to the cattle and sheep carcasses. Results showed that pH decrease 3 times faster than the control. On the other hand, no significant differences were found between the LD and SM ($p>0.05$). Eilers *et al.* (1996) reported that electrical stimulation increased the pH decrease rate in the longissimus muscle but did not have a considerable effect on other muscles.

In a study of Taylor and Martoccia (1995) on pork meat, HVES caused a 0.3 units decrease in pH at the 45 min of post-slaughter. The pH value of pork meat decreased to 5.64 in *M. longissimus* thoracis et lumborum and 5.87 in SM in 3 h after slaughter. In present study, the pH decreased 0.3 units in examined LD and SM muscles in 3 h; this value has reached 5.92 in 6 h and 5.65 in 24 h.

In the present study, HVES applied carcasses were more tender than NES at 1 and 7 days of post-slaughter period ($p<0.001$; Table 2). These findings were supported by other studies in cattle carcasses (Hwang and Thompson, 2001; Smulders *et al.* 1989; Eikelenboom *et al.* 1985). In another study, Yanar and Yetim (2003) reported

Table 1: Means (LSM), Standard Errors (SE) and importance controls of pH values in beef carcasses

Characteristics	N	pH_0	pH_3	pH_6	pH_{24}
Group		***	***	NS	***
500 V, 50 Hz, 60 sn	20	6.529±0.038^{b}	6.171±0.032^{ab}	5.987±0.037	5.673±0.025^{b}
500 V, 50 Hz, 120 sn	20	6.420±0.038^{bc}	6.098±0.032^{b}	5.894±0.037	5.660±0.025^{bc}
800 V, 50 Hz, 60 sn	20	6.397±0.038^{cd}	6.137±0.032^{b}	5.876±0.037	5.594±0.025^{c}
800 V, 50 Hz, 120 sn	20	6.300±0.038^{d}	6.127±0.032^{b}	5.933±0.037	5.623±0.025^{bc}
NES	80	6.649±0.014^{a}	6.238±0.012^{a}	5.957±0.014	5.727±0.009^{a}
Muscle		NS	NS	NS	NS
LD	80	6.460±0.017	6.143±0.014	5.920±0.016	5.657±0.011
SM	80	6.458±0.017	6.166±0.014	5.938±0.016	5.653±0.011
Group x Muscle	-	NS	NS	NS	**
Animal no.	40	***	***	***	***
General average	160	6.459±0.012	6.154±0.010	5.929±0.012	5.655±0.008

Values are expressed as Mean (LSM)±SE. $^{a-c}$Means with different letters in the same column are significantly different. (*): $p<0.05$, (**): $p<0.01$, (***): $p<0.001$; NS: Not Significant ($p>0.05$); LD: M. *longissimus* dorsi, SM: *M. semimembranosus*

that 350 V ES on 14 half carcasses of 3-5 years old sheep improved the texture of LD at p<0.01 level and made no considerable effect on the SM muscle. In the present study also, better results were obtained in the LD muscle and difference between the texture values of two sampled muscles was statistically significant (p<0.01; Table 2). The differences in pH may be the cause of the lower values of SF in meat of ES applied samples, due to decreased activity of calpain.

Colour development was observed with the findings obtained from colour measurement while significantly different results shown in Table 3 for the 2nd and 7th day were obtained (p<0.001) especially in a*. The findings in this study showed similarity with the report of Eikelenboom *et al.* (1985) and Kahraman and Ergun (2009). Kerth *et al.* (1999) studied on 5 different muscles, ES applied muscles were brighter with a better red colour than Non-treated (NES) ones. In another study, Cetin and Topeu (2009) found a significant difference for the L* value on the 7 day at post slaughter in goat carcasses. In contrary, McKenna *et al.* (2003), King *et al.* (2004) and Ledward *et al.* (1986) have found no differences between the ES and NES.

Sensory panel tests were significantly greater for stimulated carcasses (p<0.001; Table 4). Similar to those was found by Vanderwert *et al.* (1986) in bull and Channon *et al.* (2003) in pig carcasses. In contrast, Greathouse *et al.* (1983) has found no differences between ES and NES. On the other hand, between LD and SM muscles difference were significant for appearance, colour, thickness and flavour (p<0.001) at the 2nd day and for thickness, flavour (p<0.001) and colour (p<0.05) at the 7th day.

Yanar and Yetim (2003) stated that ES increased the tenderness of LD (p<0.01); however, did not cause a considerable difference in SM.

Table 2: Means (LSM), Standard Errors (SE) and importance controls of texture values in beef carcasses

Characteristics	N	T_2	T_7
Group		***	***
500 V, 50 Hz, 60 sn	20	15.007±0.577^{b}	11.493±0.538^{b}
500 V, 50 Hz, 120 sn	20	13.973±0.577^{bc}	10.986±0.538^{b}
800 V, 50Hz, 60 sn	20	13.882±0.577^{bc}	11.418±0.538^{b}
800 V, 50 Hz, 120 sn	20	13.227±0.577^{c}	11.901±0.538^{b}
NES	80	16.843±0.218^{a}	13.423±0.203^{a}
Muscle		**	**
LD	80	14.049±0.255	11.343±0.237
SM	80	15.124±0.255	12.345±0.237
Group x Muscle	-	NS	NS
Animal no.	40	***	***
General average	160	14.586±0.180	11.844±0.168

Values are expressed as Mean (LSM)±SE. $^{a-c}$Means with different letters in the same column are significantly different. (*): p<0.05, (**): p<0.01, (***): p<0.001; NS: Not Significant (p>0.05); LD: M. *longissimus* dorsi; SM: *M. semimembranosus*

Table 3: Means (LSM), Standard Errors (SE) and importance controls of instrumental colour values in beef carcasses

Characteristics	N	L^*_2	a^*_2	b^*_2	L^*_7	a^*_7	b^*_7
Group		NS	***	***	*	***	***
500 V, 50 Hz,60 sn	20	28.821±0.618	15.815±0.198^{c}	12.759±0.336^{a}	28.820±0.710^{b}	13.827±0.274^{b}	13.628±0.396^{a}
500 V, 50 Hz,120 sn	20	26.989±0.618	17.615±0.198^{b}	12.095±0.336^{ab}	30.439±0.710^{ab}	14.336±0.274^{b}	12.821±0.396^{ab}
800 V, 50 Hz, 60 sn	20	27.691±0.618	18.040±0.198^{b}	10.876±0.336^{c}	31.961±0.710^{a}	15.382±0.274^{a}	12.149±0.396^{b}
800 V, 50 Hz,120 sn	20	27.627±0.618	19.005±0.198^{a}	10.697±0.336^{c}	31.056±0.710^{a}	15.354±0.274^{a}	11.827±0.396^{b}
NES	80	27.554±0.234	14.678±0.075^{d}	11.718±0.127^{b}	31.079±0.268^{a}	12.682±0.104^{c}	13.218±0.150^{a}
Muscle		NS	***	***	**	***	***
LD	80	27.881±0.289	17.470±0.087	11.188±0.148	30.067±0.313	14.620±0.121	12.159±0.175
SM	80	27.592±0.289	16.591±0.087	12.070±0.148	31.276±0.313	14.013±0.121	13.298±0.175
Group x Muscle	-	**	**	*	***	*	NS
Animal no	40	***	***	***	***	***	***
General average	160	27.236±0.193	17.031±0.062	11.625±0.105	30.671±0.221	14.316±0.085	12.729±0.123

Values are expressed as Mean (LSM)±SE. ^{a,b,c}: Means with different letters in the same column are significantly different. (*): p<0.05, (**): p<0.01, (***): p<0.001; NS: Not Significant (p>0.05); LD: M. *longissimus* dorsi; SM: *M. semimembranosus*

Table 4: Means (LSM), Standard Errors (SE) and importance controls of sensorial values in beef carcasses

		Day 2				Day 7			
Characteristics	N	Appearance	Colour	Thickness	Flavour	Appearance	Colour	Thickness	Flavour
Group		***	***	***	***	***	***	***	***
500 V, 50 Hz, 60 sn	10	7.411±0.082^{b}	6.845±0.092^{b}	7.853±0.116^{ab}	7.498±0.116^{b}	7.516±0.097^{b}	6.940±0.116^{c}	8.316±0.120^{a}	8.137±0.110^{ab}
500 V, 50 Hz, 120 sn	10	7.501±0.082^{b}	8.372±0.092^{a}	8.085±0.116^{a}	7.928±0.116^{a}	7.723±0.097^{ab}	7.284±0.116^{c}	8.314±0.120^{a}	8.405±0.110^{a}
800 V, 50 Hz, 60 sn	10	7.912±0.082^{a}	8.125±0.092^{a}	7.686±0.116^{b}	7.462±0.116^{b}	7.851±0.097^{a}	7.492±0.116^{b}	8.058±0.120^{a}	8.004±0.110^{b}
800 V, 50 Hz, 120 sn	10	7.783±0.082^{a}	8.362±0.092^{a}	6.895±0.116^{c}	7.220±0.116^{b}	7.796±0.097^{ab}	8.074±0.116^{a}	7.459±0.120^{b}	7.817±0.110^{b}
NES	40	6.913±0.031^{c}	6.409±0.035^{c}	6.605±0.044^{d}	6.556±0.044^{c}	6.915±0.037^{c}	6.450±0.044^{d}	7.072±0.045^{c}	7.081±0.041^{c}
Muscle		***	***	***	***	***	*	***	***
LD	40	7.647±0.036	7.799±0.036	7.594±0.051	7.472±0.051	7.680±0.043	7.321±0.051	8.032±0.053	8.008±0.048
SM	40	7.360±0.036	7.446±0.036	7.256±0.051	7.194±0.051	7.441±0.043	7.176±0.051	7.655±0.053	7.769±0.048
Group x Muscle	-	NS	*	*	NS	NS	NS	NS	NS
Animal no.	40	***	***	***	***	***	***	***	***
General average	80	7.504±0.025	7.623±0.029	7.425±0.036	7.333±0.036	7.560±0.030	7.248±0.036	7.844±0.037	7.889±0.034

Values are expressed as Mean (LSM)±SE. $^{a-c}$Means with different letters in the same column are significantly different. (*): p<0.05, (***): p<0.001; NS: Not Significant (p>0.05); LD: M. *longissimus* dorsi; SM: *M. semimembranosus*

CONCLUSION

HVES applied to beef carcasses showed rapid pH decline, lower SF value, better meat colour and higher sensory scores compared to NES. Between the HVES groups, the best quality criteria in the samples were obtained by applying 800 V, 60 Hz, 120 sec and 500 V, 60 Hz, 120 sec and 800 V treatments were more effective than 500V and similarly 120 sec was superior to 60 sec. In conclusion, HVES is a useful method for improving quality criteria of beef meat.

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