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Research Article

The Effects of Electrical Stimulation on the Sensory and Textural Quality Properties of Mutton Carcasses

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Abstract: The objective of this research was to investigate the influence of electrical stimulation (ES) on the sensory and textural quality characteristics of mutton carcasses from elderly ewes. For this purpose, 14 ovine carcasses from 3-5-year-old ewes were subjected to ES with 350 V, and the effects of ES on the organoleptic and instron textural parameters were evaluated. The ES significantly ($P < 0.01$) improved the panel tenderness scores of the *Longissimus dorsi* (LD) muscle. Some of the Instron Warner Bratzler Shear parameters such as peak force and initial yield force values of the LD muscle were also highly significantly ($P < 0.01$) affected by ES, while the *Semimembranosus* (SM) muscle was not affected. Hardness and peak force 2 values of LD obtained from the Instron compression test were also significantly ($P < 0.05$) affected by ES. However, Instron compression parameters of SM muscles were not significantly influenced by ES treatment. The results revealed that the ES could considerably improve the tenderness of the LD from mutton carcasses. In conclusion, the application of ES to mutton carcasses from elderly ewes could be beneficial for the meat industry by increasing the merchandising value and quality of this sort of carcass.

Key Words: Electrical stimulation, mutton, sensory evaluation, textural quality

Elektriksel Stimulasyonun Koyun Karkaslarının Duyusal ve Tekstürel Kalite Özellikleri Üzerine Etkileri

Özet: Bu çalışmada, yaşlı koyunlardan elde edilen karkasların duyusal ve tekstürel kalite özellikleri üzerine elektriksel stimülasyonun (ES) etkileri incelenmiştir. Bu amaçla, 3-5 yaşlı 14 adet koyun karkas yarımı, 350 volt ES'ye tâbi tutulmuş ve ES'nin duyusal ve instron tekstürel parametreleri üzerine etkileri değerlendirilmiştir. ES çok önemli derecede ($P < 0,01$) *Longissimus dorsi* (LD) kasına ait panel gevreklik puanını iyileştirmiştir. LD kasına ait pik kuvveti, başlangıç kuvveti gibi Instron Warner Bratzler Shear parametreleri, ES'den çok önemli derecede ($P < 0,01$) etkilenirken, *Semimembranosus* (SM) kası ise etkilenmemiştir. Instron Compression Test sonucu, LD'den elde edilen sertlik ve pik kuvveti 2 değerleri de ES'den önemli ($P < 0,05$) dercede etkilenmiştir. Öte yandan, SM kasına ait Instron Compression Test parametreleri de ES'den etkilenmemiştir. Bu sonuçlar, ES'nin koyun karkaslarından elde edilen LD kasının gevrekliğini önemli ölçüde artırdığını göstermiştir. Sonuç olarak, yaşlı koyunlardan elde edilen karkaslara uygulanan elektriksel stimülasyonun bu tür karkasların ticari değeri ve kalitesini yükselterek et endüstrisi için faydalı olabileceği kanaatine varılmıştır.

Anahtar Sözcükler: Elektriksel stimülasyon, koyun eti, duyusal değerlendirme, tekstürel kalite

Introduction

Although sheep are a significant red meat source in developing countries, the native sheep breeds in these countries are usually small in size and grow slowly. Sheep producers usually market their sheep at older ages to secure heavier live weights and carcasses. In addition, as living standards increase, consumers are demanding high quality (more tender) meat that is not characteristic of the meat from these heavy carcasses. There have been many factors reported as influencing the meat quality of sheep, including tenderness and mutton flavor (1). For example, the results of research conducted by Tatum et al. (2) showed that the preference of the consumer was consistently in favor of meat from younger animals due to their tenderness. Advanced age and/or increased physiological maturity are associated with toughness and less desirable flavor in mutton. As a consequence of age-associated problems with tenderness, the majority of elderly ewes are commonly sold for a low price, or the tissue is used in comminuted meat products. In both cases, the mutton carcasses are usually sold for less than their potential value. A consistent method for improving the tenderness of mutton carcasses to a more acceptable level would increase their retail value and may increase marketing opportunities (3).

Tenderness improvement in ovine carcasses can be achieved by a variety of methods including aging, use of enzymes, mechanical tenderization methods and ES (4-7). In the last three decades, ES has received considerable attention, and several studies have been conducted to improve the quality characteristics of carcasses. ES reportedly speeds up the onset of rigor, lessens the aging time and produces brighter and more tender meat from the carcasses of different species (3,8). Although a great deal of research has been conducted into the effects of ES on lamb (9-12), less research has been conducted into mutton. If the tenderness of mutton carcasses can be improved by ES, mutton could be more acceptable in restaurants, hotels or similar institutions in developing countries. Mutton could also be sold through retail channels to consumers.

This research was undertaken to determine the influence of ES on some organoleptic and instrumental quality characteristics of *Longissimus dorsi* (LD) and *Semimembranosus* (SM) muscles from carcasses of elderly ewes.

Material and Methods

A total of 14 mature (3-5-year-old), Western crossbred (Black x White Face) ewes raised in Ohio were used in this research. They were slaughtered and the carcasses eviscerated and split into two halves within 30-45 min post-exsanguination. Since the use of moderate levels of voltage is less dangerous in slaughterhouses and is sufficient to produce desirable results on the sensorial quality of sheep carcasses, 350 V of current was used, as recommended by Kauffman and Marsh (13) and Vijayakumar et al. (14). ES (350 V, for 45 s using a total of 15 impulses, 1.5 s on and off) was applied to the right side of each carcass within 30-45 min postmortem. The electrode that delivered the positive charge to muscle was placed in the *triceps brachii* muscle in the shoulder region of the carcass. The earth wire, terminated with a clamp, was attached to the achilles tendon as a negative pole to complete the circuit. At 24 h postmortem, the LD and SM muscles were excised from each side of the carcasses. The left sides served as the control.

The mutton chops were cooked using a water bath as described by Bouton et al. (15) for homogeneous cooking and used for sensory evaluation. The meat samples were weighed and enclosed in water-impermeable polyethylene bags, then completely immersed in a constant temperature 90 °C water bath and cooked to an internal temperature of 70 °C. The meat was then cooled with running tap water and removed from the bags. From the sample weights, before and after cooking, percentage cooking losses were calculated. A total of six panelists independently evaluated each LD and SM sample for degree of tenderness, juiciness, amount of residue remaining after chewing, and the number of chews before break-up of the meat tissue. Scores, except those for number of chews, were obtained using a 1 to 9 point hedonic scale [extremely tough (1) to extremely tender (9) for tenderness, extremely dry (1) to extremely juicy (9) for juiciness, little (1) to a lot (9) for residue after chewing] as described by Ockerman (16). The number of chews was determined by counting the chews prior to swallowing.

A fragmentation index value was determined by the procedure described by Davis et al. (17) using a gravimetrical method. Mechanical assessment of muscle tenderness was carried out employing two different tests using the Warner Bratzler Shear (WBS) head and the compression tests on the Instron. The cooked meat samples prepared for the sensory panel evaluation were also used for Instron WBS measurements in which four 1.3 cm cores were removed, parallel to the longitudinal orientation of the muscle fibers, and sheared twice for the WBS force value. A WBS head attached to the Instron was used with a crosshead speed of 100 mm/min and with a chart speed of 100 mm/min with 50 kg being a full-scale loading. The parameters measured from the force deformation curves were initial yield force (kg), peak force (kg), initial yield distance (cm), final yield distance (cm), peak force minus initial yield force value, and work done (total amount of work needed to shear the core), which was determined by using the total area under the curve expressed in mm^2 as described by Rao and Gault (18).

The Instron compression test was performed with an Instron Universal Testing Machine Model 1000 (Instron Co. Canton, Maine) by compressing a 1 cm-thick muscle sample 80% of its original height with a 0.07 cm diameter flat plunger descending at a rate of 50 mm/min as described by Hayward et al. (19). The cooked samples were placed in the instrument with the fibers parallel to the main surface and perpendicular to the direction of plunger travel. The plunger was driven into the meat twice at the same location and the work and force penetration curves were recorded. The parameters obtained from the compression measurements were peak force 1 (hardness) (kg), peak force 2 (kg), peak force distance 1 (cm), peak force distance 2 (cm), work done 1 (area of the first peak, A_1 in mm^2), work done 2 (area of the second peak, A_2 in mm^2) and cohesiveness (the ratio of the area A_2/A_1), and chewing (peak force 1 (kg) x cohesiveness) as stated by Stolarz et al. (20).

The data obtained in the study were statistically analyzed by a Minitab version 8 computer package (21). Mean comparison for each muscle was performed by using Student's t-test.

Results

Sensory Evaluation and Fragmentation Index: The means with standard errors of scores for panel tenderness, juiciness, residue remaining after chewing, number of chews and fragmentation index score are presented in Table 1. ES significantly ($P < 0.01$) improved the panel tenderness, juiciness and number of chews scores for the LD muscle. However, the same panel parameters for the SM muscle were not significantly affected by the ES treatment.

For the LD muscle, the fragmentation index used for expression of tenderness as an objective method was also significantly ($P < 0.05$) influenced by the ES application, indicating an improvement in tenderness. On the other hand, the fragmentation index obtained from the SM muscle showed no significant differences between the stimulated and control groups.

The ES to both muscles did not result in any differences in the residue after chewing score. However, ES significantly reduced ($P < 0.05$) cooking loss values in the SM muscle (Table 1), but not in the LD.

Instron Warner-Bratzler Test: The parameters from the Instron Warner-Bratzler Shear (WBS) test are presented in Table 2. Initial yield force and peak force values for the LD muscle were significantly ($P < 0.01$) affected by ES, while the effect of the ES on the same traits of the SM muscle was not significant. The electrically stimulated LD samples had 1.0 kg and 1.15 kg lower peak force and initial force values, respectively, compared to non-stimulated mutton tissue. However, the rest of the WBS textural measurements were not significantly influenced by the ES treatment (Table 2).

Instron Compression Test: The results for the Instron compression test are presented in Table 3. The hardness and peak force 2 values of the electrically stimulated LD muscle were lower than those of the control, and the differences between the treatments were statistically significant ($P < 0.05$). These values again were in the direction of improved tenderness for LD mutton tissue

Table 1. Means with standard errors and Student's t-test results of the LD and SM muscles in mutton for some quality parameters as affected by ES.

	Panel tenderness[5]	Panel juiciness[6]	Residue after chewing[7]	Number of chews[8]	Fragmentation index[9]	Cooking loss (%)
LD[1]	**	**	NS10	**	*	NS
ES[2]	6.87 ± 0.26	5.41 ± 0.15	4.94 ± 0.41	36.72 ± 1.8	337.6 ± 24	28.74 ± 0.59
NES[3]	5.04 ± 0.53	4.68 ± 0.21	5.54 ± 0.29	46.90 ± 3.4	494.0 ± 58	29.12 ± 2.10
SM[4]	NS	NS	NS	NS	NS	*
ES[1]	5.37 ± 0.55	4.81 ± 0.17	5.39 ± 0.24	45.7 ± 3.00	498.2±59	27.92 ± 1.3
NES[2]	4.57 ± 0.43	4.70 ± 0.21	5.68 ± 0.30	49.9 ± 2.70	536.0 ± 52	30.68 ± 2.0

[1]LD = *Longissimus dorsi*, [2]ES = Electrically stimulated, [3]NES = Not electrically stimulated, [4]SM = *Semimembranosus*, [5]Scored on a scale of 1-9 [extremely tough (1) to extremely tender (9)], [6]Scored on a scale of 1-9 [extremely dry (1) to extremely juicy (9)], [7]Scored on a scale of 1-9 [(a few (1) to a lot (9)], [8]Number of chews was determined by panel members before meat sample was broken up and swallowed, [9]As fragmentation index increases, meat becomes less tender and vice versa. [10]NS = Treatments are not significantly different ($P > 0.05$), * Treatments are significantly different ($P < 0.05$), ** Treatments are significantly different ($P < 0.01$).

Table 2. Means with standard errors and Student's t-test results of the LD and SM muscles in mutton for some Instron WBS tests as affected by ES.

	Initial yield force (kg)[5]	Initial distance (cm)[6]	Peak force (kg)[7]	Final distance (cm)[8]	Peak force minus initial yield force[9]	Work done (mm^2)[10]
LD[1]	**	NS	**	NS	NS	NS
ES[2]	3.89 ± 0.21	1.09 ± 0.03	4.18 ± 0.28	2.76 ± 0.12	1.07 ± 0.52	5.04 ± 0.95
NES[3]	5.04 ± 0.34	1.24 ± 0.04	5.18 ± 0.25	3.00 ± 0.25	1.79 ± 0.80	5.90 ± 1.30
SM[4]	NS	NS	NS	NS	NS	NS
ES[1]	5.12 ± 0.58	1.16 ± 0.07	6.29 ± 0.76	2.94 ± 0.17	0.91 ± 0.25	4.66 ± 0.34
NES[2]	6.66 ± 0.60	1.15 ± 0.10	7.51 ± 0.68	2.57 ± 0.14	1.25 ± 0.62	5.59 ± 0.78

[1]LD = *Longissimus dorsi*, [2]ES = Electrically stimulated, [3]NES = Not electrically stimulated, [4]SM = *Semimembranosus*, [5]Initial yield force = First major inflexion on the force-distance curve (kg), [6]Initial distance = The distance, the first registering of force to the initial force point, [7]Peak force = Maximum force recorded on force-distance curve (kg), [8]Final distance = the distance, the first registering of force to the point where sample finally yielded, [9]Peak force minus initial force = Peak force-initial force, [10]Work done = Total area under force-distance curve, NS = Treatments are not significantly different (P > 0.05). *Treatments are significantly different (P < 0.05), ** Treatments are significantly different (P < 0.01).

Table 3. Means with standard errors and Student's t-test results of the LD and SM muscles in mutton for some parameters of Instron compression test as affected by ES.

	Chewiness (kg)[5]	Peak force 1 (hardness) (kg)[6]	Peak force 2 (kg)[7]	Peak force distance 1 (cm)[8]	Peak force distance 2 (cm)[9]	Work done 1 (mm^2)[10]	Work done 2 (mm^2)[11]	Cohesiveness 12
LD[1]	NS	*	*	NS	NS	NS	NS	NS
ES[2]	1.65 ± 0.13	4.83 ± 0.14	3.33 ± 0.46	0.89 ± 0.02	0.87 ± 0.03	5.20 ± 0.42	1.92 ± 0.13	0.49 ± 0.02
NES[3]	1.68 ± 0.12	5.75 ± 0.39	4.71 ± 0.31	0.91 ± 0.03	0.55 ± 0.02	4.91 ± 0.25	1.69 ± 0.17	0.35 ± 0.02
SM[4]	NS	NS	NS	NS	NS	NS	NS	NS
ES[1]	2.03 ± 0.17	5.45 ± 0.20	4.37 ± 0.18	0.91 ± 0.02	0.59 ± 0.02	5.28 ± 0.26	2.13 ± 0.17	0.38 ± 0.02
NES[2]	2.34 ± 0.11	5.99 ± 0.23	4.60 ± 0.30	0.86 ± 0.02	0.54 ± 0.02	5.63 ± 0.32	2.17 ± 0.11	0.40 ± 0.02

[1]LD = Longissimus dorsi, [2]ES = Electrically stimulated, [3]NES = Not electrically stimulated, [4]SM = Semimembranosus, [5]Chewiness = Hardness x (second bite area / first bite area), [6]Hardness = Peak force of first bite, [7]Peak force 2 = Peak force of second bite, [8]Peak force distance 1 = Distance from first registering of force to the peak force point of the first bite, [9]Peak force distance 2 = Distance from first registering of force to the peak force point of the second bite, [10]Work done 1 = Total area under first bite, [11]Work done 2 = Total area under second bite, [12]Cohesiveness = Second bite area / first bite area, NS = Treatments are not significantly different (P > 0.05), *Treatments are significantly different (P < 0.05), **Treatments are significantly different (P < 0.01).

after ES. However, none of the Instron compression test parameters for SM muscle from old mutton carcasses were affected significantly by the ES treatment.

Discussion

The results concerning the sensory panel scores presented in Table 1 were similar to the findings of Vijayakumar et al. (14), Solomon and Lynch (22), Reddy et al. (23) and Mahajan and Panda (24). For example, Solomon and Lynch (22) reported that tenderness panel scores for young ram lambs were improved by ES, but that the juiciness score was not affected. The number of chews before swallowing was reduced from 53 to 35 chews in mutton carcasses as a result of ES (14). Additionally, the tenderness scores for mutton carcasses were significantly increased (P < 0.05) by ES in the studies by Reddy et al. (23) and Mahajan and Panda (24). Rangaiah et al. (11) also reported that ES mutton carcasses had higher tenderness and overall acceptable panel scores than the controls.

In the present study, a significant effect of ES on panel tenderness was only observed in the LD muscle, not in the SM muscle. Kerth et al. (12) and Tornberg (25) noted that the percentage of loin chops rated better improved 30-34% by ES compared to other cuts studied.

Cooking loss values for stimulated and non-stimulated mutton SM tissue were statistically significant (P < 0.05), but not for the LD muscle. Similar observations were also reported in mutton SM, veal SM and bovine LD muscles, respectively, by Dani et al. (26), Smulders et al. (27) and Uytterhaegen et al. (28).

ES significantly lowered the initial yield force and peak force values for the LD muscle while the effect of the ES on the same traits of the SM muscle was insignificant.

Similar results were also reported by Solomon (29), who noted that the Instron peak force of the LD muscle was affected by the ES system. Although WBS peak force and initial force values for the SM muscle tended to give lower numerical values with ES, the difference was not statistically significant in the present study. Similar findings were also reported by Solomon and Lynch (10), who determined that stimulated lamb LD muscle had a significantly lower peak force value than its non-stimulated counterparts. However, ES did not reduce the peak force of the SM muscle, and these results are also in agreement with the findings of Dani et al. (26).

The results of the sensory panel, Instron WBS and compression tests indicated that the effects of ES on two different muscles in mutton carcasses were different. Solomon and Lynch (10), Solomon (29) and McKeith et al. (30) claimed that the muscle response to ES was not uniform at different locations within beef carcasses, since some muscles may not be positioned on the current pathway. The same conclusion could also be drawn from the present study for the mutton carcasses subjected to ES.

The overall results of this research indicate that the ES has a significant influence on the improvement of the quality and palatability characteristics of the LD muscle compared to the SM muscle from elderly ewes.

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