Effect of Electrical Stimulation and Age on Muscle Structure and Meat Quality of Dromedary Camel (*Camelus dromedaries*)

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Abstract

The effect of low voltage electrical stimulation (LVES) on meat quality of the one-humped camel of two age-groups (3 and 10 year) was assessed. Quality of the *Longissimus thoracis* (LT) was evaluated using shear force, pH, sarcomere lengths, myofibrillar fragmentation index (MFI), expressed juice, cooking loss and *L*, a*, b** colour values. The age of the camel and LVES had a significant effect on meat quality. LVES resulted in a significantly ($P<0.05$) more rapid pH fall in muscles during the first 12 hr after slaughter. Muscles from electrically-stimulated carcasses had significantly ($P<0.05$) longer sarcomeres, lower shear force value, higher expressed juice and MFI than those from non-stimulated ones. Electrically-stimulated muscles were significantly ($P<0.05$) lighter in colour than non-stimulated meat based on *L** value. Muscles of 3 year old camels had a significantly ($P<0.05$) lower shear force value, and pH, but longer sarcomere, and higher MFI, expressed juice, and lightness color (*L**) than those of the 10 year old camels. These results indicated that age and LVES had a significant effect on camel meat quality characteristics and muscle structure.

Introduction

The one-humped camel is the most useful domestic animal in arid and semi arid regions. Camels can produce substantial amounts of meat at a comparatively lower cost under extremely harsh environments (Tandon et al., 1988). There is some evidence of a demand for fresh camel meat due to health reasons (Perez et al., 2000). Camel meat contains relatively less fat, lower cholesterol and high polyunsaturated fatty acids compared to beef (Kadim et al., 2008). Moreover, many investigators reported that quality characteristics of the camel meat are similar to that of beef if they are slaughtered at a comparable age (Kadim *et al*., 2008). An increase in post mortem muscle metabolism and to hasten the onset of rigor mortis might improve the quality characteristics of camel meat. The objectives of the present study were to investigate the effect of age (3 and 10 years old) and LVES on meat quality characteristics of the LT muscle of the one-humped camel.

Materials and methods

A total of 10 one-humped camels representing two age groups: Group 1 (3 years old: n=10) and Group 2 (10 years old: n=10) were sampled. Animals were slaughtered and dressed following routine commercial slaughterhouse procedures according to Halal methods. Fifty percentage of the carcasses within each age group were randomly selected and subjected to LVES using a V1.3-R3B stimulator (7.5 millisecond duration every 70 milliseconds (14 Hz) and an output of 90 V, AgResearch, New Zealand). During LVES the carcasses were suspended on a gambrel by a hook. Carcasses were stimulated with a battery clip attached to the neck and stainless steel hook contacting the Achilles tendon. The current was applied for 60s, 20 minutes after complete bleeding. The LT muscle of the left side was removed between the 10-13th ribs (500 g) of each of

the camel carcasses within 20 minutes post slaughter. Samples were kept in chiller (3-4^{o}C) for 48 hrs. The pH for the LT muscle was monitored using a portable pH meter (Hanna waterproof pH meter, Model Hi 9025) fitted with a polypropylene spear-type gel electrode (Hanna Hi 1230) and a temperature adjusting probe. Measurements, designated as pH (40 min., 1, 2, 4, 6, 8, 10, 12, 24 hr post mortem) were recorded. For each measurement, the pH probe and the thermometer were inserted into muscles to a similar depth.

The ultimate pH was assessed in homogenates at 20-22^{o}C (using a Ultra Turrax T25 homogenizer) of duplicate 1.5-2 g of muscle tissue in 10 ml of neutralized 5-mM sodium iodoacetate and the pH of the slurry measured using a Metrohm pH meter (Model No. 744) with a glass electrode. Chilled muscle samples (13 mm x 13 mm cross section) for the assessment of shear force by a Warner-Bratzler shear machine were prepared from muscle samples cooked in a water bath at 70^{o}C for 90 min. Sarcomere length by laser diffraction was determined. Express juice, stained with muscle surface were measured at room temperature (25±2^{o}C) using a Minolta Chroma Meter CR-300 (Minolta Co., Ltd., Japan). MFI was used to measure the proportion of muscle fragments that passed through a 231-µm filter after the sample had been subjected to a standard homogenization treatment (Kadim et al., 2006). LT fresh muscle fibres were dissected and placed immediately after the ES in vials containing electron microscopy fixative solution. Muscle biopsies was fragmented under stereomicroscope to small sizes of 1 mm^3 using a razor blade and placed in a fresh Karnovesky's fixative for 2 h at 4^{o}C, and then washed in three 10 min changes of 1 M cacodylate buffer. The remaining steps were carried out by Leica automatic tissue processor. Semi-thin sections, 0.5 µm were prepared, stained with Toludine blue and viewed under a light microscope for selection of section areas of interest. Ultra thin sections (60-90 nm) were cut using a diamond knife and leica UCT ultra microtome, stained with aqeous urtanyl acetate and lead citrate and examined with IEOL JEM-1230 transmission electron microscope equipped with Gata 792-CCD camera operated at 60 kV. Electron images of muscle fibre ultrastructures recorded.

The effect of low voltage electrical stimulation and age of camel of Longissimus thoracis muscle samples on meat quality and their interaction were analyzed using the analysis of variance procedure (SAS, 1993). Significances between means were assessed using the least-significant-difference procedure.

Results and discussion

Effects of LVES on LT muscle pH within the two age groups of the camel at 40 min then hourly between 2 and 12 h post mortem are given in Figure 1. Although, the age had no significant effect on the rate of pH decline, there were significant ($P<0.05$) differences in muscle pH between the electrically-stimulated and non-stimulated groups within each group at various times postmortem. The most readily measurable effect of LVES was the rapid drop in pH, which is regarded as an indicator of effectiveness of stimulation. It is particularly interesting to note that LVES applied at 20 min, dropped significantly ($P<0.05$) the pH by about 0.15 units below the non-stimulated group. LVES led to significantly lower muscle pH values ($P<0.05$) during the first 12 hr post mortem (Figure 1). After a relatively fast fall within the first 4 hr, the mean pH values underwent a slow decline until an ultimate pH at 24 hr postmortem. These findings are in accordance with those of Li *et al.* (2006) that ES led to a fast fall in pH within the first 3 hr in beef cattle. The average difference in pH (1-4 hr postmortem) between the electrically-stimulated and non-stimulated carcasses ranged between 0.13-0.18 units. However, the difference in pH between electrically-stimulated and non-stimulated carcasses decreased with time as the difference was

0.18 units at 4 h and 0.12 units at 24 hr postmortem. The overall rate of pH decline variation in camel carcasses between the two treatments was the higher in the 10 year old group (0.21 units) than in the 3 year old group (0.06 units).

The ultimate pH value of meat is the result of a combination of many factors including pre-slaughter handling, post mortem treatment and muscle physiology (Thompson, 2002). There was no significant effect of LVES on ultimate pH (48 hr). The mean ultimate pH of 5.65 for the electrically-stimulated carcass samples was slightly lower than the pH of 5.70 for non-stimulated samples. In the present study, LVES consistently produced a more rapid glycolysis in muscle samples from the two age groups evaluated (Figure 1). The muscles of 10 year old camels had significantly lower ($P<0.05$) pH (5.56) than those of 3 year old (5.79) animals. Similar values for camels of various ages were reported by Kadim & Mahgoub (2007) and Kadim *et al.* (2006, 2008). Generally, young camels tend to produce meat with a higher pH than older camels, most likely due to low glycogen stores in muscles. The low muscle glycogen stores at slaughter do not allow the development of a desirable pH of the muscle after slaughter (Ashmore *et al*., 1973).

LVES had no significant effect on expressed juice of camel meat. Den Hertog-Meischke *et al.* (1997) suggested that the slight decrease in water-holding capacity of electrically-stimulated muscles might be due to an increase in the denaturation of sarcoplasmic proteins. The lower myofibrillar water-holding capacity of electrically-stimulated muscles was most probably not due to differences in pH of the myofibrillar protein suspensions (Offer & Knight, 1988). In the present study, expressed juice was significantly affected by age, with 3 year-old camels having higher express juice by 34.1% than 10 year-old animals (Table 1). Similarly, Kadim and Mahgoub (2007) and Kadim *et al*. (2006) found that camels younger than 3 years old had significantly higher expressed juice than the 6 year-old one-humped camels. These differences were due to variations in fat content or in ultimate pH. Miller et al. (1968) found a decrease in the water-holding capacity as fat levels increase. In agreement with the present study, Dawood (1995) reported that 8 month-old camel meat had significantly ($P<0.05$) higher expressed juice than 26 month-old camel meat. Cooking loss % was significantly ($P<0.05$) lower in 10 year camels than in the 3 year camels. The decreased binding ability of less mature animal meat, higher moisture content and lower degree of marbling may contribute to the variations. Similarly, Dawood (1995) found that camels at 8 months of age had significantly higher cooking loss % than camels at 26 month of age.

Muscles from electrically-stimulated carcasses had a significantly ($P<0.05$) lower shear force value (7.5 kg/cm^2) compared to non-stimulated carcasses (11.0 kg/cm^2) (Table 1). The findings of the present study indicated that electrical stimulation could exert changes in postmortem camel muscles by either physical disruption of the myofibrillar matrix (Figure 2) or acceleration of proteolysis (MFI: table 1). The main mechanism through which LVES improves tenderness is by rapidly decreasing the concentration of adenosine triphosphate (ATP) which reduces the likelihood of myofibrillar contraction and cold shortening (Davey and Gilbert, 1974). In the present study, LT muscles were chilled while still at pre-rigor mortis, therefore, non-stimulated muscles were significantly tougher than electrically-stimulated samples, suggesting that chilling treatments had induced a degree of cold-shortening. The findings of the present study indicated that LVES could exert changes in postmortem camel muscles by either physical disruption of the myofibrillar matrix or by acceleration of proteolysis (MFI: Table 1) (Hwang *et al*., 2003). The value for shear force was significantly ($P<0.05$) higher for 10 year-old camels (12.5 kg/cm^2) than for 3 year-old (6.0 kg/cm^2) camels. It is commonly accepted that younger animals yield more tender meat than older ones. A number of studies have confirmed the findings that shear values increase with an increase in the age of the animals (Kadim, *et al*., 2006, 2008). Any differences

due to age may be related to histological changes that make place in muscle structure and composition as animals mature, particularly in the connective tissue (Asghar and Pearson, 1980). The high fragmentation index in young camels may be caused by easily breaking myofibrils into shorter segments. The strength of the different muscle fiber types had a significant effect on the mechanical properties of the individual fibre types (Christensen et al. 2006).

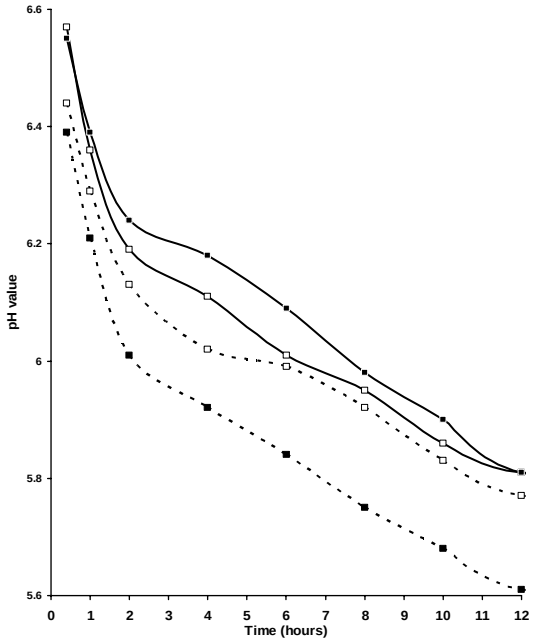

Figure 1 Mean changes in pH within the LT muscle for carcasses from 3 year-old camel stimulated:--□--,or control:□□□,and 10 year-old camel stimulated:--■--,or control□■□)

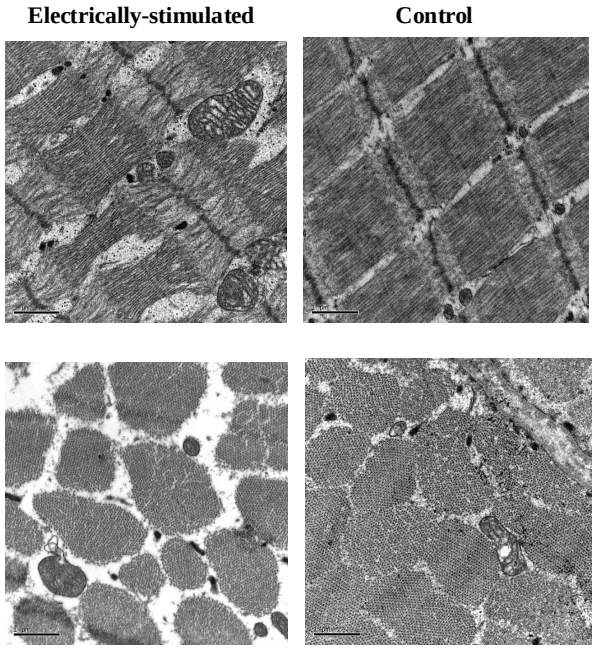

Figure 3 Micrograph from electrically-stimulated and control sections of camel LT (magnification 30000X)

Table 1. Means and Standard Error of Mean (SEM) for a range of *longissimus thoracis* muscle quality characteristics within two age groups with or without electrical stimulation (ES).

	Age (year)				SEM
	3 year		10 year		
	ES	NS	ES	NS	
Ultimate pH	5.78[b]	5.80[b]	5.52[a]	5.60[a]	0.100
Expressed juice (cm^2/g)	36.4[b]	35.2[b]	24.1[a]	23.1[a]	2.44
Cooking loss%	25.1[b]	24.4[b]	19.1[a]	18.8[a]	1.95
WB-Shear force (kg)	4.8[a]	7.1[b]	10.1[b]	14.8[c]	0.22
Sarcomere length (µm)	1.75[b]	1.70[b]	1.48[a]	1.41[a]	0.081
Myofibrillar fragmentation index[3]	78.2[d]	74.5[c]	65.6[b]	60.9a	1.15
Lightness (*L**)	44.2[d]	40.8[c]	35.0[b]	31.5[a]	1.56
Redness (*a**)	16.8[a]	16.2[a]	19.1[b]	18.[3b]	0.91
Yellowness (*b**)	6.6[a]	6.5[a]	8.6[b]	8.3[b]	0.49

[abcd] Means within the same row with different superscripts were significantly different (P<0.05).

The MFI was significantly (P<0.05) higher in the electrically-stimulated than the non-stimulated muscles, which may be attributed to either variation in muscle pH (Table 1) or to protein degradation**.** According to Ho *et al.* (1996), electrically-stimulated muscles exhibited faster protein degradation. There were significant differences between the two age groups of camels in MFI in the present study (Table 1). Lower MFI and shorter sarcomere length for the 10 year old camels are consistent with the tougher meat from that group. The high myofibrillar fragmentation index in 3 year old camels caused by easily breaking myofibrils into shorter segments may be due to higher pH or proteolytic activity, which increases proteolytic activity and leads to the rupture of myofibrils during the 48 hrs postmortem storage.

LVES significantly (P<0.05) improved the lightness (*L**) of muscles. King *et al*. (2004) reported that meat from electrically-stimulated carcasses, has a brighter colour than meat from non-stimulated carcasses. Many factors including myoglobin concentration, ultimate pH, and muscle fiber type, ES and cooling rate influence the development of muscle colour (Faustman & Cassens, 1990). Postmortem protein degradation is directly related to the ultimate pH, which increases light scattering properties of meat and thereby increases *L** value (Offer, 1991). Meat from 10 year old camels was darker (lower *L**) than that of 3 year old camels (Table 1). This darker colour is more likely a result of increased myoglobin content (Lawrie, 1979), which increases with age. Other factors causing this phenomenon include proportions of muscle fibre type and cooling rate (Faustman & Cassens, 1990; Abril *et al*., 2001). The moderately high pH values from 3 year old camels might have led to degradation of more protein. Abril *et al*. (2001) reported that reflectance spectrum value for beef Longissimus thoracis was higher with ultimate pH above 6.1.

Conclusion

Electrical stimulation had a significant effect on meat quality characteristics including pH, expressed juice, shear force value, sarcomere length, MFI and colour of camel LT muscles. The age of the camel had a significant influence on meat quality characteristics and should be taken into consideration when slaughtering camels for meat consumption.

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