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Effect of low voltage electrical stimulation on biochemical and quality characteristics of *Longissimus thoracis* muscle from one-humped Camel (*Camelus dromedaries*)

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ABSTRACT

The effects of electrical stimulation (90 V) 20 min post mortem on meat quality and muscle fibre types of four age group camels (1–3, 4–6, 7–9, 10–12 years) camels were assessed. Quality of the *Longissimus thoracis* at 1 and 7 days post mortem ageing was evaluated using shear force, pH, sarcomere length, myofibrillar fragmentation index, expressed juice, cooking loss and L^*, a^*, b^* colour values. Age of camel and electrical stimulation had a significant effect on meat quality of *L. thoracis*. Electrical stimulation resulted in a significantly ($P < 0.05$) more rapid pH fall in muscle during the first 24 h after slaughter. Muscles from electrically-stimulated carcasses had significantly ($P < 0.05$) lower pH values, longer sarcomeres, lower shear force value, higher expressed juice and myofibrillar fragmentation index than those from non-stimulated ones. Electrically-stimulated meat was significantly ($P < 0.05$) lighter in colour than non-stimulated based on L^* value. Muscles of 1–3 year camels had a significantly ($P < 0.05$) lower shear force value, and pH, but longer sarcomere, and higher myofibrillar fragmentation index, expressed juice, and lightness colour (L^*) than those of the 10–12 years camels. The proportions of Type I, Type IIA and Type IIB were 25.0, 41.1 and 33.6%, respectively were found in camel meat. Muscle samples from 1–3 year camels had significantly ($P < 0.05$) higher Type I and lower Type IIB fibres compared to those from 10–12 year camel samples. These results indicated that age and ES had a significant effect on camel meat quality.

1. Introduction

The one-humped camel (*Camelus dromedaries*) is the most useful domestic animal specie for animal production in the arid and semi arid regions. They can produce good quality meat at comparatively low cost under extremely harsh environments. The camel has great tolerance to high temperatures, solar radiation, water scarcity, sandy terrain and poor vegetation due to their unique anatomy and physiology as well as for their feeding habits (Shalash, 1983). The camel, therefore, can be economically raised for meat production in these ecologically constrained areas (Tandon, Bissa, & Khanna, 1988).

A camel carcass can provide a substantial amount of meat for human consumption. There is evidence of a great demand for fresh camel meat and for camel meat in blended meat products even in societies not herding camels (Morton, 1984; Pérez et al., 2000; Shalash, 1979). This demand for camel meat appears to be increasing due to health reasons. Camel meat contains less fat, lower cholesterol and relatively high polyunsaturated fatty acids compared to beef (Dawood & Alkanhal, 1995; Kadim, Mahgoub, & Purchas, 2008; Rawdah, El-Faer, & Koreish, 1994). These characteristics are important for reducing cardiovascular diseases risk related to high saturated fat consumption (Giese, 1992). As camels are generally used in less developed countries, research into improving meat characteristics is lacking (Skidmore, 2005). There is also reluctance towards consuming camel meat in general as it is thought to be tough, coarse and watery. This is mainly because camel meat usually comes from old animals that have served other functions in their life or predominantly at the time their labour performance and milk yield declines (Wilson, 1998). However, many investigators reported that quality characteristics of the camel meat are very similar to that of beef if they are slaughtered at a comparable age (Elqasim, Elhag, & Elnawawi, 1987; Kadim et al., 2008; Tandon et al., 1988).

An approval to increase post mortem muscle metabolism and hasten the onset of rigor mortis might improve the quality characteristics of camel meat. Additionally, a more rapid pH decline could

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potentially result in a brighter coloured meat (King et al., 2004; Riley, Savell, Smith, & Shelton, 1981). Electrical stimulation is a proven method for improving tenderness and meat colour from several species (McKeith, Savell, Smith, Dutson, & Shelton, 1979; Savell, Smith, Dutson, Carpenter, & Suter, 1977). No reports are available on the effects of electrical stimulation on meat quality characteristics of camel meat. The objectives of the present study were to investigate the effect of age (1–3, 4–6, 7–10 and 10–12 years), ageing (1 vs. 7 days) and low voltage electrical stimulation on biochemical changes and meat quality characteristics of the *Longissimus thoracis* muscle of the one-humped Omani camel.

2. Materials and methods

2.1. Animals

A total of 72 Arabian one-humped camels representing four age groups: Group 1 (1–3 years old: $n = 16$), Group 2 (4–6 years old: $n = 16$), Group 3 (7–10 years old: $n = 16$) and Group 4 (10–12 years old: $n = 24$) were sampled. The animals were exposed to normal pre-slaughter handling and transportation processes and subsequently held in a lairage for 1–2 h. Animals were slaughtered and dressed following routine commercial slaughterhouse procedures according to Halal methods. The ambient temperatures on slaughter days ranged between 25 °C and 27 °C.

2.2. Electrical stimulation

Fifty percentage of the carcasses within each age group were randomly selected and subjected to electrical stimulation using a V1.3-R3B stimulator (7.5 ms duration every 70 ms (14 Hz) and an output of 90 V, AgResearch, New Zealand). During electrical stimulation 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 60 s, 20 min after complete bleeding.

2.3. Muscle samples

The *L.* thoracis muscle of the left and right sides were removed between the 10–13 ribs (800–1000 g) of each of the camel carcass within 20 min post slaughter. Samples were kept in zipped plastic bags in an insulated box, then transferred to a chiller (1–3 °C) within about 4–4.5 h post mortem and kept for 24 h before running quality measurements. The samples from the left side of each carcass were then frozen (24 h post mortem), while the samples from the right side were kept in the chiller (2–3 °C) for another six days (seven days ageing) and then frozen.

2.4. Muscle pH decline

The pH for the *L.* thoracis muscles from each side were 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.

2.5. Histochemistry

Core samples of the right *L.* thoracis at the last rib location were removed immediately after electrical stimulation cut into 1×1 cm pieces (parallel to the muscle fibres) and frozen in iso-pentane cooled in liquid nitrogen and then snapped in liquid nitrogen. Samples were stored at −80 °C Ultra-Low Temperature Freezer (MDF-392, Sanyo Electric Biomedical Co. Ltd. Japan) until further analysis. Muscle samples were cut into 8-μm-thickness on a cryostat (Model Bright, England) at −23 °C, and mounted on silane-treated microscope slides. Two sections from each sample were incubated in an acid at pH 4.35 and 4.60 for 10 min and then incubated at ATP substrate (adenosine 5-triphosphate) pH 9.5 for 45 min. The sections were then incubated for three minutes in an aqueous cobalt chloride and finally, they were incubated in a solution of ammonium sulphide. A blackish–brownish cobalt sulphide is generated in the reaction to replace cobalt phosphate (Brooke & Kaiser, 1970). One more section from each sample was stained for succinate dehydrogenase; the section was incubated in a solution containing nitro blue tetrazolium, 0.2 M phosphate buffer pH 7.6 and 0.2 M sodium succinate for two hours at 37 °C. The dehydrogenase enzyme in the muscle section act on the substrate and the tetrazolium salt is reduced to from blue-purple deposition at the site of the enzyme activity. (Sheehan & Hrapchak, 1989). Staining sections were viewed under a Leitz (Wetzlar, Germany) divert inverted phase contrast-fluorescence microscope at a magnification of 160X. Images were taken using a Spot 2 Slider (model 1.4.0, Diagnostic Instruments, Inc.) camera. The cross-sectional area of 500 fibres on four viewing frames per sample was measured using IP Lab scientific imaging software (Scanalytics, Inc., Fairfax, VA). The diameter for each muscle fibre type was calculated. The proportions of muscle fibre types were calculated by dividing the number of each muscle fibre type by the total number of muscle fibre types in an area containing at least 1500 fibres.

2.6. Transmission electron microscopy

L. thoracis fresh muscle fibres were dissected and placed immediately after the electrical stimulation in vials containing electron microcopy fixative solution (Karnovesky's fixative; 2.5% gluteraldehyde and 4% paraformaldehyde in 1 M cacodylate buffer pH 7.2). Muscle biopsies was fragmented under stereomicroscope to small sizes of 1 mm^3 using razor blade and placed in a fresh Karnovesky's fixative for 2 h at 4 °C, and then washed in three 10 min changes of 1 M cacodylate buffer. The remaining processing steps were carried out by Leica automatic tissue processor. Secondary fixation was carried out in 1% Osmium Tetraoxide in distilled water for 60 min. Further three changes of 10 min washes in 1 M cacodylate buffer were carried out to wash off excess Osmium Tetroxide, then samples were placed in graded concentration of acetone followed by three changes of absolute acetone. The blocks were then infiltrated with Araldite epoxy resin. Embedded in pure Araldite epoxy resin and polymerized overnight at 60 °C. Semi-thin section, 0.5 μm was prepared, stained with Toludine blue and viewed under 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 JEOL JEM-1230 transmission electron microscope equipped with Gata 792-CCD camera operated at 60 kV. Electron images of muscle fibre ultrastructures recorded.

2.7. Meat quality evaluation

The *L. thoracis* muscles were evaluated for a range of quality characteristics including ultimate pH, expressed juice, cooking loss%, Warner-Bratzler shear force value, sarcomere length, myofibrillar fragmentation index and colour (L^*, a^*, b^*). The ultimate pH was assessed in homogenates at 20–22 °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