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EFFECT OF AGE ON QUALITY CHARACTERISTICS AND COMPOSITION OF MUSCLES OF SUDANESE CAMEL (*Camelus dromedarius*)

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ABSTRACT

This study was aimed to investigate the effect of camel age and muscle type on meat quality and composition of *Longissimus thoracis, biceps femoris, semitendinosus* and semimembranosus muscles. Selected muscles were randomly collected from 12 Sudanese (*Camelus dromedarius*) of two age groups: group one ((3-4 year-old) and group two (6-7 year-old) at the Tambol slaughterhouse, Al-Butana State, Sudan. Moisture, protein, fat and ash contents of freeze dried samples were determined. Meat quality parameters including muscle ultimate pH, shear force, expressed juice, cooking loss%, myofibril fragmentation index and colour lightness (L*), redness (a*) and yellowness (b*) were determined. There were significant differences in moisture, fat, and protein contents between muscles. The results also showed that old camel longissimus thoracis muscle had significantly higher fat content than the young one. The *semimembranosus* muscle sample from 6-7 year-old camel had significantly lower expressed juice than 3-4 year-old camel. The longissimus thoracis had the lowest and highest shear force and lightness values than other muscles. The semitendinosus had the highest shear force value, while semimembranosus had the lowest lightness than other muscle samples. This study indicated that composition and quality parameters varied among camel muscles and the knowledge of this variation allows for better marketing and processing of camel meat.

Key words: Age, composition, dromedary camel, meat quality, muscles

The Sudanese camels are mostly exposed to Egypt, Libya and other countries for meat production. Camel can provide high quality meat as alternative source of protein for human consumption (Kadim *et al,* 2011). The demand for camel meat appears to be increasing, especially in arid regions. Camel meat is healthier as they produce carcasses with less fat as well as having low levels of cholesterol in fat than other meat animals. Camel meat is also relatively high in polyunsaturated fatty acid in comparison to beef (Kadim *et al,* 2008). Camel meat could become an ideal choice for health conscious consumers due to its low fat content and relatively high content of polyunsaturated fatty acids in comparison to beef (Kadim *et al,* 2008). Traditionally, meat comes mostly from males, seven years and above and females that are primarily kept for milk, racing, and transportation rather than for meat production (Kurtu, 2004). Kadim *et al* (2006) concluded that the age of Arabian camel has an important influence on the composition and meat quality and should be taken into consideration for meat consumption. A comprehensive review (Kadim *et al,* 2008) also revealed that camel age is the most important factor affecting quality characteristics. Therefore, the general consumers view is that camel meat is unacceptably tough. The aim of this study was to investigate the effects of age on the chemical composition and meat quality characteristics of the Sudanese dromedary camels.

Material and Methods

Meat Samples

Forty-eight meat samples from each longissimus thoracis, biceps femoris, semitendinosus and semimembranosus muscles were collected from 12 Sudanese camels slaughtered at the Tambol slaughterhouse (yard) at Al-Butana State, Sudan. The camels were classified into group 1 (3-4 year old) and group 2 (6-7 year old). Animals were slaughtered after having been held in a lairage for 1–2 h and dressed following routine commercial slaughterhouse procedures. The selected muscles were removed from the left side within 60 min of post-mortem. Each individual muscle was trimmed off external fat, kept

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in zipped plastic bags and transported in insulated cool box and kept on -18°C for 7 days in University of Khartoum, College of Animal Production Lab, then transported to Meat Lab at Sultan Qaboos University, College of Agricultural and Marine Since, Department of Animals and Veterinary Sciences and kept in chiller on-18°C until chemical composition and quality measurements were determined.

Chemical Analysis

Any visible fat was removed from the muscles, then approximately 100 g of meat samples from each muscle were chopped into small pieces, weighed into pre-weighed containers then immediately frozen (-2°C) and dried in a freeze dryer (MODULOD Freeze Dryer thermo electronic corporation) for seven days under 100-mbar pressures at -50°C. The samples were reweighed after making these completely dried, then ground to a homogenous mass through a 1 mm mesh in a micro-Wiley mill and stored in plastic air-tight containers and cooled in -4°C for chemical analysis. The analysis was carried out in duplicates following the standard methods of AOAC (2000). Protein was determined by the Kjeldal procedure (AOAC, 2000). The procedure consists of three steps: digestion, distillation and titration. Approximately 0.5 g of each sample was weighed and transferred into Kjeldal flask. A K_2SO_4Se catalyst and 10 ml of concentrated sulfuric acid were added, respectively. The flask was kept in the digesting system at 42°C for 2 hours until all organic matter was oxidised and the nitrogen got converted into ammonium sulfate. The solution was then cooled overnight. Distillation and titration were completed in Kjeldal manual unit. Approximately 200 ml distilled water, and 50 ml of 40% sodium hydroxide solution were added to each flask. The ammonia was volatilised using Kjeltec Tecator Distillation. The ammonia was captured in weak acid solution (boric acid) containing methyl red and bromocresol indicator then titrated with known standard 0.2N hydrochloric acid (HCl) to determine the amount of nitrogen in the original sample. Fat was determined by Soxtec system HT 1043 extraction of the dry sample, using petroleum ether (AOAC, 2000, procedure # 991.36). Clean flasks were dried in an oven for one hour at 100°C and kept in a desiccator for 45 minutes to cool and weighed. One gram of each sample was weighed (in duplicate) onto filter paper and transferred into thimble and plugged with cotton wool. Thimbles were then placed into the extractor that was fixed to each flask and were placed on the heaters. One hundred ml of petroleum ether was added to each extractor. The condensers were fixed to the extractors and water was turned on to condense the hot solvent at 60°C. Extraction was carried out for eight hours. Thimbles were then removed and the distilled solvent was collected in a bottle (recovered solvent). Flasks were placed in an oven at 100°C for two hours allow the remaining solvent to evaporate. Flasks were cooled in a desiccator for 45 min, and then weighed with the extracted fat. Total ash was determined according to standard methods of AOAC (2000). One gram of sample (in duplicate) was weighed into porcelain dishes and placed in the muffle furnace Gallen Kamp Size 3 (500°C) for 24 hours. The muffle was turned off and allowed to cool at room temperature. The dishes were transferred to desiccators, then weighed.

Meat quality evaluation

Meat quality measurements including ultimate muscle pH, expressed juice, cooking loss per cent, tenderness, sarcomere length, myofibril fragmentation index and colour L*, a*, b* were determined. The ultimate pH was assessed in homogenates at 20–22°C (usingan Ultra Turrax T25 homogenizer) of duplicate 1.5–2 gof muscle tissue in 10 ml of neutralised 5-mM sodium iodoacetate and the pH of the slurry measured using a Metrohm pH meter (Model No. 744) with a glass electrode. Expressed juice was assessed using a filter paper method, as the total wetted area less the meat area (cm^2) relative to the weight of the sample in gram (Hamm, 1986). A cube of 500±20 mg of meat sample was placed on a filter paper (Whitman N°1, 11.0 cm diameter) between two Perspex plates for exactly 5 min. The wet and meat areas were measured with a plan meter. Duplicate measures of expressed juice were made for each sample. Expressed juice values were calculated according to the following formula: Expressed juice (cm^2/g) = (Wet area – meat area) / meat weight.

The muscles slices (2.5 mm thick) were placed in polyethylene bags, cooked in a water bath at 70°C for 90 minutes and then cooled in a chiller (2-3°C) over night. Samples were carefully dried using paper tissues for removing excess surface moisture and then re-weighed for cooking loss per cent determination. Chilled muscle samples (13 mm • 13 mm cross section) were used for assessment of shear force by a texture analyser machine (Stable Micro Systems, Texture Analyser, Model TA.XT. Plus, UK) from muscle samples cooked in a water bath at 70°C for 90 min. Sarcomere length by laser diffraction was determined using the procedure described by Cross *et al* (1980/1981). Myofibrillar fragmentation index (MFI) was measured using a modification of the

method of Johnson *et al* (1990). This basically measured theproportion of muscle fragments that passed through a 231-lm screen after sample had been subjected to a standard homogenisation treatment. A 5 g (±0.5 g) sample of diced (6 mm^3 pieces) was added to 50 ml of cold physiological saline (85% NaCl) plus five drops of antifoam A emulsion (Sigma Chemical) in a 50 ml graduated cylinder, and homogenised at 1/4 speed using an 18 mm diameter shafton an Ultra-Turrax homogeniser for 30-s periods separated by a 30 second rest period. The homogenate was poured into apre-weighed filter (231 • 231 lm holes). The filter typically ceased dripping after 2–3 h, at which time they were dried at 26–28°C in an incubator for 40 h before being reweighed. The MFI values presented here in were calculated as 100 minus the percentage of the initial meat sample weight that remained on the filter. Approximately 30 min after exposing the fresh surface, CIE L*, a*, b* light reflectance coordinates of the muscle surface were measured at room temperature (20 ± 2°C) using a Minolta Chroma Meter CR-300 (MinoltaCo., Ltd., Japan) with a colour measuring area 1.1 cm diameter. The meter was calibrated using a Minolta calibration plate (L*=97.59, a*=-5.00, b*=6.76). The L* value relates to Lightness; the a* value to Red-Green hue where a positive value relates to the red intensity, and the b* value to the Yellow-Blue where a positive value relates to yellow. The average of two measurements from each sample was recorded as the colour coordinate value of the sample.

Statistical analysis

The general liner model (GLM) procedure within Statistical Analysis System (SAS, 1993)was used to evaluate the effect of age on meat composition and quality characteristics. Significant differences between means were assessed using the least-significant-difference procedure.

Results and Discussion

Chemical composition

The chemical composition of muscles is presented in Table 1. Generally the values for moisture, protein, fat and ash were within the range reported for dromedary camel meat (Babiker and Yousif, 1990; El-Faer *et al,* 1991; Elgasim and Alkanhal, 1992; Kadim *et al,* 2006, 2008, 2013). The overall mean moisture of 72.7% (66.1 to 75.3%) was similar to that reported by Dawood and Alkanhal (1995) and Kadim *et al* (2006), but lower than the values (73–78%) reported by Shalas (1988), El-Faer *et al* (1991) and Elgasim and Alkanhal (1992) for Saudi camels. These differences may probably be due to variations in slaughtering techniques, muscle locations or age of animals. In the present study, the longissimus thoracis muscle had significantly (P<0.05) lower moisture than other muscles. The importance of moisture in camel meat lies in its pronounced effects on the functional properties of meat, its processing potential and sensory characteristics (Kadim *et al,* 2013). The semitendinosus and semimembranosus and biceps femoris muscles had the highest moisture: protein ratio compared with other muscles. The present study indicated that the moisture to protein ratio of the four selected muscles were moderate to high, which reflect the suitability for camel meat for processing (Forrest *et al,* 1975). The mean protein of 18.2% for four camel muscles is lower than value reported by Kadim *et al* (2006). This level of protein indicates that the camel meat is a source of high quality protein in harsh climate arid regions. The semimembranosus muscle had significantly (P<0.05) higher protein content than longissimus thoracis muscle (Table 1). Similarly, Kadim *et al* (2013) found that semimembranosus muscle from Omani dromedary camel had significantly (P<0.05) higher protein than longissimus thoracis and semitendinosus muscles. The range of fat content (2.0 to 10.1%) of the current study confirmed that camel meat could be leaner than meat produced by other species such as sheep, cattle or pig (Kadim *et al,* 2008) especially if it is slaughtered at a young age. The mean fat (4.9%) of camel's muscles was lower than 7.7% (Kadim *et al,* 2006) and 6.7% (Dawood, 1995) but similar to the ranges listed by Shalash (1988), El-Faer *et al* (1991) and Elgasim and Alkanhal (1992) and higher than those 0.50–1.43% reported by Babiker and Yousif (1990) and 3.6% found by Kadim *et al* (2013). The mean ash of 1.3% ash in the present study with no significant differences between muscles was in agreement with those of Kadim *et al* (2006, 2008, 2013). The range of values of ash content in Sudanese camel meat (Table 1) was comparable to those reported by Elgasim and

Table 1. Proximate composition (%) of longissimus thoracis (LT), bicepis femoris (BF), semitendinosus (ST) and semimembranosus (SM) muscles of Sudanese dromedary camel.

Composition	Muscle				SEM[1]
	LD	BF	ST	SM	
Moisture	68.7^{a}	73.8^{b}	74.1^{b}	74.3^{b}	0.72
Protein	17.4^{a}	17.9^{ab}	18.6^{ab}	19.1^{b}	0.38
Fat	10.1^{b}	2.0^{a}	3.6^{a}	3.9^{a}	0.44
Ash	1.44	1.21	1.25	1.13	0.09
Moisture: protein ratio	3.95	4.12	3.98	3.89	0.38

[1]SEM: standard error of Mean. Means within each row with different letters were significantly different (P<0.05).

Table 2. Mean and Standard Error of Mean (SEM) of chemical composition for two age groups (3-4 and 6-7 year-old) of the Sudanese camel muscles.

Composition	Muscle1								SEM
	LD		BF		ST		SM		
	Age (year)								
	3-4	6-7	3-4	6-7	3-4	6-7	3-4	6-7	
Moisture	71.3^{b}	66.1^{a}	72.6^{bc}	74.9^{c}	74.0^{bc}	74.1^{bc}	75.3^{c}	73.2^{bc}	0.69
Protein	17.7^{ab}	17.1^{a}	18.6^{ab}	17.1^{a}	18.8^{bc}	18.4^{ab}	18.4^{ac}	19.8^{c}	0.26
Fat	7.84^{e}	12.40^{d}	2.49^{b}	1.57^{ab}	3.47^{cb}	3.74^{c}	3.33^{c}	4.38^{c}	0.24
Ash	1.41	1.47	1.37	1.04	1.26	1.23	1.13	1.13	0.13

[1]Muscle: LD: Longissimus thoracis, BF: Bicepis femoris, ST: Semitendinosus, SM: Semimembranosus.
Means within each row with different letters were significantly different (P<0.05).

Alkanhal (1992), Kadim *et al* (2006) and Kadim and Mahgoub (2008) for dromedary camel.

The mean of chemical composition of the Sudanese camel muscles within two age groups is presented in Table 2. With exception of the longissimus thoracis, there were no significant differences between the two age groups within each muscle. Longissimus thoracis muscle sample had significantly (P<0.05) lower moisture content (68.7%) than biceps femoris (73.8%), semitendinosus (74.1) and semimembranosus (74.3%). In contrast, Kadim *et al* (2006) and Kadim and Mahgoub (2008) reported no significant effect of age on moisture content of longissimus thoracis muscle of dromedary camel. The level of variation between the different studies in moisture content of dromedary meats may be due to physiological factors, which may play a major role in determining the moisture contents in camel meat.

The present study revealed no significant differences in protein content between the two age groups (3-4 vs. 6-7 year-old) within each muscle. The insignificant differences in protein content between the two age groups in the currents study is in agreement with those reported by Kadim *et al (*2006), who found that protein content remained unaffected between 3-5 and 6-8 year-old camels. In contrast, Kadim and Mahgoub (2008) reported that 4-8 year-old camel had significantly lower protein (20.5%) than 2-4 year-old (22.7%) camel. The maximum value recorded for fat in the present study was 12.4% in longissimus thoracis muscle for 6-7 year-old group, which indicated that fat content of camel meat may increase significantly with age. This study confirmed that meat sample from camels above 6 years contained significantly (P < 0.01) higher fat than below 4 year-old (Table 2). The high fat content is a well-documented phenomenon in meat animals as they deposit more body fat with progressing age because fat is a late maturing body tissue. This implies that meat industry should target younger camels for prime meat production, which is in line with other recommendations for slaughtering camels less than 3 years of age (Kadim *et al,* 2006). The longissimus thoracis muscle from group 2 (6-7 year-old) had significantly (P<0.01) higher fat content than group 1 (3-4 year-old). Kadim and Mahgoub (2008) reported that longissimus thoracis muscle from 4-8 year-old dromedary camel had significantly (P<0.05) higher fat content than 2-4 year-old camel. However, Kadim *et al* (2006) studied effect of camel age on chemical composition of longissimus thoracis and found no significant differences between 3-5 and 6-8 year of age. The fat content of different muscles appeared to be controversial between different studies, may be due to nutrition status, sex, age, and breed, which will affect the percentage of fat in the same study.

In the present study, there were no significant differences in ash content between the two age groups within each muscle, which in agreement with the results of Kadim *et al* (2006 and 2008), who reported that age had no significant effect on ash content. As for other species, ash content of camel meat varied widely most probably because of differences in sampling methods, sites in the carcass (Kadim *et al,* 2008) or to wide range of variability within individual animals.

Meat quality

Meat quality characteristics of the Sudanese dromedary camel muscle are presented in Table 3. Value for meat quality characteristics including ultimate pH, shear force value, sarcomere length, myofibrillar fragmentation index, expressed juice, cooking loss and colour (L*, a*, b*) were within the range reported for dromedary camel meat (Kadim *et al,* 2008, 2009, 2013).

Ultimate pH is one of the main factors influence the organoleptic characteristics of meat, which is related to the biochemical processing during the transforming of muscle to meat (Dutson, 1983;

Watanabe *et al,* 1966). In the current study, there were no significant differences in ultimate pH between selected muscles (Table 3). The ultimate pH values of the Sudanese camels were within the normal range for dromedary camel meat (Abdelhadi *et al,* 2012; Kadim *et al,* 2006, 2008, 2013). The ultimate pH values of the *longissimus thoracis* (5.53), *biceps femoris* (5.63), *semitendinosus* (5.63) and *semimembranosus* (5.54) found in this study were lower than the values of 5.61, 5.74, 5.67 and 5.74, respectively reported for the dromedary Omani camel muscles by Kadim *et al* (2013). Moreover, the pH values of the *longissimus thoracis* and *biceps femoris* muscles observed in the current study were also lower than the values for the same camel muscles reported by Suliman *et al* (2011) and Kadim *et al* (2006). The differences between the current study and other studies may be due to a combination of several factors including pre-slaughter handling, post-mortem treatment and metabolism of the muscles, with low muscle glycogen stores at slaughter preventing the development of a desirable ultimate pH (Ashmore *et al,* 1973).

Table 3. Meat quality characteristics of the *longissimus thoracis* (LT), *biceps femoris* (BF), *semitendinosus* (ST) and *semimembranosus* (SM) of Sudanese camel.

Parameter	Muscle				SEM[1]
	LD	BF	ST	SM	
Ultimate pH	5.53	5.63	5.63	5.54	0.039
Expressed Juice	34.4	35.6	33.6	34.6	0.718
Cooking loss%	23.3	29.3	34.6	34.5	0.428
Tenderness (kg)	5.67^{a}	8.47^{b}	11.4^{b}	9.33^{b}	0.649
Sarcomere length (µm)	1.95	1.85	1.95	1.85	0.167
Myofibrillar fragmentation index Colour	75.2	75.0	74.6	75.9	1.17
Lightness (L*)	33.2^{b}	28.7^{ab}	29.4^{ab}	27^{a}	1.21
Redness (a*)	11.9	10.2	11.2	10.6	0.39
Yellowness (b*)	4.25	3.21	3.35	3.29	0.311

[1]SEM: standard error of mean. Means within each row with different letters were significantly different (P<0.05).

Expressed juice reflects the ability of muscle to retain its constituent water between the actin and myosin filaments when an extraneous force is applied to it (Offer and Knight, 1988). Therefore, it is an important camel meat quality characteristic because of its influences on the nutritional value, appearance and palatability. Meat sample that lose water easily are drier and would lose more water during refrigeration, storage, transport and marketing. The present study indicated that expressed juiced was not affected by muscle type. With significant differences in expressed juice between the selected muscles, the *biceps femoris* muscle had the highest value and *semitendinosus* muscle had the lowest value compared to other muscles. When expressed juice was calculated by combining pressing losses and cooking losses, the mean value of *longissimus thoracis* muscle was the lowest and *semimembranosus* muscles was the highest. The pre-slaughter condition for animals in the present study was the same. Therefore, it is possible that the rapid decline of temperature due to muscle sizes and removal from carcasses pre-rigor made the *longissimus thoracis* muscle remained comparatively lower in protein functionality and expressed juice (Joo *et al,* 1999).

Tenderness is presently rated most important by the average consumer out of all the meat quality attributes and appears to be sought at the expense of flavour or colour (Lawrie, 2006). The shear force values for muscles in the current study were within the same range reported by Kadim *et al (*2006, 2009, 2013). The *longissimus thoracis* muscle had significantly (P<0.05) lower shear force values (5.67 kg) than biceps femoris (8.47 kg), semitendinosus (11.36 kg) and semimembranosus (9.33 kg) muscles, which might be due to less connective tissue. Similarly, Kadim *et al* (2013) found that camel longissimus thoracis muscle had significantly lower shear force values than biceps femoris, semitendinosus and SM muscles. The muscle had more soluble collagen than other muscles (Kamoun, 1995), which rendered it more tender. Higher shear force values of the biceps femoris, semitendinosus and semimembranosus muscles may be due to the post-mortem contraction of the myofibrillar proteins and amount of structure of the connective tissue. Relatively high shear force values with leg muscle samples further support previous published conclusion of Belew *et al (*2003) that muscles of the loin region had lower shear force value and had delectable connective tissue than muscles from the leg region. According to Koohmaraie *et al (*1987), all muscles with the same pre-slaughter treatments had similar tenderness, and that differences in tenderness were created during the first 24 h post-mortem. The rate of muscle pH and temperature decline, intramuscular fat, connective tissue structure, size of the muscle bundles, rigidity and water retention capacity are among many other features contributing to the tenderness of the muscle (Asghar and Pearson, 1980; Rees *et al,* 2003).

Meat colour is one of the most important criteria for initial selection, which is related with the concentration of pigments, the chemical state of the myoglobin, structure of muscle protein, and proportion of intramuscular fat. In the present study,

muscle L* values indicated that the *longissimus thoracis* muscle (33.2) had significantly (P<0.05) higher lean colour than *semimembranosus* muscle (27). Other factors causing this phenomenon include muscle fibre type and cooling rate of individual muscle (Abril *et al,* 2001; Faustman and Cassens, 1990). Post-mortem protein degradation increases light scattering properties of meat and thereby increase L*, a* and b* values (Offer, 1991), which is also directly related to the pH (Abril *et al,* 2001). In the present study, low pH values across muscles might have led small degradation of muscle protein. The *longissimus thoracis*, *biceps femoris*, *semitendinosus* and *semimembranosus* muscles had similar redness (a*) values. The highest average yellowness (b*) value was recorded in the *longissimus thoracis* muscle (4.25) with comparable values with the *biceps femoris*, *semitendinosus* and *semimembranosus* muscles. Similarly, no difference between the longissimus thoracis and biceps femoris, semitendinosus and semimembranosus muscles in redness was reported by Kadim *et al* (2013) for dromedary camel. Myoglobin concentration, pH and muscle fibre type influence the development of muscle colour (Faustman and Cassens, 1990). The lightness, redness and yellowness values in the present study are lower than those reported by Kadim *et al* (2013). The difference between the two studies values might be due to age, breed and post-mortem treatment.

Meat quality characteristics of Sudanese dromedary camel muscles from two age's groups are presented in table 4. Although, there were no significant differences in ultimate pH between the two age groups, the 6-7 year-old camel produced numerically higher ultimate pH value than 3-4 year-old animal (Table 4). The trend of high ultimate pH of the samples from older camels in the present study might be due to differences in proportions of muscle fibre types and or lower muscle glycogen stores at the time of slaughter. Fibre types have been shown to differentiate at various stage of development and therefore have different metabolic functions in the body (Ashmore *et al,* 1972). The proportion of red muscle fibres with high glycogen content is increasing with animal age (Cornforth *et al,* 1973). Such differences might cause different patterns of muscle metabolism (Swatland, 1982) and ultimate muscle pH.

The present study indicated that expressed juiced was not affected by age within each muscle. The semimembranosus muscle sample from 3-4 year-old camel had significantly (P<0.05) higher expressed juice (37.1 cm^2/g) than 6-7 year-old camel (32.1 cm^2/g). In agreement with the present study, (Dawood, 1995) reported that young camel meat (8 month of age) had significantly (P < 0.05) higher expressed juice than the meat from 26 month of age. In general, for longissimus thoracis and biceps femoris muscle, younger camels had numerically lower expressed juice than older camels, while the opposite for semitendinosus and semimembranosus muscles (Table 4). The small variation between the two age groups for expressed juice may have been due to variations in fat content or muscle functions. Miller *et al* (1968) found a decrease in the water-holding capacity as fat levels increase due to an increase in the ratio of moisture to protein. The current findings are for muscles removed from the carcass pre-rigor, which may cause some muscle stimulation. This is explained by the strong contraction that takes place when muscle is removed soon after slaughter (Bendall, 1973). Meat of a high pH value has a greater water holding capacity than low pH value (Abril *et al,* 2001). The effect of age on cooking loss is also shown in Table 4. In the present study, there were no significant differences between the two age groups within each muscle. In contrast, Dawood (1995) found that younger camels had significantly more cooking loss than older camels.

The value for shear force was significantly (P < 0.001) higher for 6-7 than 3-4 year-old camels longissimus thoracis (7.06 vs. 4.27 kg/cm^2), biceps femoris (12.0 vs. 4.93 kg/cm^2), semitendinosus (14.1 vs. 8.61 kg/cm^2) and semimembranosus (12.2 vs. 6.46 kg/cm^2). However, myofibrillar fragmentation index showed no significant differences between the two age groups of camels within each muscle in the present study (Table 4). In excised camel muscles that were cooled while still a pre-rigor condition, cold shortening might take place. Therefore, some of the muscles in the present study might have undergone cold-shortening, which has been shown to be associated with high shearforce. However, muscles from young camel were not affected by cold-shortening as much as for old camel. The differences between the two age groups might be due to connective tissue structure and its heat stability and related to histological changes that take place in muscle structure and composition as animal's mature (Asghar and Pearson, 1980; Bruce *et al,* 2004). It is commonly accepted that younger animals yield more tender meat than older ones. A number of studies have substantiated the findings that shear values increase with increase age of camels (Kadim *et al,* 2006; 2008).

Small differences between the two ages groups within each muscle indicated that high fat

Table 4. Means and Standard Errors of Mean (SEM) for some meat quality characteristics of Sudanese *longissimus thoracis* (LT), *biceps femoris* (BF), *semitendinosus* (ST) and *semimembranosus* (SM) from 3-4 and 6-7 year-old groups.

Parameter	Muscle1								SEM[1]
	LD		BF		ST		SM		
	Age (year)								
	3-4	6-7	3-4	6-7	3-4	6-7	3-4	6-7	
Ultimate pH	5.47	5.59	5.59	5.66	5.61	5.64	5.48	5.60	0.058
Expressed Juice	33.7^{a}	35.0^{ab}	34.1a	37.0^{ab}	34.9^{a}	32.3^{a}	37.1^{b}	32.1^{a}	0.651
Cooking loss%	22.7^{a}	23.9^{a}	29.1b	29.4^{b}	34.5^{c}	34.6^{c}	34.1^{c}	34.8^{c}	0.533
Tenderness (kg)	4.27^{a}	7.06^{b}	4.93^{a}	12.0^{c}	8.61^{b}	14.1^{c}	6.46^{a}	12.2^{c}	0.731
Sarcomere length 3(µm)	1.95	1.94	1.92	1.77	2.19	1.71	1.88	1.81	0.127
Myofibrillar fragmentation index Colour	75.1	75.3	75.0	75.0	75.2	73.9	75.2	76.5	1.071
Lightness (L*)	30.7^{ab}	35.6^{b}	30.5ab	26.9^{a}	30.3^{ab}	28.4^{a}	26.9^{a}	27.1^{a}	1.19
Redness (a*)	11.1^{ab}	12.7^{b}	9.48a	10.9^{ab}	10.9^{ab}	11.4^{b}	9.51^{a}	11.7^{b}	0.46
Yellowness (b*)	4.27^{b}	4.23^{b}	3.58ab	2.83^{a}	3.16^{ab}	3.53^{ab}	3.56^{ab}	3.01^{a}	0.26

[1]SEM: standard error of mean. Means within each row with different letters were significantly different (P<0.05).

[2]MFI: Myofibrillar fragmentation index. [3]SL: Sarcomere length.

content in older camels reduce the concentration of myoglobin with increasing age. Other factors causing this phenomenon include muscle fibre type and cooling rate of individual muscle (Abril *et al,* 2001; Faustman and Cassens, 1990). Post-mortem protein degra dation increases light scattering properties of meatand thereby increase L*,a* and b* values (Offer, 1991), which is also directly related to the pH (Abril *et al,* 2001). In the present study, low pH values across muscles and age groups might have led small degradation of muscle protein. The semimembranosus muscle from 6-7 year-old camel had significantly higher redness (11.7) than counter part from 3-4 year-old camel (9.51). Similar conclusion was reported by Kadim *et al* (2006), who found that camel at 6-8 year-old had significantly higher redness value than camel at 3-5 year-old.

Conclusion

This study revealed that type of muscle and age of camel had a significant influence on composition and quality parameters of Sudanese camel muscles. The Longissimus thoracis muscle proved to be one of the best quality muscles for marketing. The young camel (3-4 year-old) meat contains low fat as well as being a good source of minerals and better quality than old camel (6-7 year-old). This study concluded that individual muscles and age of camel are the main factors that determine the composition and meat quality characteristics and should be considered for development of positive marketing strategies towards consumer perception of camel meat.

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