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INFLUENCE OF FEEDING INTAKE AND TYPE OF MUSCLE ON QUALITY AND HISTOCHEMICAL CHARACTERISTICS OF DROMEDARY CAMEL (*Camelus dromedarius*) MEAT

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ABSTRACT

The aim of this study was to evaluate the effect of three levels of feed intake (1.5%, 2% or 2.5% of body weight) and individual muscle on quality and histochemical parameters of 10 dromedary camel (1-2 year-old). Meat quality including ultimate muscle pH, Warner-Bratzler shear force, sarcomere length, myofibrillar fragmentation index, expressed juice, cooking loss%, and colour *L*, a*, b** were measured using standard methods. The histochemical staining properties of the myosin ATPase and succinate dehydrogenase stains were evaluated. The pH from the left side of Infraspinatus (IS), *Triceps brachii* (TB), *Longissimus thoracis* (LT), *Biceps femoris* (BF), *Semitendinosus* (ST) and *Semimembranosus* (SM) muscles was monitored using a portable pH meter at 1, 2, 4, 8, 12, 24 and 48 hr postmortem. Feeding level had no significant effect on the initial muscle pH or rate of pH decline or muscle fibre type or meat quality characteristics. However, type of muscle had a significant effect on quality and muscle fibre type proportion and diameter. The LT muscle had the highest cooking loss (33.7%) and TB muscle had the lowest (28.8%). The Shear force values of ST (9.3 kg), SM (10.5 kg) and BF (9.9 kg) muscles were significantly higher than LT (5.7 kg) and IS (6.68 kg) muscles. The LT muscle had significantly higher values for *L*, a*, b** than ST. The IS muscle had the highest myofibrillar fragmentation index (74.5), while BF muscle had the lowest value (63.0). The BF muscle had the highest proportion of Type I and the lowest proportion of Type IIA than other muscles. This study indicated that type of muscle had more effect than feeding level on quality characteristics of dromedary camel.

Key words: Camel, influence of feeding, meat

The general public perception is that camel meat is tough and has low quality characteristics compared to other red meats. This perception is most possible because camel meat comes mostly from old animals that are primarily kept for other purposes then slaughtered late in life for meat production (Kadim *et al,* 2008). Camel meat toughness is mostly attributed to myofibrillar proteins and connective tissue contents of muscles (Chen *et al,* 2006). Many factors influence meat quality such as ageing, intramuscular fat, muscle fibre type, intramuscular connective tissue and contractile state of the muscle (Kadim *et al,* 2008). These factors also contribute to the differences in quality between different muscles within the same camel carcass. Moreover, many other factors influence the quality of camel meat, such as genetics associated factors, nutrition, rearing conditions, handling of animals before slaughter, transportation, slaughtering and cooling rate of carcasses.

Globally, the consumer is associating the quality of meat with rearing conditions (housing) for animals, their welfare and ethical issues. From the aspect of meat industry and the desire to satisfy the consumer, quality of meat is associated with safety, chemical composition, nutritional value and sensory properties of meat (Jovanović *et al,* 2009b). Animal nutrition is one of the major factors influencing the quality of meat. Nutrition enables maximum use of the genetic potential of the animal for optimum production. Nutrition of animals and its impact on the quality of meat has always been considered exceptionally significant. This influence relates to numerous meat quality parameters such as: meat safety (biological, chemical and physiological hazards); nutritional value of meat; postmortem changes in meat and its quality properties (pH, colour, water holding capacity); content of intramuscular fat; meat colour; fatty acid composition and stability of fat during cooling (freezing) and distribution; acceptability of meat to consumers subsequent to heat treatment (Marković *et al,* 2010).

In Oman, the camel has a prominent cultural, social, economic and aesthetic to camel owners. The

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traditional feeding systems of camel in Oman are based on consuming a range of plants and agriculture by-products. Local camel owners prefer to raise animals under extensive management systems due to shortage of feed. Various studies investigated the effect of different feeding systems on meat quality characteristics of beef, pork, and sheep (Priolo *et al,* 2002; Dufrasne *et al,* 1995; French *et al,* 2000; Sami *et al,* 2004). Although, the role of camel as meat producers is increasing, the effect of nutrition on camel meat quality has not been studied. The current study aimed to investigate the effect of three feeding levels (1.5%, 2% or 2.5% of body weight) and type of muscle on quality and histological characteristics of individual muscles in the dromedary camel muscles.

Materials and Methods

Animal management

Ten 1-year-old camels were housed under intensive management in individual shaded pens and equipped with individual feed and water troughs at the Agricultural Experiment Station, College of Agricultural and Marine Sciences at Sultan Qaboos University. The animals were divided into: group 1 (3 animals) fed concentrate and Rhodes grass hay equivalent to 1.5 of body weight, group 2 (3 animals): fed concentrate and Rhodes grass hay equivalent to 2.0% of body weight, and group 3 (4 animals) fed concentrate and Rhodes grass hay equivalent to 2.5% of body weight. The animals were fed 60:40 concentrate: hay ratio for the first 10 weeks as adaptation period followed by an 80:20 concentrate: hay ratio for the rest of experimental period. At the end of the feeding period (162 days) the camels were slaughtered according to Islamic (Halal) method and dressed following routine commercial slaughterhouse procedures.

Sample collection

The *Infraspinatus* (IS), *Triceps brachii* (TB), *Longissimus thoracis* (LT), *Biceps femoris* (BF), Semitendinosus (ST) and Semimembranosus (SM) muscles were dissected within 30 min. postmortem from left side of each carcass. The muscles were kept in zipped plastic bags and transferred in a cold insulated box to a chiller (1-3°C) within 2-3 hrs post slaughter and then kept in a chiller (1-3°C) for 48 hrs.

Muscle pH decline

The pH from the left side of IS, TB, LT, BF, ST and SM 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 (1, 2, 4, 8, 12, 24 and 48 hr postmortem) were recorded. For each measurement, the pH probe and the thermometer were inserted into muscles to a similar depth (5 cm).

Histochemistry

Core samples from IS, TB, LT, BF, ST and SM muscles at the last rib location were removed immediately after slaughter, cut into 1×1 cm pieces and snapped frozen in liquid nitrogen. Muscle samples were cut into 8-µm-thickness on a cryostat (Model Bright, England) 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 minutes and then incubated at adenosine 5-triphosphate substrate pH 9.5 for 45 minutes. The sections were then incubated for three minutes in an aqueous cobalt chloride and a solution of ammonium sulphide. A blackish–brownish cobalt sulphide is generated in the reaction to replace cobalt phosphate (Brooke and Kaiser, 1970). Another 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 (succinate dehydrogenase) (Sheehan and Hrapchak, 1989). Staining sections were viewed under an Olympus BX51 light microscope (Olympus, Japan) at a magnification of 40X. Images were taken using an Olympus DP70 camera. The area and number of muscle fibres were measured in five randomly selected fields (approximately 250 fibres in each filed) using life science soft image system (Olympus, Japan). The diameter of 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.

Meat quality characteristics

Meat quality measurements including ultimate pH, expressed juice, cooking loss, Warner-Bratzler shear force, sarcomere length, myofibrillar fragmentation index, and colour L*, a*, b* were determined in left and right sides of the IS, TB, LT, BF, ST and SM muscles. The ultimate pH was assessed in homogenates at 20-22°C (using an Ultra Turrax T25 homogeniser) of duplicate 1.5-2.0 g of 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. Chilled muscle samples (13 mm x 13 mm cross section) for assessment of shear force by a

digital Dillon Warner-Bratzler shear device from muscle samples were 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 was measured using a modification of the method of Johnson *et al* (1990). This basically measured the proportion of muscle fragments that passed through a 231-µm screen after the sample had been subjected to a standard homogenization treatment. A 5g (±0.5 g) sample of diced muscle (6 mm3 pieces) was added to 50 ml of cold physiological saline (85% NaCl), plus 5 drops of antifoam A emulsion (Sigma Chemical), in a 50 ml graduated cylinder, and homogenized at ¼ speed using an 18 mm diameter shaft on an Ultra-Turrax homogenizer for 30-second periods separated by a 30 second rest period. The homogenate was poured into a pre-weighed filter (231 x 231 µm holes). The filter typically ceased dripping after 2-3 hrs, at which time the samples were dried at 26-28°C in an incubator for 40 hrs before being re-weighed. The myofibrillar fragmentation index values presented herein were calculated as 100 minus the percentage of the initial meat sample weight that remained on the filter. Expressed juice was assessed by a filter paper method, as the total wetted area less the meat area (cm2) relative to the weight of the sample (g). Approximately 60 min after exposing the fresh surface, CIE L*, a*, b* light reflectance coordinates of the muscle surface were measured at room temperature (20±2oC) using a Minolta Chroma Meter CR-300 (Minolta Co., Ltd., Japan).

Statistical analysis

The general liner model, ANOVA procedure within SAS (1993) was used to compare the effect of three feeding levels on muscle fibre type, meat composition and quality characteristics of camel *Infraspinatus, Triceps brachii, Longissimus thoracis, Biceps femoris, Semitendinosus and Semimembranosus* muscles. Significant differences between means were assessed using the least-significant-difference procedure.

Results and Discussion

Kinetics of muscles pH decline

Change in pH-time curves for the IS, TB, LT, BF, ST and SM muscles representing the three feeding levels at 1, 2, 4, 8, 12, 24, and 48 hours post-mortem are presented in Fig 1. Major determinants of meat quality are the rate and extent of postmortem glycolysis. The most readily measurable glycogen, glucose and glucose-6-phosphate degraded into lactic acid are the cause in the drop in pH value. Changes in glycolysis between different muscles were monitored by measuring the rate of pH fall after slaughter. The rate and extent of postmortem pH decline may induce protein denaturation, affecting tenderness, juiciness and colour (King *et al,* 2004). Neither muscles' initial pH (1 hr postmortem) nor pH decline were affected by feeding level or feeding

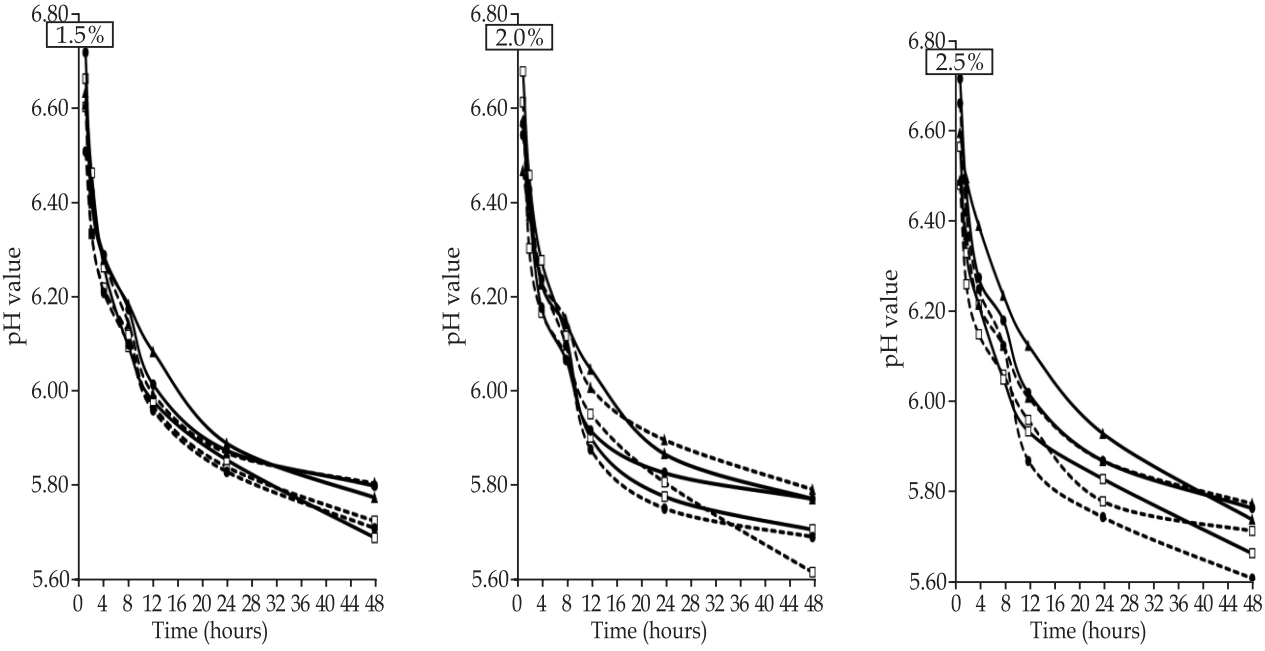

Fig 1. Mean changes in pH within the *Iinfraspinatus, Triceps brachii, Longissimus thoracis, Semitendinosus, Semimembranosus,* and *Biceps femoris* muscles from camel carcasses fed on 1.5%, 2.0% and 2.5% body weight requirement.

level by muscle interaction. The highest drop in pH values at 2 hrs in 1.5% group (0.23 unit), compared with 2.0% group (0.18 unit) and 2.5% group (0.19 unit). At 1 hr postmortem, there was little variation between the three feeding groups across the six muscles (Fig 1). The greatest pH fall occurred at 2 hrs postmortem in IS (0.27 unit) and ST muscles (0.30 unit), while the lowest pH falls (0.18 unit) occurred in LT and SM. In group 2, the pH fall in TB (0.31 unit) and LT muscles (0.22 unit) were significantly higher than in SM muscle (0.09 unit). In group 3, the BF muscle had significantly lower drop in pH (0.10 unit) than IS (0.22 unit), TB (0.24 unit) and LD (0.24 unit) muscles. After a relatively fast fall within the first 2 h, the mean pH values underwent a slow decline until an ultimate pH was achieved at 48 h postmortem. The average difference in 1–4 h postmortem pH between the muscles ranged between 0.21 and 0.44 unit. The time needed for muscle pH values to fall to 6.0 is a reflection of earlier rigor onset (Simmons *et al,* 2008). There was slight difference in time to reach pH 6.0 between the three feeding levels groups. The muscle pH from 1.5% group has fallen to 6.0 at 12 hrs postmortem, while the other two groups took less time for muscle pH to fall to 6.0. The IS, TB and LT muscles needed less time to reach pH 6.0 than ST, SM and BF muscles (Fig 1). There are smaller amounts of glycolytic enzymes in camel meat than in other meat species in contrast to its higher concentration in the hump (Immonen and Puolanne, 2000). This may result in slower glycogen degradation and consequently slower pH decline. These findings are in accordance with reports in camel LT muscle (Kadim *et al,* 2009a,b,c, 2013).

Muscle fibre types

Three types of muscle fibres were found in camel meat (type I (βR), type IIA (αR) and type IIB (αW) (Fig 2). Effect of feeding levels on proportion and diameter of the muscle fibre types (slow-twitch oxidative: Type I, fast-twitch high oxidative: Type IIA and fast-twitch fibres: Type IIB) are presented in Table 1. Muscle fibre types may influence meat quality characteristics (Ashmore and Vigneron, 1988) and are valuable for predicting meat tenderness (Tuma *et al,* 1962). Although, the feeding level had no significant effect on the proportions of muscle types, the diameter of muscle fibre types were affected by feeding level. In general, the proportions of Type IIA numerically increased while Type I proportion decreased with increasing feeding levels from 1.5% to 2.5%. The present results are consistent with the finding of Nissen, *et al* (2013) for pig and Nordby *et al* (1987), Greenwood *et al* (1999) and McCoard *et al* (2000) in lambs. In contrast, the effects of reduced feeding level on muscle fibre characteristics in cattle indicated that low feeding level led to a higher frequency of slow- or fast-twitch oxidative and a lower frequency of fast-twitch glycolytic fibres (Johnson *et al,* 1990). The effect of high levels on muscle fibre types may be due to the enlarge muscle size due to an increase the diameter of muscle fibre types with higher proportion of oxidative fibres than glycolytic fibres. In this respect, the feeding level had significant effect on the diameter of muscle fibre types (Table 1). Muscle fibre diameters from 2.5%-group muscles were significantly ($P<0.05$) larger than muscles from 1.5% and 2.0% groups. Type I fibre was the smallest diameter with Type IIA fibre medium and Type IIB fibre the largest diameter. Similar findings were reported by Kadim *et al* (2009a,b) who used similar camel breed. The present study showed that the SM and IS muscles had significantly the smallest muscle fibre types than other muscles.

The proportion of Type I was significantly ($P<.0.05$) higher in ST muscle than other muscles, while the proportion of Type IIA was significantly higher in SM and BF muscles than in IS and ST muscles. With the exception of SM muscle, the present study revealed that small non-significant variations between the three muscle fibre types within each muscle. Type IIA was significantly higher than Type I in camel SM muscle. In contrast, Kadim *et al* (2009a, b) used similar camel breeds and found that the proportion of Type IIB muscle fibre was significantly ($P<0.05$) higher than Type I oxidative or Type IIA high-oxidative in camel LT muscle. However, Kassem *et al* (2004) found the proportion of Type IIA high oxidative was higher than Type I oxidative and Type IIB fibre types in LT of two year-old camel muscles. Saltin *et al* (1994) found that the Gluteus medius muscle in the dromedary camels had a clear predominance of muscle Type I fibre type (73.6%), while the ST muscle had only 19.4% (Type I fibres), and the *Supraspinatus* muscle contained an average of 93.6% type I fibres whereas the TB had 35.9% of type I fibres. Differences between the presenting findings and those of Saltin *et al* (1994) and Kadim *et al* (2009a,b) and Kassem *et al* (2004) might be attributed to variations due to heterogeneity of dromedary camels. Sampling technique is another possible explanation for differences, in which inconsistent measurements may be present in the study of Saltin *et al* (1994), when muscle fibre composition is based on a small tissue sample (biopsy). According to Heneiksen-larsen *et al*

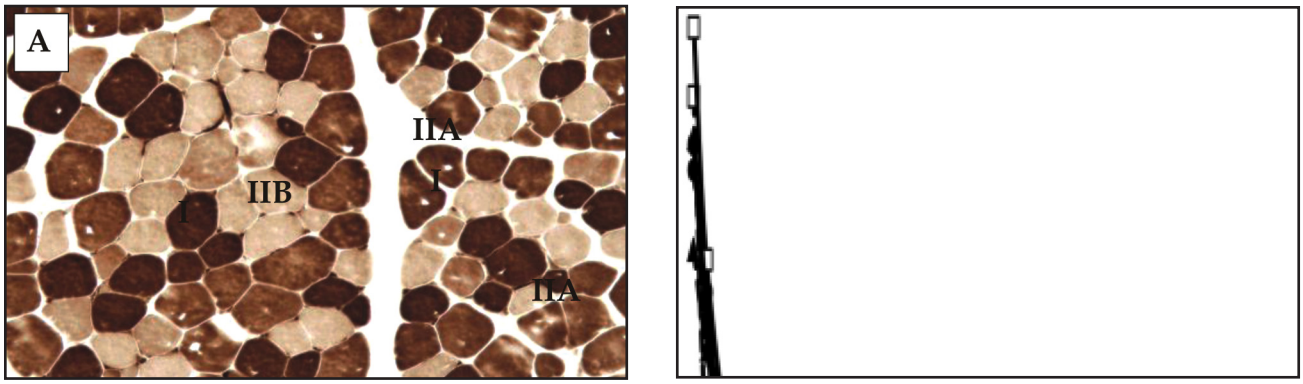

Fig 2. Photomicrograph of serial sections of camel muscle, staining ATPase, note the activity of the slow myosin isoenzyme of type I fibre, type IIB fibres stain more intensely than type IIA fibres in this species (A), confirmed by staining for succinate dehydrogenase activity, an enzyme associated with oxidative phosphorylation (B).

(1983) fibre types are heterogeneously distributed in camel muscles.

Meat quality characteristics

Effect of feeding levels on quality characteristics of the dromedary camel muscles are presented in Table 2. The ultimate pH is the major determinant of meat quality and is related to the rate of glycogen breakdown and liberation of lactate pre- and post-mortem (Watanabe *et al,* 1996). A low plane of feeding may result in chronic nutritional stress, characterised by low reserves of muscle glycogen and increased final pH values in the meat (Bray *et al,* 1989). The plane of feeding and the type of feed are closely related to the effect of the period of preslaughter fasting and stress before slaughter. Ultimate muscle pH ranged between 5.61 and 5.89. There were no significant differences in ultimate pH between the feeding level groups. The lack of feeding effect on muscle pH in the current study agreed with that of French *et al* (2000) and Sami *et al* (2004) in beef and Priolo *et al* (2002) in sheep. In contrast, Young *et al* (1997) reported in cattle a higher ultimate pH variability between animals raised on different feeding systems. Immonen *et al* (2000) reported that high-energy diets protect animals from potentially glycogen depleting stressors. Vestergaard *et al* (200a) stated that postmortem glycogen store is converted to lactate and the H+ results in a decreased pH of meat. The glycogen level at slaughter is inversely related to the ultimate pH value. Consequently changes in the pH during postmortem influence the organoleptic characteristics of meat (Dutson, 1983; Watanabe *et al,* 1966). The present study showed small variation in ultimate pH values between muscles, which may reflect the variation in muscle fibre types and led to differences in the patterns of muscle metabolism (Swatland, 1982), and consequently differences in ultimate pH value.

Expressed juice affects the retention of vitamins, minerals and salts, as well as the volume of water retained between the thin and thick filaments when an extraneous force is applied to it (Offer and Knight, 1988). Muscles that lose water easily are drier and would lose more weight during refrigeration, storage, transport and marketing. The present study indicated that expressed juice was not significantly affected by feeding level (Table 2). However, the values of expressed juice slightly decreased with increasing feeding level. Cooking loss results in agreement with those reported for cattle (Fiems *et al,* 1999) and Sami, *et al* (2004), where feeding level had no significant effect. On the other hand, Vestergaard *et al* (2006) stated that cooking loss was higher in extensively fed than in intensively fed bulls. May *et al* (1992) found that juiciness of Angus × Hereford steaks were not significantly influenced by feeding a high concentrate diet or the period fed. When expressed juice was calculated by combining pressing losses and cooking losses, the LT had the highest and the IS and TB had the lowest values. It is possible that the rapid decline of temperature due to muscle sizes and removal from the carcasses pre-rigor made the IS and TB muscles remain comparatively lower in protein functionality and expressed juice (Joo *et al,* 1999). Bouton *et al* (1972) reported that expressed juice was affected by the location of the muscle in the carcass with muscles in the posterior end having a lower expressed juice. These differences can be explained by differences in muscle activity, proportion of muscle fibre types, pH, intramuscular fat and the ratio of water to protein. The current study indicated that expressed juice in camel meat was higher than in other studies with similar muscles probably due to age difference

Table 1. Effect of feeding systems on proportion, area and diameter of muscle fibre types of *Infraspinatus* (IS), *triceps brachii* (TB), *Longissimus thoraces* (LT), *Semitendinosus* (ST), *Semimembranosus* (SM), and *Biceps femoris* (BF) muscles of the dromedary camel.

		Level of feed intake[1]																		Significance[2]			
		(1.5%)						(2%)						(2.5%)									
		Muscles[1]																					
		IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF	SEM[3]	Treat	Muscle	T×M
Proportion	Type IIA	28.8^{a}	30.0^{a}	30.0^{b}	29.5^{a}	30.4^{a}	32.8^{a}	33.5^{a}	30.9^{a}	31.7^{a}	30.4^{a}	33.2^{a}	35.9^{b}	33.7^{a}	36.3^{ab}	36.1^{b}	31.7^{a}	38.3^{b}	36.4^{b}	1.80	NS	***	NS
	Type IIB	36.7^{b}	38.3^{b}	35.1^{a}b	33.5^{ab}	37.0^{b}	35.4^{ab}	33.0^{ab}	38.0^{b}	35.0^{ab}	37.0^{b}	34.6^{ab}	34.2^{ab}	33.5^{ab}	29.4^{a}	35.1^{ab}	27.1^{a}	34.0^{ab}	24.9^{a}	2.17	NS	NS	NS
	Type I	34.5^{ab}	31.7^{ab}	34.9^{ab}	37.0^{b}	32.6^{a}	31.8^{ab}	33.5^{ab}	31.1^{ab}	33.3^{ab}	32.6^{ab}	32.2^{ab}	29.9^{a}	32.8^{ab}	34.3^{ab}	28.8^{a}	41.2^{c}	27.7^{a}	38.7b^{c}	2.29	NS	**	NS
Diameter	Type IIA	84.0^{a}	89.9^{ab}	93.2^{b}	96.2^{bc}	81.0^{a}	86.3^{a}	85.0^{a}	94.8^{b}	101.5^{c}	98.7^{b}	83.2^{a}	96.0^{b}	87.6^{a}	100.0^{c}	109.6^{c}	103.8^{c}	86.0^{a}	102.4^{c}	3.02	***	***	NS
	Type IIB	86.3^{a}	95.4^{a}	95.4^{a}	100.4^{b}	86.2^{a}	88.9^{a}	91.3^{a}	96.5^{ab}	105.2^{b}	101.0^{b}	92.0^{a}	101.5^{b}	92.8^{a}	102.9^{b}	112.5^{b}	100.2^{b}	92.2^{a}	105.5^{b}	3.05	***	***	NS
	Type I	86.3^{a}	94.8^{ab}	94.6^{ab}	100.4^{b}	86.9^{a}	91.0^{ab}	96.3^{b}	98.1^{b}	99.5^{b}	104.4^{b}	89.3^{a}	98.1^{b}	92.8^{ab}	100.0^{b}	115.9^{b}	103.2^{b}	94.4^{ab}	109.5^{a}	2.8	***	***	NS

[1]Level of feed intake: 1.5, 2, 2.5% of body requirements. [2]Significance: [4]NS; not significant, **P<0.01, ***P<0.001. [3]SEM: standard error for the mean.

Table 2. Effect of feeding systems on meat quality characteristics of *Infraspinatus* (IS), *triceps brachii* (TB), *Longissimus thoraces* (LT), *Semitendinosus* (ST), *Semimembranosus* (SM), and *Biceps femoris* (BF) muscles of the dromedary camel.

	Level of feed intake[1]																		Significance[2]		
	(1.5%)						(2%)						(2.5%)								
	Muscles[1]																				
	IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF	SEM[3]	Treat	Muscle
Ultimate pH	5.73	5.69	5.71	5.82	5.81	5.78	5.63	5.69	5.89	5.77	5.79	5.77	5.72	5.67	5.61	5.77	5.78	5.74	0.061	NS	NS
Expressed juice (cm2/g)	38.7^{ab}	40.9^{bc}	43.3^{c}	40.0^{bc}	39.4^{b}	41.9^{bc}	40.7^{bc}	37.8^{a}	40.5^{b}	42.5^{c}	36.9^{a}	40.5^{b}	34.8a	42.1^{bc}	41.8^{bc}	36.8a	42.4^{bc}	40.2^{b}	2.90	NS	***
Cooking loss %	31.0^{ab}	27.9^{a}	34.3^{c}	30.2^{ab}	29.8^{a}	30.1^{ab}	33.2^{bc}	29.4^{a}	33.4^{bc}	29.4^{a}	29.1^{a}	32.6^{bc}	31.6ab	29.2^{a}	33.5b^{c}	28.5a	30.6^{ab}	29.5^{a}	1.17	NS	***
W-B Shear force value (Kg)	7.02^{b}	8.22^{b}	4.58^{a}	9.27^{bc}	7.90^{b}	10.11^{cd}	6.76^{a}	7.93^{b}	5.95^{a}	9.62^{bc}	10.77^{cd}	9.16^{bc}	6.26a	6.65^{a}	6.54^{a}	9.03^{bc}	12.94^{d}	10.29^{cd}	1.098	NS	***
Sarcomere length (µm)	1.43	1.43	1.31	1.43	1.53	1.31	1.41	1.43	1.41	1.39	1.35	1.38	1.49	1.50	1.46	1.27	1.58	1.48	0.073	NS	NS
Myofibrillar Fragmentation Index	74.7^{c}	69.0^{b}	74.1^{c}	70.8^{bc}	73.8^{c}	64.2^{b}	73.2^{c}	72.8^{c}	70.0^{c}	65.2^{ab}	69.3^{b}	65.3^{ab}	72.5^{c}	76.1^{c}	67.0^{b}	77.6^{c}	68.7^{b}	59.6^{a}	72.5	NS	**
Lightness (L*)	31.05^{bc}	27.95^{a}	34.33^{c}	30.27^{bc}	29.89^{ab}	30.13^{b}	33.25^{c}	29.42^{ab}	33.48^{c}	29.40^{ab}	29.15^{ab}	32.61^{bc}	31.68^{bc}	29.20^{ab}	33.53^{c}	28.53^{a}	30.63^{b}	29.55^{ab}	1.176	NS	***
Redness (a*)	13.09^{b}	12.01^{ab}	14.44^{b}	11.88^{a}	13.34^{b}	13.79^{b}	14.65^{bc}	12.51^{ab}	14.25^{bc}	10.97^{a}	13.61^{b}	15.89^{c}	12.70^{ab}	12.56^{ab}	14.03^{bc}	10.52^{a}	13.59^{b}	13.29^{b}	0.835	NS	***
Yellowness (b*)	3.72^{abc}	3.13^{ab}	4.11^{bc}	4.00^{bc}	3.55^{ab}	4.41b^{c}	4.38^{bc}	3.49^{ab}	3.90^{bc}	3.15^{ab}	3.67^{ab}	5.07^{c}	2.57^{a}	3.74a^{bc}	4.07^{bc}	2.18a	2.90a	3.77^{abc}	1.176	*	*

[1]Level of feed intake: 1.5, 2, 2.5% of body requirements. [2]Significance: [4]NS; not significant, **P<0.01, ***P<0.001. [3]SEM: standard error for the mean.

(Kadim *et al,* 2009a,b, 2013). A significant increase in cooking loss was observed in the LT muscle (41.9%) when compared with the IS (38.1%), TB (40.3%), ST (39.8%), SM (39.6%) and BF (40.9%) with no significant differences between the last five muscles. In contrast, Suliman *et al* (2011) found that BF muscles had higher cooking loss than LT muscles in four different camel breeds.

The Warner–Bratzler shear force value of meat is the most important organoleptic characteristic and the predominant quality determinant of red meat at the expense of flavor and colour (Koohmaraie, 1988). Tenderness appears to be related to the rates of postmortem degradation of the myofibrillar network linked to biochemical proteolysis and the amount of collagen around and between the fibres (Maltin *et al,* 2001). The effect of feeding levels on Warner–Bratzler shear force values of camel muscles are given in Table 2. Feeding levels had no effect on the shear force values of muscles but there was a significant ($P<0.001$) variation in shear force values between muscles. Noloney *et al* (2001) stated that factors related to animal feeding have a smaller impact on beef tenderness than postmortem carcass factors. The present study showed that feeding levels had no significant effect on intramuscular fat, sarcomere length, myofibrillar fragmentation index, ultimate pH and expressed juice to affect the tenderness attributes. These results followed the equivocal trend found in the previous literature in beef (Maltin *et al,* 2001; Sinclair *et al,* 1998; Van Koevering *et al,* 1995; Vestergaard *et al,* 200b). However, muscles of the 1.5% group were numerically more tender with no significantly different from the 2.0% or 2.5% groups. Higher non-significant contents of intramuscular fat in the 1.5% group may contribute to improve the muscle tenderness of this group. Wood *et al* (1999) indicated that a high intramuscular fat content decreases the muscle resistance to shearing because of dilution of fibrous protein by soft fat. In agreement with these results, lower shear force values were detected for Simmnetal steaks fed low energy diet relative to steers fed high energy diet (Mandell *et al,* 1998). Dikeman *et al* (1986) fed high or low energy diets to Angus male calves and found that collagen content was not affected by diet and do not account for tenderness variation in LT muscle. They added that sarcomere shortening could cause structural changes in collagen that might increase resistance to shear and decrease collagen solubility but it was not strongly correlated with tenderness. This study indicated that the shear force value increased (not significantly) with increasing feeding levels from 1.5 to 2.5% of body weight. The slight increase in shear force value with increase feeding levels may be due to increase muscle weight which accompanied by increasing connective tissue due to enlarge of the muscles. In the present study shear force values for LT, ST and TB were higher than those reported by Babiker and Yousif (1990) for the same muscles. In the present study, variation in muscle fibre types between the muscles may have contributed in differences in patterns of muscle metabolism (Swatland, 1982). The IS (6.68), TB (7.6), and LT (5.69) muscles had significantly ($P<0.05$) lower shear force values than ST (9.31), SM (10.54) and BF (9.85) muscles, which might be due to less connective tissue. Higher shear force values of the SM muscles (12.9 kg) may be due to the postmortem contraction of the myofibrillar proteins and amount and structure of the connective tissue. Kamoun (2004) reported a similar observation for camel muscles. Similarly, Suliman *et al* (2011) found that camel LT muscle had significantly lower shear force values than BF muscle. 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 less delectable connective tissue than muscles from the leg region. The latter authors reported that the SM muscle of beef ranked last in terms of tenderness. Koohmaraie *et al* (1987) stated that at slaughter, all muscles with the same pre-slaughter treatments had the similar tenderness level, and that differences in tenderness were created during the first 24 h postmortem. Intramuscular fat, connective tissue structure and amount, size of the muscle bundles, rigidity and water retention capacity are among many other features contributing to the shear force value of the muscle (Asghar and Pearson, 1980). This suggests that the variation between muscles might be due to connective tissue structure and its heat stability (Bruce *et al,* 2004). Moreover, one-fourth to one-third of the variability in shear force values between muscles was related with the variability of various muscles characteristics (Renand *et al,* 2001).

The differences in myofibrillar fragmentation index between the three feeding level groups were not significant (1.5%: 74.4%, 2.0%: 72.6 and 2.5%: 70.25%). However, significant differences in myofibrillar fragmentation index between the muscles, which ranged between 63.0 BF to 73.7% LT muscles. This may be due to protein degradation and variation in muscle ultimate pH values. The high myofibrillar

fragmentation index in LT muscle may be due to shorter segments which led to a rupture of myofibrils during the 48 h postmortem. The high fragmentation index in some camel muscles may be have caused by easily breaking myofibrils into shorter segments. The strength of the different muscle fibre types had a significant effect on the mechanical properties of individual fibre types (Christensen *et al,* 2006). The differences in rates of fragmentation of myofibrillar proteins may therefore account for differences in the rate of postmortem tenderization of meat (Nagaraj *et al,* 2005; Thomson *et al,* 1996). In the present study, the BF muscle had the lower myofibrillar fragmentation index among all muscles, which was in agreement with Suliman *et al* (2011), who compared four breed and two muscles LT and BF.

Muscle colour is an important criterion by which many consumers evaluate meat quality and acceptability (Brewer and Mckeith, 1999). Zhu and Brewer (1999) reported that instrumental colour characteristics (L*, a*, b*) were highly correlated with visual redness of fresh meat. Therefore, consumers were visually perceptive to the instrumental colour differences. The feeding level had no significant effect on muscle colour. In agreement with the current results, French *et al* (2000) found that there were no differences in the colour of LT steaks of steers under three different nutritional systems. Vestergaard *et al* (2000a) explained the low lightness (L*) and redness (a*) values in the extensively fed bulls firstly by the high pH of the meat, which is inversely related to the lightness and secondly, to the high haem pigment concentration, which was higher in the extensively fed bulls. High planes of nutrition increase the tenderness of lamb meat through an increase in intermuscular fat and a relative decrease in muscle collagen (Kemp *et al,* 1981). Although meat from 1.5% group had slightly higher fat content than in other two groups, the small difference is not likely to have played a direct role in meat lightness. The lightness (L*), yellowness (b*) and redness (a*) values were significantly (P<0.001) different between muscles. In the present study the range of lightness value was from 27.95 to 33.48, redness from 10.52 to 15.89 and the yellowness from 2.57 to 5.07. These finding were in line with results reported by Kadim *et al* (2006, 2009a, b, 2008a,b, 2010, 2013) for dromedary camels. Muscle L* values indicated that the LT muscle (33.8) had the lightest (P<0.05) lean colour, which was possibly due to high fat content. The ST muscle (29.4) had the darkest colored lean compared with other muscles. The IS, LT, SM and BF muscles had significantly (P<0.05) higher redness (a*) values than ST muscle, while a* value for TB muscle was in between. CIE a* values were similar among IS, LT, SM and BF muscles. The highest average b* value was recorded in the BF muscle (4.42) muscle with comparable values with the LT muscle (4.03). Similarly, no difference between the LT and BF muscles in redness was reported by Suliman *et al* (2011). Myoglobin concentration, pH and muscle fibre type influence the development of muscle colour (Faustman and Cassens, 1990; MacDougall and Rhodes, 1972). The isoelectric point of proteins of 5.5 results in an open structured muscle and a greater diffusion of light between the myofibrils of the muscle, which make the surface of the meat lighter (Seideman and Crouse, 1986). The redness and yellowness values in the present study are in agreement with those reported for camel and beef by Kadim *et al* (2009a). Furthermore, the present study had similar L* values, relatively higher a* values and lower b* values than those reported by Shariatmadari and Kadivar (2006) for Iranian camel.

Conclusions

The three feeding levels in the present study had no significant effect on decline pH, meat quality characteristics and histochemistry parameters of dromedary camel muscles. The feeding levels had only a significant (P<0.001) effect on diameter of muscle fibre types. The type of muscle had a significant influenced on camel muscle quality parameters. Variation among muscles may be due to different functional properties according to their locations. In general, the camel meat would be considered a comparable in quality parameters to other meat species livestock.

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