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Composition, Quality and Health Aspects of the Dromedary *(Camelus dromedarius)* and Bactrian *(Camelus bacterianus)* Camel Meats: A Review

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القيمة الغذائية والصفات النوعية والصحية للحوم الإبل ذات السنام الواحد والسنامين: استعراض عام

عصام توفيق كاظم[1] و عثمان محجوب[1] و وليد المرزوقي[1] وربيع المقبالي[1] وسميرة قاسم خلف[1] و قولجان رامبوك[2]

الخلاصة: تعتبر الإبل ذات السنام الواحد أو السنامين من المصادر الجيدة للبروتين ذو القيمة الغذائية العالية وخاصة في المناطق ذات الطبيعة البيئية القاسية والتي تؤثر سلبياً على بقاء حيوانات المزرعة الأخرى. تتميز الإبل بصفات وظيفية فريدة والتي تتضمن تحملها لدرجات الحرارة العالية أو المنخفضة واشعة الشمس المباشرة وقلة توفر المياه والطبوغرافيا القاسية للمناطق التي تعيش فيها وقلة الغطاء النباتي. تربى الإبل بطرق تقليدية مع عدم توفر متطلباتها الغذائية وتذبح عند أعمار كبيرة بعد انتهاء العمر الانتاجي للحيوان من انتاج الحليب أو التي لم تعد صالحة للسباق. تحتوي ذبائح الإبل بصورة عامة على 57% من العضلات و 26% من العظام و 17% من الدهون مع ثقل الربع الامامي مقارنة بالربع الخلفي للذبيحة. تتكون لحوم الإبل من 78% من الماء و 19% من البروتين و 3% من الدهن و 1.2% من الأملاح وتعتبر قلة الدهون العضلية للحوم الإبل من المواد الغذائية الصحية في تغذية العدد المتزايد من البشر. يعتبر محتوى لحوم الإبل من الأحماض الأمينية والأملاح المعدنية أعلى من مثيلاتها من لحوم بقية الحيوانات بسبب انخفاض نسبة الدهون في عضلاتها. يمكن صنع الهمبيرجر والنقانق والشاورما من لحوم الإبل لزيادة قيمتها الغذائية. لذلك يجب أن تتركز البحوث المستقبلية على تحسين طرق التربية لزيادة إنتاج اللحوم مع الاهتمام بتحسين تقنية تصنيع لحوم الإبل ولتسويق اللحوم ومنتجاتها.

كلمات مفتاحية: ابل ، الصفات النوعية ، القيمة الغذائية ، التركيب الكيميائي ، تصنيع اللحوم.

ABSTRACT: The dromedary and bactrian camels are good sources of high quality protein especially in areas where the climate adversely affects the survival of other livestock. The camel has unique physiological characteristics, including a great tolerance to high and low temperatures, solar radiation, water scarcity, rough topography and poor vegetation. Camels are mostly produced under traditional systems on poor levels of nutrition and are mostly slaughtered at old ages after completing a career in work, racing or milk production. In general, camel carcasses contain about 57% muscle, 26% bone and 17% fat with fore-quarters (cranial to rib 13) significantly heavier than the hind halves. Camel lean meat contains about 78% water, 19% protein, 3% fat, and 1.2% ash with a small amount of intramuscular fat, which renders it a healthy food for growing human populations. The amino acid and mineral contents of camel meat are often higher than other meat animals, probably due to lower intramuscular fat levels. Camel meat has been processed into burgers, patties, sausages and shawarma to add value. Future research efforts need to focus on exploiting the potential of the camel as a source of meat through multidisciplinary research into efficient production systems and improved meat technology and marketing.

Keywords: Camel, meat quality, nutritive value, meat composition, meat processing.

Introduction

The family Camelidae include two subfamilies: Camelinae (Old World Camelids) and Laminae (New World Camelids). The subfamily Camelidae includes two species: *Camelus dromedarius* and *Camelus bacterianus*. The dromedary or the one-humped camel (*Camelus dromedarius)* is mostly distributed in the hot arid areas of the Middle East, Asia and Africa, whereas the bactrian two-humped camel *(Camelus*

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bacterianus) is found in central Asia, Kazakhstan, Russia and China (Dorman, 1986). The New World camelids consist of the following species: the guanaco (*Lama guanacoe*) and the vicuna (*Vicugna vicugna*), which are wild and the llama (*Lama glama*) and the alpaca (*Lama pacos*),which are domesticated and mainly found in South America (Murray, 1989). The camel was domesticated by secondary nomads around 5000 years ago in South Arabia primarily for transport and labour (Wilson, 1998). The dromedary is more abundant than the bactrian camel representing almost 90% of the genus Camelus. Phylogenetic analysis (micro-satellite loci) showed that camel breeds can be classified according to countries of origin (Mburu *et al.,* 2003).

The camel is an important domestic animal in various countries for producing valuable food and for its adaptation to extremely harsh environments (Kadim *et al*., 2008). It can survive on sandy terrain with poor vegetation and may chiefly consume feeds unutilized by other domestic species (Tandon *et al.,* 1988). Therefore, the role of the camel as a meat producer is becoming more important due to the versatile role it plays rather than as a symbol of social prestige, which was the major role it used to play, and which has since greatly diminished (Dawood and Alkanhal, 1995). Camel meat is described as tough, coarse, watery and sweetish in taste compared to meats from other animals. This may be partly attributed to the fact that camel meat is usually a by-product of primitive traditional systems of production where it is mainly obtained from old males and females that have become less effective in their primary roles of providing transportation, milk, or as breeding females (Kadim *et al*., 2008). However, evidence suggests that the quality characteristics of camel meat are not much different from beef if animals are slaughtered at comparable ages (Khatami, 1970; Knoess, 1977; Elgasim *et al.*, 1987; Tandon *et al.*, 1988; Kadim *et al.,* 2011).

Although the marketing systems for camel meat are not well organised, there is evidence of a high demand for camel meat (Kadim *et al*., 2008). Camel meat could be a good source to meet the growing needs for meat in developing countries, especially for low income population groups (Kadim *et al.,* 2008). Generally, camel meat is a significant source of animal protein and preferred over other meat animal species due both to the belief in it medicinal benefits and to its availability at affordable prices. This review outlines the nutritional and health value, quality characteristics and the availability of muscle bioactive compounds in dromedary and bactrian camel meats. A comparison of the nutritional properties of dromedary and bactrian camel meats with other species is also highlighted.

Chemical Composition of Camel Meat

Camel meat composition varies according to breed, age, sex, condition and location on the carcass. However, the composition of camel meat is generally similar to meat from other species where an inverse relationship existed between the moisture and protein and fat content of the meat (Table 1). Composition is an important indicator of meat functionality. For instance, moisture content plays an important role in keeping and eating qualities of camel meat (Kadim *et al.,* 2008) whereas protein and fat contents dictate the manufacturing quality of meat.

Table 1 shows that moisture content varies widely in camel meat (67.8 to 78.9%). Different muscles within the same camel carcass appear to have similar moisture contents (Babiker and Yousif, 1990; Gheisari *et al.,* 2009; Kadim *et al.,* 2013) as well as for the bactrian (Raiymbek *et al*., 2012a). However, the range of moisture content of *Biceps femoris* (74.3-78.5%) and *Triceps brachii* (77.7-78.4%) muscles was higher than those from *Longissimus dorsi* muscle (72.1-73.8%) due to the higher fat content in the *Longissimus thoracis muscle* (Kadim *et al*., 2013; Raiymbek *et al.,* 2012a). According to Kadim *et al.* (2006), the moisture content of dromedary camel meat decreases with the increases in the animal age. The differences between the maximum and minimum moisture contentsof camel *Longissimus thoracis* were 3.2, 6.4 and 12.3% for 1-3, 3-5 and 6-8 years age groups, respectively (Kadim *et al*., 2006). This indicates that the variation in moisture content within the samples is greater in older animals. Gheisari *et al.* (2009) found no differences in moisture content between camel meat and meat from other species at a similar age and sex.

The protein content of camel meat is in the range of 17.0 to 23.7% (Table 1). There are slight differences between various muscles and different age groups (El-Faer *et al.* 1991; Kadim *et al.,* 2006, 2012; Raiymbek *et al.,* 2012a). Meat from young camels has similar protein content to those found in young cattle, lamb and goat meats (Elgasim and Alkanhal, 1992; Kadim *et al*., 2009b). The protein contents of six skeletal muscles (*Semitendinosus, Infraspinatus, Semimembranosus, Biceps femoris, Triceps brachii and Longissimus thoracis*) in dromedary and bactrian camels were studied by Kadim *et al.* (2013) and Raiymbek *et al.* (2012a). The highest protein content was found in the *Semitendinosus* muscle in bactrian, while the *Semimembranosus* contained the highest protein content in dromedary camel (Kadim *et al.,* 2013; Raiymek *et al.,* 2012a). Total collagen content is higher in camel *Longissimus thoracis* muscle than in *Semitendinosus* or *Triceps brachii* muscles, possibly due to morphological requirement for stabilizing the hump attached to the *Longissimus thoracis* (Babiker and Yousif, 1990).

The fat content of camel meat ranged from 1.1 to 10.6 % (Table 1). Differences in the fat content in various camel muscles were reported (El-Faer *et al.,* 1991; Elgasim and Alkanhal, 1992; Kadim *et al.,* 2006, 2008, 2009a,b; Gheisari *et al*., 2009). An animal's age has a great effect on the fat content, with camel meat from older animals' containing higher fat compared with meat from younger animals (Kadim *et al.,* 2006).

The ash content in the dromedary and bactrian camel meats has been reported in the range of 0.75 to

Table 1. Chemical composition (%) of dromedary and bactrian camel muscles.

Muscle Type	Moisture	Protein	Fat	Ash	
Dromedary camel					
Longissimus thoracis	73.8	19.0	6.2	0.85	Kadim *et al.* (2013)
Infraspintus	73.2	18.2	5.3	0.96	
Triceps brachii	77.7	17.1	1.9	1.00	
Semitendinosus	75.4	18.5	3.1	0.91	
Semimembranosus	63.0	22.1	2.5	0.93	
Biceps femoris	74.3	20.8	2.5	1.00	
Longissimus thoracis	65.7	19.5	2.1	1.20	Kadim *et al.* (2011)
Longissimus thoracis	73.8	23.7	3.6	-	Al-Bachir & Zeinou (2009)
Biceps femoris	73.0	22.8	1.1	0.75	Gheisari *et al.,* (2009)
Triceps brachii	72.0	21.2	1.4	0.81	
Longissimus dorsi	68.3	21.5	1.6	0.69	
Biceps femoris	71.4	22.2	1.6	0.98	
Triceps brachii	70.5	20.3	2.4	1.06	
Longissimus dorsi	67.8	20.5	2.5	0.95	
Longissimus thoracis	74.8	21.1	2.8	1.34	Kadim *et al.* (2009a)
Longissimus thoracis	71.7	22.7	4.4	1.10	Kadim *et al.* (2006)
Longissimus dorsi	75.9	21.6	1.4	1.05	Babiker and &Yousif (1990)
Semitendinosus	75.8	21.4	1.4	1.38	
Triceps brachii	75.2	22.1	1.4	1.22	
Bactrian camel					
Longissimus thoracis	72,1	17.0	10.0	0.9	Raiymbek *et al.* (2012a)
Infraspintus	78.5	18.0	2.5	1.0	
Triceps brachii	78.4	17.5	3.0	1.0	
Semitendinosus	78.0	18.8	2.2	1.0	
Semimembranosus	79.0	18.2	2.0	1.0	
Biceps femoris	78.5	18.3	2.1	1.1	

1.38% (Table 1). Ash content varies with muscles and between muscles (Babiker and Yousif, 1990; Dawood and Alkanhal, 1995; Gheisari *et al*., 2009; Kadim *et al*., 2013; Raiymbek *et al*., 2012a). Gheisari *et al.* (2009) found that age had a significant effect on ash content of camel meat, whereas others found no effect of age on ash content (El-Faer *et al*., 1991; Al-Shabib and Abu-Tarboush, 2004; Shehata, 2005; Kadim *et al.,* 2006, 2008). Camel meat has relatively lower ash content than beef, lamb and goat meat (Elgasim and Alkanhal, 1992; Gheisari *et al.,* 2009; Kadim *et al*., 2008).

Amino Acid Composition

According to Dawood and Alkanhal (1995), the essential amino acid content of camel meat is not affected by an animal's age. Camel meat has a comparable essential amino acid contents to beef, lamb and goat meat (Table 2). The amount of camel meat required to supply the daily requirements of essential amino acids for adult consumer is similar to that from lamb (based on methionine which has the lowest content in meat) but is less than the amount required from beef.

Table 2 shows that leucine (7.08 to 9.51% of protein) and lysine (8.33 to 9.85% of protein) are among the highest essential amino acids in camel meat. Essential amino acids contents of camel meat varied slightly among different muscle locations in the carcass. The essential amino acid contents in *Longissimus dorsi* and *Semitendinosus* muscles differed by >2.1% with the exception of leucine, methionine and tryptophan, which differed by 18.5, 25.4 and 14.6 %, respectively (Al-Shabib and Abu-Tarboush, 2004). Similarly, essential amino acid contents in the *Infraspinatus, Longissimus dorsi* and *Semitendinosus* muscles differed by > 4.2% with the exception of isoleucine, methionine, threnonine, tryptophane and valine which differed between 8 to 42% (Dawood and Alkanhal, 1995). On the other hand, differences in essential amino acids reported across

Table 2. Essential amino acid composition in camel meat (mg/100g).

	Amino acid[1]									
	His	Ileu	Leu	Lys	Met	Phe	Thr	Trp	Val	
Longissimus thoracis	4.4	4.7	8.3	9.4	2.9	4.3	4.5	-	5.6	Kadim *et al.* (2011)
Longissimus Dorsi	3.4	4.2	7.1	9.1	1.6	5.6	4.8	1.6	4.7	Al-Shabib &Abu-Tarboush (2004)
Semitendinosus	3.4	4.3	8.4	9.1	1.3	5.5	4.8	1.9	4.6	
Infraspinatus	4.7	5.3	8.6	8.4	2.6	4.1	4.2	0.5	4.9	
Longissimus Thoracis	4.3	5.4	8.3	8.6	2.2	4.4	4.7	0.7	5.3	Dawood & Alkanhal (1995)
Semitendinosus	4.5	4.9	8.3	8.3	2.5	4.2	4.2	0.6	5.4	
Longissimus dorsi & Semitendinosus	5.6	5.9	9.5	8.9	3.6	4.7	4.8	-	6.3	Elgasim & Alkanhal (1992)
Camel	5.6	5.9	9.5	8.9	3.5	4.7	4.8	-	6.3	
Beef	6.2	6.5	10.7	9.1	2.7	5.7	5.5	-	6.6	
Lamb	5.9	5.8	9.6	8.5	3.3	4.9	4.2	-	5.9	
Goat	4.7	6.0	7.9	10.9	3.9	6.5	4.4	-	6.8	
Camel	3.4	4.3	7.7	9.1	1.4	5.5	4.8	1.8	4.7	Al-Shabib &Abu-Tarboush (2004)

[1]Amino acids: His - Histidine, Ileu - Isoleucine, Leu - Leucine, Lys - Lysine, Met - Methionine, Phe - Phenylalanine, Thr - Threonine, Trp - Tryptophane, Val - Valine

different camel muscles ranged between 0.5 to 9.5% (Elgasim and Alkanhal, 1992; Dawood and Alkanhal, 1995; Al-Shabib and Abu-Tarboush, 2004). Tryptophan concentration in camel meat was lower than in other meats (Dawood and Alkanhal, 1995). Al-Shabib and Abu-Tarboush (2004) reported that tryptophan concentration was 1.76% of the total amino acids, which was higher than the 1.28% reported for beef (Kadim *et al.,* 2008).

The glutamic and aspartic acids, the major non-essential amino acids in camel meat ranged from 15.95 to 18.60% and from 9.30 to 10.80% of protein, respectively (Table 3). Similar to the essential amino acids, non-essential amino acid content also varied slightly between muscles, and larger variations are found between studies. In general, camel meat maybe a better source of non-essential amino acids than beef, lamb, and goat meats (Table 3). Although, Elgasim and Alkanhal (1992) found low alanine levels in camel meat compared to other red meats, Dawood and Alkanhal (1995), Al-Shabib and Abu-Tarboush (2004) and Kadim *et al.* (2011) found similar concentration of alanine in camel meats and other red meats.

Fatty Acid Composition

The fatty acid composition of meat is of great concern to consumers due to its important effects on human health. Reduction of saturated fatty acid intake is very important to prevent obesity, hypercholesterolemia and to decrease the risk of cancer (Chizzolini *et al*., 1999). On the other hand, diets containing lipids with a high level of monounsaturated fatty acids and polyunsaturated fatty acids have been shown to be effective in lowering serum cholesterol levels (Mensink and Katan, 1989). Rawdah *et al.* (1994) identified 22 fatty acids in camel meat (Table 5). Major fatty acids in camel meat were also reported by Al-Bachir and Zeinou (2009) and Kadim *et al.* (2011). Rawdah *et al.* (1994) reported levels of 18.93% oleic (C18:1) and 12.07% linoleic acid (C18:2) in the camel meat. However, about twice the percentage of oleic (C18: 1) and less than half the percentage of linoleic acid (C18: 2) were reported by Al-Bachir and Zeinou (2009) and Kadim *et al.* (2011). Linoleic acid is derived entirely from the diet (Wood *et al.,* 2008) and such differences are not unexpected from studies from different regions. The major saturated, monounsaturated and polyunsaturated fatty acids in camel meat are (C16:0), (C18:1) and (C18: 2), respectively (Table 4). The variation of total saturated fatty acids (51.5-53%) was small in comparison to monounsaturated (29.9 and 41.4%) and polyunsaturated (5.6% and 18.6%) fatty acids, which is in agreement with Rawdah *et al.* (1994) and Kadim *et al*. (2011).

The fatty acid composition, total saturated, unsaturated, monounsaturated and polyunsaturated fatty acids of *Infraspintus*, *Triceps brachii*, *Longissimus*

Table 3. Non-essential amino acid composition in camel meat (mg/100g).

	Amino acid[1]								
	Ala	Arg	Asp	Glu	Gly	Pro	Ser	Tyr	
Longissimus thoracis	6.5	6.6	9.3	15.9	4.3	3.9	3.6	3.5	Kadim *et al.* (2011)
Infraspinatus	6.3	7.5	9.3	17.1	6.0	5.4	3.5	3.0	Dawood & Alkanhal (1995)
Longissimus dorsi	6.2	7.1	9.3	17.3	5.9	4.9	3.8	3.4	
Semitendinosus	6.3	7.5	8.6	16.4	5.9	5.9	3.6	3.3	
Longissimus dorsi and *Semitendinosus*	3.9	7.1	10.8	18.6	6.1	3.9	3.2	3.8	Elgasim &Alkanhal (1992)
Camel	3.9	7.1	10.8	18.6	6.1	3.9	3.2	3.8	
Beef	7.7	7.1	10.8	16.5	6.2	4.5	4.2	4.1	
Lamb	6.7	6.9	10.3	17.9	5.5	3.8	2.9	3.5	
Goat	4.7	7.1	10.8	15.6	5.2	3.8	3.6	5.9	
Camel	6.5	6.9	9.7	17.0	6.2	-	4.3	3.3	Al-Shabib & Abu Tarboush (2004)

[1]Amino acid: Ala - Alanine, Arg- Arginine, Asp - Aspartic acid, Glu - Glutamic acid, Gly - Glycine, Pro - Prolene, Ser - Serine, Tyr - Ttyrosine

Table 4. Fatty acids composition (%) of the *Infraspinatus* (IS), *Triceps brachii* (TB), *Longissimus thoraces* (LT), *Semitendinosus* (ST), *Semimembranosus* (SM), and *Biceps femoris* (BF) muscles of the dromedary camel (Kadim *et al*., 2013).

	Muscle						
	IS	TB	LT	ST	SM	BF	SEM[1]
Saturated fatty acid							
12:0	1.71[c]	1.42	1.13[a]	1.66	1.53	1.44	0.186
13:0	1.22	1.13	1.24	1.24	1.24	1.21	0.066
14:0	7.62	7.78	7.16	7.24	7.48	7.83	0.544
15:0	2.32	2.14	2.39	2.40	2.35	2.12	0.095
16:0	27.64	27.26	26.92	25.09	26.45	26.16	2.378
17:0	2.38	2.17	2.46	2.21	2.38	2.15	2.088
18:0	8.79	8.90	9.82	8.71	8.37	8.02	2.277
20:0	0.08	0.03	0.09	0.02	0.04	0.03	0.022
21:0	0.03	0.00	0.03	0.01	0.01	0.00	0.007
22:0	0.02	0.01	0.02	0.01	0.00	0.02	0.004
Mono-unsaturated fatty acids							
14:1	1.63	1.62	1.35	1.73	1.63	1.62	0.112
15:1	1.04	1.03	1.01	1.01	1.03	1.02	0.051
16:1	8.88	8.56	8.25	8.79	8.66	8.57	2.233
17:1	0.16	0.14	0.14	0.15	0.11	0.11	0.039
C18:1n9	25.04	26.26	26.21	26.42	26.80	26.88	2.182
Poly-unsaturated fatty acids							
C18:2n6	7.14	7.83	7.11	7.79	7.98	7.94	0.207
C18:3n3	0.64	0.43	0.59	0.62	0.54	0.54	0.122
C20:2	0.52	0.34	0.62	0.64	0.43	0.42	0.016
C20:3n6	0.33	0.23	0.34	0.43	0.42	0.41	0.009
C20:4n6	2.81	2.72	2.84	2.83	2.55	3.51	0.033
Total saturated FA (SFA)	51.81	50.84	51.26	48.59	49.85	48.98	8.942
Total unsaturated FA (USFA)	48.19	49.16	48.74	50.41	50.15	51.02	2.311
Total Mono- unsaturated FA (MUSFA)	36.75	37.61	37.24	38.10	38.23	38.20	2.174
Total Poly - unsaturated FA (PUSFA)	11.44	11.55	11.50	12.31	11.92	12.8	0.217
SFA: USFA	1.08	1.03	1.05	0.96	0.99	0.98	3.869
SFA: MUSFA	1.41	1.35	1.38	1.28	1.30	1.28	4.113
SFA: PUSFA	4.54	4.40	4.46	3.95	4.18	3.82	4.120

[1]SEM: standard error for the mean. Means on the same row with different superscripts are significantly different ($P<0.05$).

Table 5. Fatty acid composition of the fat in camel meat.

Fatty acids (%)	Rawdah *et al.* (1994)	Al-Bachir and Zeinou (2009)	Kadim *et al.* (2011)
Saturated (S)			
14:0	7.68	4.53	3.10
15:0	1.66	-	2.10
16:0	25.98	30.29	28.50
17:0	1.48	2.54	-
18:0	8.63	25.51	19.30
Monounsaturated (MUS)			
14:1	1.0	-	1.60
16:1	8.06	-	6.30
17:1	0.94	-	-
18:1	18.93	32.01	33.50
20:1	trace	-	-
Polyunsaturated (PS)			
18:2 ω 6	12.07	5.13	3.20
20:2 ω 6	0.11	-	-
18:3 ω 3	0.52	-	1.20
20:3 ω 9	0.37	-	-
20:3 ω 6	0.30	-	-
20:4 ω 6	2.84	-	1.20
22:4 ω 6	0.10	-	-
20:5 ω 3	0.32	-	-
22:5 ω 3	0.48	-	-
22:6 ω 3	0.10	-	-
P/S	0.36	-	0.11
Total saturated	51.54	-	53.00
Total MUSFA	29.90		41.40
Total PUSFA	18.55	-	5.60
ω 3/ ω 6	0.092	-	-

thoraces, *Semitendinosus*, *Semimembranosus*, and *Biceps femoris* muscles of the dromedary was studied by Kadim *et al.* (2013) (Table 5). The fatty acid composition of the six muscles was generally similar with the exception of palmitic and oleic fatty acids. The *Semitendinosus* muscle had lower palmitic acid than *Infraspintus*, *Triceps brachii*, *Longissimus thoraces* and *Semimembranosus* muscles. The *Infraspintus* muscle contained lower oleic acids than other muscles. Of the six muscles studied, palmitic acid is the most abundant saturated fatty acid in camel intramuscular fat, followed by stearic acid, and myristic acid. The main monounsaturated fatty acids in the six muscles were oleic acid followed by palmitoleic acid. The main polyunsaturated fatty acids in the muscles were linoleic acid and archidonic acid. The percentage of polyunsaturated fatty acids in camel meat (18.6%) was within the range reported for beef (8.8%) and buffalo (28.6%) and deer (31.4%) (Sinclair *et al*., 1982). The ratio of linoleic and linolenic acids in camel meat is about 10.9 which is much higher than that of the meat of cattle, sheep or goat (2.0, 2.4 and 2.8, respectively) (Sinclairb *et al*., 1982).

The camel hump is commonly used as cooking oil in camel producing countries. On a fresh weight basis, the camel hump is composed of about 64.2-84.8% fat, with a very high content of saturated fatty acids of about 63.0% (Rawdah, *et al.,* 1994; Kadim *et al.,* 2002). Researchers, therefore, focused on the composition of the hump (Mirgani, 1977; Emmanuel and Nahapetian, 1980; Abu-Tarboush and Dawood, 1993; Kadim *et al*., 2002). Palmitic acid, stearic acid and oleic acid are the most abundant fatty acids in the hump. The composition of the hump fatty acids is affected by the animal age. The highest percentage of unsaturated fatty acids and lowest percentage of saturated fatty acids were in animals of less than one year whereas an opposite trend was in animals in the 1-3 years old age group (Kadim *et al.,* 2002).

Mineral Composition

Minerals are generally classified as essential elements that are required for growth and health or toxic elements, which pose health risk to animals and humans. Both the deficiency and excess intake of essential elements as well as exceeding the safe limits of toxic elements can be detrimental to human health. Table 6 gives essential mineral contents of various cuts of camel meat by various authors.

Calcium content (mg/100g fresh weight) was reported to be in the range of 4.9- 11.48 (Table 6). The level of variation reported by Kadim *et al*. (2006; 2011), indicates that physiological factors play a major role in determining the calcium contents in camel meat. Small variations in calcium content are found among different meat cuts (Table 6). The calcium content between different meat cuts range from 10 to 27% (Dawood and Alkanhal, 1995; Rashed, 2002) Cobalt and chromium contents were in the range of 0.003-0.004 and 0.008- 0.03 (mg/100g fresh weight) (Kadim *et al.,* 2006). Copper contents in camel meat ranged between 0.04 to 0.12 mg/100g fresh weight (Table 6). The foreleg contains a higher copper content compared with other meat cuts (Rashed, 2002). The iron content in camel meat (1.16-3.39 mg/100 g fresh meat) varied among different meat cuts (Table 6) which is most probably due to the different physiological requirements of myoglobin of different muscles. As with other red meat species, meat cuts containing oxidative muscles (e.g. leg and neck) have a higher iron content than glycolytic muscles. Potassium is the major element in camel meat (193.4-379.1 mg/100g fresh weight) and magnesium content in camel meat ranges between 10.41- 21.03 mg/100g fresh weight (Kadim *et al.,* 2009). Meat cuts from the limbs have higher potassium and magnesium content compared with the loins and ribs (Table 6). Meat from Saudi Arabian camels contained similar manganese content (0.01 mg/100g fresh weight) across four different meat cuts (El-Faer *et al*., 1991; Elgasim and Alkanhal, 1992). However, meat from camels in Egypt appears to have higher manganese content (mg/ 100g dry matter) and the concentration varied among different meat cuts (Rashed, 2002). The sodium content in

Table 6. Mineral concentrations in camel meat (mg/100g fresh weight.

Factor	Mineral[1]													
	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn	
Rump	-	0.004	-	0.12	2.5	-	-	-	0.04	-	-	-	-	Badiei *et al.* (2006)
Intercostal	8.5	0.29	0.42	0.13	51.0	515	29.5	0.19	-	300.5	-	-	74.0	Rashed (2002)
Scapula	10.0	0.35	0.32	0.21	54.5	670	51.0	0.22	-	225.0	-	-	58.0	
Sirloin	10.2	0.27	0.41	0.16	44.0	446	28.0	0.16	-	188.5	-	-	66.0	
Flank	8.4	0.32	0.33	0.12	49.0	811	49.5	0.19	-	223.0	-	-	69.5	
Front knuckle	8.4	0.26	0.42	0.25	44.5	630	37.0	0.17	-	299.5	-	-	73.5	
Front limb	9.8	0.19	0.37	0.26	50.5	548	42.5	0.19	-	312.5	-	-	85.5	
Chuck	11.5	-	-	-	3.2	249	17.4	-	-	73.5	-	-	3.7	Dawood &Alkanhal (1995)
Ribeye	8.1	-	-	-	2.9	231	16.3	-	-	67.1	-	-	3.7	
leg	10.3	-	-	-	3.4	251	17.1	-	-	69.7	-	-	3.9	
Leg+loin	4.9	-	-	0.04	1.9	228	17.7	0.01	-	47.9	-	-	3.2	Elgasim &Alkanhal (1992)[2]
Shoulder	5.1	-	0.01	0.07	1.2	357	20.6	0.01	-	69.1	196	56.1	3.5	El-Faer *et al.* (1991)
Thigh	5.4	-	0.01	0.09	1.4	361	21.0	0.01	-	70.4	199	55.0	3.1	
Ribs	4.7	-	0.01	0.07	1.2	324	18.5	0.01	-	84.1	181	58.0	3.9	
Neck	5.6	-	0.03	0.09	1.4	338	18.5	0.01	-	87.3	181	64.4	4.8	
Effect of specie														
Camel	5.9	0.003	0.008	-	-	193	12.9	-	0.08	45.3	105	-	-	Kadim *et al.* (2009a)
Beef	6.2	0.003	0.009	-	-	416	20.5	-	0.006	51.0	162	-	-	
Camel	4.9	-	-	0.04	1.94	228	17.7	0.01	-	47.9	-	-	3.2	Elgasim & Alkanhal (1992)
Beef	6.97	-	-	0.06	2.66	277	24.8	0.02	-	31.2	-	-	4.1	

[1]Mineral: Ca - Calcium, Co - cobalt, Cr - Chromium, Cu - Copper, Fe - Iron, K- Potassium, Mg - magnesium, Mn - Manganese, Mo - Molybdenum, Na - Sodium, P - Phosphorus, S - Sulfate, Zn -Zinc

camel meat was in the range of 40.2-87.3 mg/100g (Table 7). The loin cuts had the lowest sodium content among the different meat cuts (Elgasim and Alkanhal, 1992; Rashed, 2002; Kadim *et al*., 2006). Phosphorus is the second most abundant element in camel meat (105.6-199.0 mg/100g fresh weight) and the leg and shoulder cuts have a slightly higher phosphorus content than ribs and neck cuts (El-Faer *et al.,* 1991). The sulfur content was in the range of 54.99-136.57 mg/100g fresh weight. The sulfur content in four meat cuts varied by 17% only (El-Faer *et al*., 1991). Red meat is an important source of zinc. Camel meat contains about 3.07 to 4.80 mg/100g fresh weight (Table 6). The variation between different cuts was 7.6% (Dawood and Alkanhal, 1995) but a higher percentage of variation (47-56%) has been reported in other studies (El-Faer *et al*., 1991; Rashed, 2002).

The mineral concentrations of *Infraspinatus*, *Triceps brachii, Longissimus thoraces*, *Semitendinosus, Semimembranosus,* and *Biceps femoris* muscles of the dromedary (Kadim *et al*., 2013) and bactrian camels (Raiymbek *et al*., 2012) are presented in Table 7. The phosphorus magnesium, sodium, potassium and iron contents of camel muscle samples varied between muscles. The *Triceps brachii* muscles and had the highest mean value of phosphorus, calcium, magnesium and potassium (Table 7). The *Semitendinosus* muscle in the dromedary and bactrian camels had more magnesium than *Infraspinatus*, *Triceps brachii, Longissimus thoracis*, and *Biceps femoris* muscles. The *Semitendinosus* and *Semimembranosus* muscles had more iron than other muscles in the dromedary. The *Longissimus thoracis* muscle had a lower and the *Triceps brachii* higher ($P<0.05$) potassium than other muscles (Table 7). For trace elements (zinc, iron, lead, selenium, copper), there was small variation between the muscles of dromedary and bactrian camels (Table 7).

Table 7. Macro and micro-element levels (mg/100g) in *Infraspinatus* (IS), *Triceps brachii* (TB), *Longissimus thoraces* (LT), *Semitendinosus* (ST), *Semimembranosus* (SM), and *Biceps femoris* (BF) muscles of the dromedary (Kadim *et al*., 2013) and bactrian camels (Raiymbek *et al*., 2012b).

	Dromedary						Bactrian					
	Muscle						Muscle					
	IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF
Phosphorus	6.49	7.76	5.23	6.39	7.96	6.79	3.32	3.72	2.29	3.97	3.66	3.74
Calcium	0.07	0.08	0.05	0.07	0.08	0.07	0.05	0.05	0.05	0.05	0.05	0.05
Magnesium	1.73	2.21	1.37	3.39	2.17	1.84	2.48	3.03	2.51	3.5	3.27	3.45
Sodium	6.33	5.98	5.18	7.38	5.78	6.93	5.01	4.57	3.59	5.78	4.93	5.16
Potassium	81.7	103	25.2	71.3	80.9	85.6	74.4	80.5	36.9	80.0	77.7	73.5
Zinc	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Iron	0.02	0.06	0.03	2.42	2.52	0.05	0.06	0.08	0.05	0.08	0.12	0.08
Lead	0.001	0.01	0.01	0.01	0.03	0.002	0.03	0.03	0.03	0.03	0.03	0.02
Selenium	0.003	0.003	0.004	0.004	0.003	0.003	-	-	-	-	-	-
Copper	0.002	0.001	0.001	0.05	0.07	0.004	0.002	0.002	0.004	0.002	0.002	0.001

[1]SEM: standard error for the mean. Means on the same row with different superscripts are significantly different (P<0.05).

The concentrations of silver, gold and nickel in five camel meats have been reported at 0.06-0.12, 0.10-0.21 and 0.05-0.38 mg/100g dry matter, respectively (Rashed, 2002). The concentration of the three minerals varied among different muscles by 100, 110 and 750% (Table 8). The concentrations of nickel, beryllium and vanadium increased in the dromedary camel *Longissimus thoracis* with increasing animal age (Kadim *et al.,* 2006). The level of lead in camel *Longissimus thoracis* was 2.5 times the concentration in beef *Longissimus thoracis* (Kadim *et al.,* 2009). Studies on the levels of trace and heavy elements in camel blood concluded that camels could be less efficient than other ruminants in detoxifying these elements in its body (Al-Qarawi and Ali, 2003).The monitoring of toxic material levels in camel products should pay particular attention to toxic compounds in the offal because this is consumed by low income people as a source of animal protein (Faye *et al.,* 2008).

Nutrition, management, breed, sex and age of animals play an important role in determining the level of various elements in the meat and the camel blood (Faye *et al*., 2008). For instance, the calcium content in the camel

Table 8. Toxic/non-essential elements concentrations (mg/100g) of fresh weight.

	Mineral[1]							
Factor	Ag	Al	Au	Cd	Ni	Pb	Sr	
Effect of meat cut								
Intercostal	0.07	-	0.11	-	0.24	-	-	Rashed (2002)
Scapula	0.06	-	0.10	-	0.38	-	-	
Sirloin	0.11	-	0.19	-	0.05	-	-	
Flank	0.09	-	0.12	-	0.13	-	-	
Front knuckle	0.12	-	0.17	-	0.19	-	-	
Front limb	0.11	-	0.21	-	0.21	-	-	
Shoulder	-	0.51	-	-	-	-	0.02	El-Faer *et al.* (1991)
Thigh	-	0.15	-	-	-	-	0.03	
Ribs	-	0.12	-	-	-	-	0.02	
Neck	-	0.58	-	-	-	-	0.03	
Effect of specie								
Camel	-	-	-	0.003	0.025	0.015	-	Kadim *et al.* (2009b)
Beef	-	-	-	0.003	0.044	0.006	-	

[1]Mineral: Ag - Silver, Al - Aluminum, Au - gold, CD - cadmium - Ni - nickel, Pb - Lead, Sr - Strontium

Table 9. Effect of age on some meat quality characteristics of the dromedary camel *Longissimus thoracis* muscle.

	Kadim *et al.* (2006)			Kadim *et al.* (2009b)	
	Age group (yr)			Age group (yr)	
	1-3	3-5	5-8	1-2	8-10
Ultimate pH	5.91	5.84	5.71	5.68	5.65
WB- Shear force value (Newton)	68.4	79.5	131.9	66.1	87.3
Sarcomere length (μm)	1.85	1.24	1.06	1.66	1.60
Myofibrillar fragmentation Index (%)	80.99	73.3	60.4	72.2	67.3
Expressed juice (cm^2/g)	29.6	27.36	21.26	38.1	37.4
Cooking loss (%)	26.06	23.72	22.42	23.4	22.0
Colour parameters					
*L** (lightness	37.74	34.03	31.69	39.1	38.1
*a** (redness	13.37	13.82	16.18	16.5	15.6
*b** (yellowness)	6.09	6.78	7.26	5.58	6.29

meat reported from the same laboratory (Kadim *et al*., 2006; 2011) or across different laboratories (Dawood and Alkanhal, 1995; Kadim *et al.,* 2006) supports this contention. It is worth mentioning that the biological variation of elements even within the same herd that has a similar farming background is very high (Kadim *et al.,* 2006).

Meat Quality Characteristics

Camel meat is often regarded as inferior to other meats. This might be attributed to the strong reluctance of camel owners to sell their young stock, and they usually slaughter older camels at the end of their productive life. Most camel meat trade is of meat from old camels with a low quality, which has a direct bearing on the extent of demand for meat outside the camel herding societies. However, numerous studies have reported that meat quality characteristics from young dromedary camels are comparable to those of beef (Leupold, 1968; Fischer, 1975; Knoess, 1977; Mukasa-Mugerwa, 1981; Kadim *et al.,* 2006, 2009; Shariatmadari and Kadivar, 2006). Nevertheless, camel meat had a significantly lower level of sarcoplasmic proteins as a proportion of total proteins than beef (Babiker and Tibin, 1986).

Camels 2-4 years-old and beef 2-3 years-old had similar meat quality characteristics of the *Longissimus thoracis* muscle (Kadim and Mahgoub, 2008). The camel *Longissimus thoracis*, *Semitendinosus* and *Triceps brachii* muscles lose more water during cooking than beef (48% vs. 37%) while no tenderness differences were observed between the two species (Kamoun, 1995a,b). In contrast, Babiker and Tibin (1986) reported that camel meat has less cooking losses and higher water holding capacity than beef meat. The effect of age on meat quality is discussed in order to optimize the best age for slaughtering camel for high quality meat. Table 9 depicts the effect of camel age on meat quality parameters and shows that meat becomes less tender and of inferior quality with increasing animal age (Kadim *et al.,* 2006). However, Kamoun (1995a,b) noted that age is not a predominant factor in meat quality, in the case of dromedarius fed the same diet and slaughtered between one and four years of age. Kadim *et al.* (2006) suggested that the male camels should be slaughtered between one to three years of age. This is in agreement with the conclusion of Dina and Klintegerg (1977). At this age the animals were not yet fully grown, averaging about 60-70% of full live weight, and therefore, their meat is tender.

Meat quality parameters of *Longissimus thoracis* and *Biceps femoris* muscles inf our Indian camel breeds was compared by Suliman *et al*. (2011), and the results indicated little variation between the four breeds (Table 10). The shear force values in *Longissimus thoracis* muscles ranged from 6.45 kg in Magahem to 14.32 kg in Shoal, while in *Biceps fermoris* muscles the ranges were between 19.44 kg for Wodoh to 23.3 for Shoal. On the other hand, various breeds exhibited a similar myofibrillar fragmentation index, ultimate pH and sarcomere length for both *Longissimus thoracis* and *Biceps femoris* (Table 10). Muscles of the loin region were tenderer than those from the leg.

The eating quality of six muscles of the dromedary camel was studied by Kamoun (1995b) who concluded that the *Vastuslateralis* muscles had the highest weight and volume losses (51.1 and 47.8%, respectively) whereas *Psoas major* muscles had the lowest (44.6 and 41.1%, respectively) (Table 11). The *Triceps brachii* and *Vastuslateralis* muscles contained more soluble collagen than *Semitendinosus, Psoas major*, *Longissimus thoracis* and *Semimembranosus* muscles, possibly indicating a less thermal stable bond between collagen molecules and weaker connective tissue structures of those muscles (Kamoun, 1995b). Although all six muscles studied by Kamoun (1995b) were ranked acceptable for tenderness, the *Longissimus thoracis* muscle was tenderer and had less detectable connective tissue than the other muscles. The *Longissimus thoracis* muscle had the highest juiciness score and the *Semitendinosus* and *Vastuslateralis* muscles were less juicy than *Psoas major*, *Semimembranosus* and *Triceps brachii* muscles.

Ultimate Muscle pH

The ultimate pH of muscles is a consequence of lactic acid accumulation via glycolysis that affects meat quality characteristics (Simek *et al.*, 2003). According to Laack *et al.* (2001), 40-50% of variation in ultimate pH is determined by glycogen concentration. It needs 0.81g/100g of glycogen to lower the pH of one kg of muscle from 7.2

Table 10. Effect of Camel breed on some meat quality characteristics of the dromedary camel *Longissimus thoracis* and *Biceps femoris* muscles (Suliman, *et al.*, 2011).

	Breed							
	Magahem		Wodoh		Shoal		Sofor	
	Muscle[1]		Muscle[1]		Muscle[1]		Muscle[1]	
	LT	BF	LT	BF	LT	BF	LT	BF
Ultimate pH	5.76	5.90	5.87	5.90	5.91	5.82	6.07	6.03
WB- Shear force value (kg)	6.45	23.32	13.73	19.44	14.32	23.25	10.40	22.77
Sarcomere length (μm)	1.69	1.68	1.68	1.66	1.64	1.69	1.65	1.67
Myofibrillar fragmentation index (%)	71.6	62.4	66.2	60.9	65.4	63.0	67.0	61.2
Cooking loss (%)	23.7	28.3	21.9	26.0	22.9	31.2	22.4	28.7
Colour parameters								
*L** (lightness)	31.6	30.0	33.4	28.1	31.6	31.2	31.2	29.7
*a** (redness)	11.8	13.3	13.0	13.6	12.8	13.4	15.0	13.1
*b** (yellowness)	4.03	4.07	4.74	3.91	4.43	4.26	4.85	3.91

[1]Muscle: LT - *Longissimus thoraces*, BF - *Biceps femoris.*

to 5.5 (Warris, 1990). The ultimate pH of camel muscles is the result of a combination of many factors including pre-slaughter handling, postmortem treatment, glycogen storage and muscle physiology. Low muscle glycogen stores at slaughter prevents the development of a desirable pH postmortem (Ashmore *et al.,* 1973). A high ultimate pH in camel muscles is a consequence of low muscle glycogen as a result of pre-slaughter stress, including, poor nutrition, rough handling and long transportation. The ultimate pH has an effect on several meat properties like colour, tenderness, water-holding capacity, flavor, and drip loss all of which influences consumer acceptance of camel meat. Glycogen degradation speed differs between "red" and "white" muscles. Red muscles have many red fibres, which contract slowly, have an oxidative metabolism and a low concentration of glycogen. White muscles contract rapidly and have a high concentration of glycogen, normally with a glucolytic metabolism and an active degradation to lactic acid (Lawrie, 2006).

Table 11. Eating quality attributes of the six major muscles (Kamoun, 1995b).

Parameter	Muscle[1]					
	PM	LT	SM	ST	VL	TB
Myoglobin (mg/g)	3.9	4.1	5.8	3.4	4.1	5.1
Collagen (mg/g)	3.3	4.1	5.0	7.5	6.6	5.6
Sensory tenderness	7.2	6.6	3.7	3.6	1.9	3.9
Collagen soluble (%)	29	29	30	34	42	41
Sensory juiciness	6.2	6.8	5.2	3.8	4.1	5.8
Cooking weight loss (%)	45	45	49	48	51	51
Cooking volume loss (%)	41	42	46	44	48	45

[1]Muscle: PM - *Psoas major,* LT - *Longissimus thoracis*, SM - *Semimembranosus*, ST - *Semitendinosus*, VL - *Vastus lateralis,* TB - *Triceps brachii.*

The ultimate pH of dromedary camel meat ranges between 5.5 and 6.6 (Babiker and Yousif, 1990; Kadim *et al.*, 2006, 2009a,b, 2010, 2013). Generally, young camels tend to produce meat with a higher pH than older camels due to lower levels of glycogen. In this respect, Kadim *et al.* (2006) found that camels younger than three years had a pH value (5.91) which was higher than camels older than six years (5.71). The ultimate pH of *Longissimus thoracis* muscles varied between 5.53 and 5.75 and between 5.68 and 5.80 for electrically stimulated and non-stimulated camel carcasses, respectively (Kadim *et al.,* 2009a). The breed of camels did not differ in terms of ultimate pH in *Longissimus thoracis* and *Biceps femoris* muscles (Suliman *et al.,* 2011).

Tenderness (Shear Force Value)

Tenderness is the most important organoleptic characteristic and is the predominant quality determinant of meat compared to flavor and colour (Koohmaraie, 1988). Muscle characteristics, glycogen content, collagen content, solubility, and the activities of proteases and their inhibitors are the most important physiological parameters that determine meat tenderness (Hocquette *et al.,* 2005). Major variation in meat tenderness is related to the variability of muscle characteristics (Renand *et al.*, 2001). The *Longissimus thoracis* muscle had more soluble collagen than the *Semitendinosus* and *Triceps brachii* muscles (Kamoun *et al.,* 1995b). The *Triceps brachii* muscle had the highest shear force values, maximum connective tissue strength and lowest collagen solubility compared to *Longissimus thoracis, Semitendinosus*, *Semimembranosus, Psoas major* and *Vastuslateralis* in camels, indicating that it is the toughest muscle in this group (Babiker and Youssif, 1990) The *Psoas major* and *Longissimus thoracis* muscles were the most tender and had less detectable connective tissue than other muscles. In another study, Kadim *et al*. (2013) found that *Infraspinatus, Triceps brachii* and *Longissimus thoracis* camel muscles had lower shear force values than *semitendinosus, semimembranosus* and *biceps femoris* muscles, which might be due to less connective tissue (Table 12).

Raiymbek *et al.* (2012) reported a similar observation for bactrian camel muscles (Table 12). The tenderization process starts after slaughter and it varies among individual carcasses and depends on the postmortem activity of the calpainproteolytic enzymes that include calpastatin (Parr *et al.,* 1999). The most marked difference in meat quality characteristics between camel meat and other livestock is largely believed to be tenderness (Mukasa-Mugerwa, 1981). Camels are usually slaughtered at the end of their productive life (more than10 years) which is classified as of low quality compared with meant from other animals. Average shear force value of camel meat at 5-8 years was 48% and 40% higher than those of 1-3 and 3-5 year olds, respectively (Kadim *et al.*, 2006). A number of studies have also shown that shear values of meat increase with increasing camel age (Dawood, 1995; Kadim *et al.,* 2006). Differences due to age may be related to changes in muscle structure and composition as an animal matures, particularly in the nature and quantity of connective tissue (Asghar and Pearson, 1980), Significant differences (P<0.05) were found between the different ages (8, 16 and 26 months of age) and cuts (chuck, ribeye and leg) for shear force values of male Nahdi camels (Dawood, 1995).

Aging

Historically, meat has been aged to improve its quality characteristics because meat is often unacceptably tough immediately following rigor onset. Ageing is the process that causes an improvement in tenderness, flavour, colour and texture over time and involves specific degradation of structural proteins (Hwang *et al.,* 2003; Jaturasitha *et al.*, 2004). The time required for ageing varies with the type, size, species, and age of the animal. Moderate temperature

Table 12. Meat quality characteristics of six muscles of the dromedary and bactrian camel carcasses.

	References											
	Kadim *et al.* (2013)						Raiymbek *et al.* (2012)					
	Muscle[1]						Muscle[1]					
	IS	TB	LT	ST	SM	BF	IS	TB	LT	ST	SM	BF
Age (yr)	1.5-2						2-3					
Ultimate pH	5.64	5.73	5.61	5.67	5.83	5.74	5.73	5.69	5.63	5.68	5.60	5.68
WB-Shear Force	34.8	42.1	41.8	36.8	42.4	40.2	10.8	8.9	6.0	10.0	9.8	8.6
Sarcomere length (µm)	31.6	29.2	33.5	28.5	30.6	29.5	1.45	1.54	1.70	1.47	1.53	1.52
Myofibrillar fragmentation index (%)	6.3	6.7	6.5	9.0	12.9	10.3	76.8	76.9	73.9	77.7	76.7	78.4
Water-holding capacity	1.7	1.7	1.7	1.5	1.4	1.5	38.2	37.9	37.1	40.4	41.3	38.8
Cooking loss (%)	31.6	29.2	33.5	28.5	30.6	29.5	32.7	32.6	25.1	34.3	33.9	32.1
Colour												
*L**	41.7	40.2	43.5	40.5	40.6	40.6	32.4	30.8	33.4	30.2	30.8	30.1
*a**	12.7	12.6	14.0	10.5	13.6	13.3	13.2	13.1	13.8	12.8	13.8	13.5
*b**	2.6	3.7	4.1	2.2	2.9	3.8	3.8	3.4	3.9	3.2	3.5	3.6

[1]Muscle: IS - *Infraspintus*, TB - *Triceps brachii*, LT - *Longissimus thoracis*, ST - S*emitendinosus*, SM - *Semimembranosus*, BF - *Biceps femoris.*

Table 13. Effects of age and ageing on meat quality attributes of *Longissimus thoracis* of dromedary camel (Kadim *et al.,* 2009a).

	Age (year)							
	1-3		4-6		7-9		10-12	
	Ageing 7-day	Ageing 2-day	Ageing 7-day	Ageing 2-day	Ageing 7-day	Ageing 2-day	Ageing 7-day	Ageing 2-day
Ultimate pH	5.86	5.85	5.79	5.78	5.71	5.71	5.60	5.61
Expressed juice (cm2/g)	38.6	37.2	37.2	36.6	30.8	30.3	21.3	21.1
Cooking loss (%)	25.7	25.0	23.9	22.7	21.3	19.8	18.9	17.8
WB-shear force (kg)	7.28	8.10	8.41	8.97	9.14	9.76	11.29	12.79
Sarcomere length (μm)	1.73	1.47	1.65	1.67	1.48	1.47	1.39	1.37
Myofibrillar fragmentation index	77.9	73.5	71.6	69.8	66.9	64.5	62.7	60.2
Lightness (L*)	40.5	39.80	38.71	36.86	35.31	33.72	30.15	28.47
Redness (a*)	15.6	15.7	16.9	16.1	18.2	19.0	19.9	19.5
Yellowness (b*)	5.40	5.51	6.04	6.03	7.03	7.05	7.93	7.98

storage may accelerate the ageing process by keeping carcasses at temperatures of 15^{o}C or greater (Petrovic *et al.,* 1993). The ageing processes originate within the myofibers and are responsible for degradation of cellular constituents. This resembles the method adopted by Kadim et al. (2009a), where camel *Longissimus thoracis* muscles were stored at a temperature of 2-3^{o}C for seven days. Ageing at 2-3^{o}C for 7-days improved camel meat quality characteristics (Table 13). This implies that ageing may be one of the postmortem treatments which increase camel meat tenderness that might be adopted in the camel meat industry. According to Lagerstedt *et al.,* 2008), increasing ageing time from four to seven days may cause more cooking losses in beef meat. However, Kadim *et al.* (2009a) found no differences in cooking loss with ageing of camel *Longissimus thoracis* muscles from two to seven days. The level of improvement in tenderness within a certain ageing time varies among different meat cuts, ages of the animal and species due to differences in the level of endogenous enzymes, contraction status and connective tissue content (George-Evins *et al.,* 2004). In general, ageing can improve quality characteristics of meats that have relatively small amounts of connective tissue and that have not cold-shortened (Wheeler *et al.,* 1999).

Myofibrillarfragmentation Index

The myofibrillar fragmentation index is a useful indicator of the extent of myofibrillar protein degradation of post-slaughter camel meat (Kadim *et al.*, 2006, 2009a,b, 2011, 2013; Raiymbek *et al.,* 2012). The differences in rates of fragmentation of myofibrillar proteins may account for differences in the rate of postmortem tenderization of meat (Nagaraj *et al*., 2005). The structural changes occurring in muscle tissue after slaughter are generally believed to be caused by alterations in and interactions of myofibrillar proteins in the tissue (Nagaraj *et al.*, 2006). Claeys *et al.* (1994) reported that at a higher pH, proteins preferentially solublized were titin, filamin, nebulinand myosin heavy chain. Except for myosin, all are preferentially degraded by calpains, which has an optimum effect atpH values near neutrality. Similarly, Silva *et al.* (1999) verified that the myofibrillar fragmentation index in meat was significantly higher at ultimate pH 6.5 than at 5.7. There is a correlation between the myofibrillar fragmentation index and the tenderness of meat (Veiseth*et al.*, 2001). The myofibrillar fragmentation index of camels above 6 years was lower than those of 1-3 years of age (Kadim *et al.*, 2008, 2009a). The same authors established a strong relationship between physical disruptions of the myofibrils and the tenderness of camel meat.

Water Holding Capacity (Expressed Juice)

Water retention in meat is primarily caused by immobilization of water within the myofibrillar system. Applying pressure can cause a shift of water from the intercellar to the extracellular space and then onto the meat surface as a result of structural alterations at the level of the sarcomeres or of the myofilaments structure. Water retention affects the retention of minerals, vitamins and volume of water (Beriain *et al.,* 2000) and is influenced by muscle pH because of the electrostatic effects of meat proteins (Hamm, 1975). The dromedary and bactrian camel meats contain higher expressed juice than other camelidae such as llama and alpaca, possibly because of the lower fat content (Cristofaneli *et al.,* 2004). The amount of water loss was likely due to the ultimate pH of the muscle, composition of muscle and denaturation of proteins by the ionic strength of the extracellular fluid and oxidation of lipids which decreases the solubility of proteins (Dyer and Dingle, 1967). Kadim *et al.* (2006) reported that meat from camels slaughtered at one to three years had higher water-holding capacity values than those slaughtered at five to eight years of age, probably due to variations in fat content and the binding ability of meat proteins (Table 9). The water-holding capacity decreases as fat levels increase due to an increase in the ratio of moisture to fat (Miller *et al.,* 1968). Dawood (1995) reported that young camel meat (eight months of age) had significantly higher water-holding capacities than meat from 26 month-old camels.

The volume of the dromedary camel meat was reduced by 44.3% and weight by 48.2% after being boiled in water for 40 min (Kamoun, 1995b). The *Longissimus thoracis* and *Biceps femoris* muscles from mature camels had 37.9 and 37.1% cooking loss which was higher than the 33.2 % cooking loss in *Semitendinosus* muscle, which coincided with its high water-holding capacity (Babiker and Yousif, 1990). A higher cooking loss was observed in the *Longissimus thoraces* muscle (33.5%) when compared to the *Infraspinatus* (31.6%), *Triceps brachii* (29.2%), *Semitendinosus* (28.5%), *Semimembranosus* (30.6%) *Biceps femoris* (29.5%) with no significant differences between the last five muscles (Kadim *et al.,* 2013). In the bactrian camel (Table 12), variation in expressed juice between *Infraspinatus*, *Triceps brachii*, *Longissimus thoracis*, S*emitendinosus*, *Semimembranosus*, and *Biceps femoris* muscles ranged from 37.10cm^2/g (*Longissimus thoraces*) to 41.27cm^2/g (S*emimembranosus)* cm^2/g (Raiymbek *et al.*, 2012a). The variation between muscles might be due to location, activity, proportion of muscle fiber types, pH, intramuscular fat and the ratio of water to protein of individual muscles. However, Suliman *et al.* (2011) found that *Biceps femoris* muscles had a higher cooking loss than *Longissimus thoraces* muscles in four different camel breeds. According to Shehata (2005), young camels (10-12 months old) had a higher cooking loss than old animals. *Longissimus thoracis* from two to three year old camels had significantly lower cooking loss (24.3%) than the values mentioned above (Kadim *et al.,* 2009a,b). The cooking loss of camel *longissimus thoracis* was not different from that in cattle *Longissimus thoracis* of the same age. Cooking loss is important because of its potential to change the level of nutrients in the meat once it is cooked. For example, while it generally regarded that the protein content of camel meat is similar to other red meats (Elgasim and Alkanhal, 1992; Gheisari *et al.,* 2009), the higher cooking loss in camel meat (33-38%), compared to beef (24.6%), will generate a more nutritionally dense cooked meat (Kadim *et al.,* 2009).

Colour (L, a*, b*)*

Meat colour is one of the most important sensory characteristics according to which consumers make judgments on meat quality. The degree of meat pigmentation is directly related to the chemical structure of myoglobin content. Myoglobin concentration within a given muscle will differ according to the species or age and is dependent on muscle fibre type proportions, muscle pH, age, intramuscular fat, and muscle texture (Gardner *et al.,* 1999; Lawrie, 2006). There was a negative linear relationship between colour values and pH in *Longissimus thoracis* muscles (Menzies and Hopkines, 1996). Postmortem protein degradation is directly related to the ultimate pH, which increases light scattering properties of meat and thereby increases L^* value (Offer, 1991). Low ultimate pH meat samples might lead to more protein degradation resulting in higher colour values than the high ultimate pH meat samples. Abril *et al.* (2001) reported that reflectance spectrum value for meat samples was higher for an ultimate pH above 6. Postmortem glycolysis decreases muscle pH making muscle surfaces brighter and superficially wet. If the ultimate meat pH is high, the physical state of the proteins will be above their iso-electric point, and the proteins will associate with more water in the muscle and therefore, fibers will be more tightly packed (Abril *et al.*, 2001). Babiker and Yousif (1990) reported that dromedary camel *Longissimus dorsi* muscles had higher lightness (L^*), redness (a^*) and yellowness (b^*) values than S*emitendinosus* and *Triceps brachii* muscles. Suliman *et al.* (2011) found that the colour of the *Biceps femoris* muscle was not affected by breed of camels. A high redness (a^*) colour component in the camel *Longissimus thoracis* muscle was associated with a lower lightness (L^*), which might be due to an increase in myoglobin content. Camel muscle lightness L^* values indicated that the *Longissimus thoraces* muscle (43.5) had the lightest ($P<0.05$) lean colour, which was possibly due to high fat content (Kadim *et al.,* 2013). The *Semitendinosus* muscle had the darkest coloured lean compared to *Infraspinatus, Longissimus thoraces*, *Triceps brachii, Semimembranosus*, and *Biceps femoris* camel muscles. The *Longissimus thoraces, semimembranosus* and *biceps femoris* dromedary camel muscles had higher redness (a^*) values than the *Semitendinosus* muscle, while a* value for *Infraspinatus* and *Triceps brachii* muscles were in between. CIE a* values were similar among *Longissimus thoraces, Semimembranosus* and *Biceps femoris* muscles (Kadim *et al.,* 2013). In camels, the highest average yellowness (b^*) value was recorded in the *Longissimus thoraces* muscle with comparable values to the *Triceps brachii* and *Biceps femoris* muscles.

In bactrian camel, the *Longissimus thoraces* muscle had higher lightness (L^*) values and *Infraspinatus* han *Triceps brachii*, *Semitendinosus*, *Semimembranosus* and *Biceps femoris* muscles (Raiymbek *et al.,* 2012a). The age of the camels has a significant effect on their meat colour (Kadim *et al.*, 2006). Meat colour from 6-8 and 10-12 year old dromedary camels was darker (lower L^*), redder (higher a^*) and yellower (high b^*) than 1-3 year old camels because of higher concentrations of myoglobin (Kadim *et al.,* 2006).

Health Aspects of Camel Meat

Meat is a valuable source of food rich in many essential amino acids, minerals, vitamins and bioactive compounds such as carnosine, anserine, glutathione and essential fatty acids such as Omega 3 fatty acids (Williams, 2007; Schonfeldt and Gibson, 2008). Apart from the nutritional value of meat, it provides several eating attributes and fulfilling experiences that normally are not achieved by other protein sources. Beef, lamb, pork, poultry and fish are considered the major sources of animal protein worldwide. However, in Africa, the Middle East and some Asian countries, especially in arid and semi-arid regions, camel meat is regarded as a main source of animal protein that equals and in some cases surpasses other meats in commercial importance.

Several epidemiological studies linked health problems such as obesity and high saturated fat and cholesterol intake to increased consumption of animal products (Biesalski, 2005; Chao *et al.,* 2005). This has led to a concern that total dietary fat intake should be restricted by consuming smaller portions less frequently (Schonfeldt and Gibson, 2008) or replacing red meat consumption with white meat. The low cholesterol and fat contents in camel meat could potentially be considered as a better alternative to the higher fat and cholesterol contents of mutton and beef.

Camel Meat as Medicine

Meat in general is considered a functional food for cures of many ailments and for improved performance in many cultures around the world (Migdal and Živkovic, 2007). Camel meat and offals such as liver are believed to have medicinal properties and are eaten raw (Bin Saeed *et al*., 2005). Kadim *et al.* (2008) stated that Somalis and Indians particularly believe in the health benefits of consuming camel meat. Among many African and Asian countries, camel meat has traditionally been used to cure the following ailments: (1) seasonal fever, sciatica and shoulder pain, as well as for removing freckles (by placing hot camel meat slices on the freckled area); (2) camel meat soup was used to cure corneal opacity and to strengthen eyesight; (3) camel fat was used to ease hemorrhoidal pains and the hump fat was used to remove tapeworm; and (4) dried camel lungs used to be prescribed as a cure for asthma, especially if taken with honey. Kurtu (2004) reported that the majority of camel meat consumers believe it is a healthier option during the dry season in which cattle are infected with various zoonotic diseases. This belief probably originated from the historical use of animals' organs, including meat, in folklore and traditional medicine. Lev (2006) cited the use of camel meat in remedial formulation by Al-Tabari, Al-Kindi and Al-Qazwini which indicate the roots of some of the current beliefs.

The camel is distinguished from other animals by the fact that the percentage of its intramuscular fat declines as the animal gets older. This quality, only found in camels, makes their meat less fatty, so its consumption is healthy and recommended for weight loss. And this quality also reduces the risk of cardiovascular disease and atherosclerosis since it lowers the percentage of cholesterol in the blood. Camel meat has other medical qualities, too, such as protecting against cancerous tumors, as claimed by some researchers, because it contains unsaturated fatty acids like linoleic acid which interact with other unsaturated fatty acids taken from vegetable oils to protect against cancer. Camel meat can also be used as a cure for exhaustion and fatigue because it contains energy needed by body cells. Such energy comprises sugar not fat, since, a camel's fat is concentrated in its hump whereas other animals store it in their muscles. In addition, camel meat contains glycogen, a carbohydrate which is easily absorbed and metabolized in the body, and which is converted to glucose which in turn activates nerve as well as other cells.

Conclusion

The nutritional value of dromedary and bactrian camel meat is similar to other red meats. However, meat from young camels can be considered as a healthy option due to its low fat and cholesterol contents. The quality characteristics of camel meat are similar to beef meat quality when they are slaughtered at similar ages. According to the composition and quality parameters of camel meat, it can be successfully marketed alongside that from cattle, deer, sheep and goat. Pre- and post mortem factors should be carefully considered to improve meat quality characteristics.

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