Food Chemistry 52 (1995) 115–122

0308-8146/95/$9.50

ELSEVIER

Milk composition of Majaheim, Wadah and Hamra camels in Saudi Arabia

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(Received 1 January 1994; revised version received and accepted 16 March 1994)

The chemical composition and nitrogen distribution of camel milk from three ecotype (Majaheim, Wadah and Hamra) camels, in the central region of Saudi Arabia, were studied. The average results for pH, and percentage acidity, total solids, fat, protein, lactose and ash for Majaheim were 6·63, 0·144, 11·35, 3·22, 2·91, 4·43 and 0·79, for Wadah they were 6·65, 0·14, 10·07, 2·46, 2·36, 4·44 and 0·81, and for Hamra they were 6·65, 0·137, 10·63, 2·85, 2·52, 4·46 and 0·80, respectively. The mean values (mg/100 ml) for nonprotein N (NPN), protein N, casein N and whey protein N for Majaheim were 44·6, 411, 300 and 112; for Wadah they were 38·1, 331, 244 and 87·6 and for Hamra they were 40·4, 354, 255 and 99·4, respectively.

With respect to mineral contents, the levels of Ca, Mg, P, Na and K of Majaheim, Wadah and Hamra camel milks were 120, 109 and 119, 13·0,12·4, and 11·6; 88·6, 83·5 and 90·1; 65·0, 73·4 and 64·6, and 135, 172 and 124 mg/100 g, respectively. However, the contents of Cu, Fe, Mn and Zn of Majaheim, Wadah and Hamra camel milk were similar, with some individual variations.

INTRODUCTION

The total population of camels in the world is about 19 million of which 14 million are in Africa and the Near East and 4·9 million in Asia (FAO/WHO/OIE, 1992). The vast majority of camels are dromedaries (*Camelus dromedarius*; one-humped camel) and are found particularly in desert (arid) areas, whereas bactrians (*Camelus bactrianus*; two-humped camel) are more prevalent in the cooler areas (Chapman, 1991). The one-humped camel was domesticated about 3000 BC in Arabia (Bulliet, 1975). The population of camels in Saudi Arabia is estimated to be 600 000 and they are all dromedaries (Chapman, 1991). Camels in Saudi Arabia play a major role in supplying the desert dwellers with milk of high nutritional quality and meat under extremely hostile conditions of temperature, drought and lack of pasture (Yagil & Etzion, 1980). Moreover, camel milk has been suggested to have a relatively high content of vitamin C (Rao *et al.*, 1970; Knoess, 1977; Mehaia, 1994).

Most camel milk produced in Saudi Arabia was traditionally consumed fresh, as raw milk, or when soured. Recently, however, camel milk is gaining more popularity, and several commercial farms are being established to supply fresh pasteurized milk to consumers.

Indigenous camels in Saudi Arabia can be classified into different ecotypes: Majaheim or Malha, Wadah, Hamra, Safrah and Omani among others (Bhattacharya, 1988; Saoud *et al.*, 1988; Elamin & Wilcox, 1992). Majaheim are camels of central Arabia, with some spread eastward. They are large, are blackish-brown in colour, and are considered to be the best local variety available for milk production. Wadah are restricted to the western part of the country and are also found in the central and northern part of the country. They are small and white in colour and they produce small amounts of milk. Hamra are fawn-coloured camels found in small numbers in central and northern parts of the country. Safrah are camels of the northern part of the country. They are brownish-yellow in colour and have small heads and large abdomens. Omani are light weight and are used mainly for riding; at present, they are bred for racing. However, Saoud *et al.* (1988) reported that the average milk yields of Majaheim, Safrah, Wadah and Hamra camels were 3896, 2336, 2236 and 1857 kg per lactation, respectively.

Although the composition of camel milk has been studied in various parts of the world (Ohri & Joshi, 1961; El-Bahay, 1962; Rao *et al.*, 1970; Knoess, 1977; Yagil & Etzion, 1980; Sohail, 1983; Khanna, 1986; Yagil, 1987) including Saudi Arabia (Sawaya *et al.*, 1984; Abu-Lehia, 1987; Mehaia & Al-Kanhal, 1989; Elamin & Wilcox, 1992), there is limited information on the chemical composition, nitrogen distribution and mineral contents of camel milk produced from different ecotype camels in Saudi Arabia.

The present investigation was undertaken to study the gross composition, nitrogen distribution and mineral contents of Majaheim, Wadah and Hamra camel milks in the central region of Saudi Arabia (Qassim area). The information complements existing data and provides background information for the nutritional quality of milk from different ecotype camels.

MATERIALS AND METHODS

Milk samples

Milk samples were taken from each female dromedary Majaheim, Wadah or Hamra camel at the morning milking. All camels were in good health and in midlactation (2nd to 5th month of lactation). Samples were collected from eight camels of each ecotype (Majaheim, Wadah and Hamra), from Mansour Al-Hawas farm, Al-Methneb in the central region (Qassim area) of Saudi Arabia. Each sample represented an individual camel in each ecotype. The samples collected were immediately refrigerated and transferred to the laboratory. The feeding regime was approximately the same for all camels in the farm: alfalfa, hay, grass and grain concentrate. Samples were taken three times and the data were from two analyses of each individual sample. For comparison, bulk cow milk of Friesian breed, obtained from the University Farm, was used.

Proximate analysis

Samples were analysed for total solids, fat, ash and titratable acidity according to procedures outlined in AOAC (1980). The pH was measured with an Orion pH meter (Orion Research Cambridge, MA, USA). Lactose was determined by difference.

Determination of protein fraction

Nitrogen was determined by the standard micro-Kjeldahl method of the AOAC (1980). A nitrogen conversion factor of 6·38 was used for calculation of protein contents of milk samples and various fractions. Milk samples were fractionated for total nitrogen (TN) and noncasein nitrogen (NCN) by the method of Rowland (1938). The NPN was determined on the supernatants as outlined by Cerbulis & Farrell (1975). Nitrogen fractions were calculated as follows: protein nitrogen (PN) = TN–NPN, casein nitrogen (CN) = TN–NCN, and whey protein nitrogen (WPN) = NCN–NPN.

Mineral analyses

For the determination of mineral elements the ash was dissolved in 2% HCl. The final diluted solution for calcium and magnesium determination contained 1% lanthanum to overcome phosphate interference. All minerals except phosphorus were determined with a Pye Unicam atomic absorption spectrophotometer. Phosphorus was determined spectrophotometrically using the procedure of Watanabe & Olson (1965). All chemicals are of reagent grade.

RESULTS AND DISCUSSION

Chemical composition

The chemical composition of milk samples from Majaheim, Wadah and Hamra camels and the corresponding values for cow's milk are presented in Table 1. Although the number of samples which have been available to this study were quite small, the data obtained showed a wide range of variation in the chemical composition between different camel milk samples. Individuality is considered to be a significant genetic factor affecting the milk composition (Jenness & Patton, 1959), especially under noncontrolled environmental conditions, as is mostly the case locally.

Majaheim camel milk exhibited the highest fat, pro-

Table 1. Chemical composition of milks from Majaheim, Wadah and Hamra camels and Friesian cows of Saudi Arabia. Results presented as mean ± standard deviation (range given in parentheses)

Component	Camel			Cow
	Majaheim	Wadah	Hamra	
pH	6·63 ± 0·027 (6·61–6·68)	6·65 ± 0·035 (6·61–6·68)	6·65 ± 0·032 (6·61–6·68)	6·63 ± 0·01
Acidity (%)	0·144 ± 0·005 (0·14–0·15)	0·14 ± 0·008 (0·13–0·15)	0·137 ± 0·008 (0·13–0·15)	0·16 ± 0·01
Fat (%)	3·22 ± 0·37 (2·65–3·70)	2·46 ± 0·20 (2·12–2·71)	2·85 ± 0·26 (2·61–3·26)	3·41 ± 0·15
Protein (%)	2·91 ± 0·23 (2·52–3·21)	2·36 ± 0·13 (2·20–2·54)	2·52 ± 0·19 (2·31–2·75)	3·29 ± 0·10
Lactose (%)	4·43 ± 0·13 (4·25–4·60)	4·44 ± 0·15 (4·35–4·60)	4·46 ± 0·10 (4·38–4·61)	4·90 ± 0·10
Ash (%)	0·79 ± 0·013 (0·77–0·81)	0·81 ± 0·013 (0·79–0·83)	0·80 ± 0·016 (0·78–0·82)	0·73 ± 0·02
TS[a] (%)	11·35 ± 0·71 (10·23–12·22)	10·07 ± 0·35 (9·55–10·49)	10·63 ± 0·42 (10·19–11·25)	12·33 ± 0·21

[a]Total solids.

tein and total solids contents, while Wadah camel milk had the lowest values. On the other hand, there were small differences in pH, titratable acidity and ash contents between the Majaheim, Wadah and Hamra camel milks. Similar observations, for cow's milk obtained from different breeds, were reported by Armstrong (1959 and Walstra & Jenness (1984).

Average values for pH of camel milk were close to that of cow's milk. However, the titratable acidity was on the low side in comparison with that of cow's milk. It is worth mentioning here that the acidity of camel milk is still of particular importance in determining the freshness and keeping quality of camel milk. Ohri & Joshi (1961) found that the acidity of camel milk 2 h after milking was low (0·03%) and increased to 0·14% in 6 h. They also reported that camel milk soured in 8 h when kept at 30°C, compared with cow's milk, which soured within 3 h at the same temperature. Moreover, Yagil *et al.* (1984) reported that cow's milk turned sour after 48 h at 30°C, while camel milk did not sour before 7 days. Differences in hygiene of the actual milking and in the total microbial count and its activity in milk could account for the differences in the increase in acidity.

The mean values for total solids, fat, protein and lactose of camel milk were slightly lower than that of cow's milk, whereas the ash contents was relatively higher than that of cow's milk. However, our data, for

Table 2. Average chemical composition of Majaheim camel milk in Saudi Arabia

Component	This work	Sawaya *et al.* (1984)	Abu-Lehia (1987)	Elamin & Wilcox (1992)	Mehaia (1994)	Mehaia & Al-Kanhal (1989)
pH	6·63	6·49	—	—	6·61	6·50
Acidity (%)	0·144	0·13	0·15	0·15	0·14	0·13
Fat (%)	3·22	3·60	3·31	3·15	3·50	3·24
Protein (%)	2·91	2·95	2·68	2·81	2·80	3·35
Lactose (%)	4·43	4·40	4·67	4·16	4·60	4·52
Ash (%)	0·79	0·79	0·80	0·83	0·79	0·80
TS[a] (%)	11·35	11·74	11·29	10·95	11·69	11·91

[a]Total solids.

Table 3. Average chemical composition (%) of dromedary camel milk from various parts of the world

Reference	Total solids	Protein	Fat	Lactose	Ash
Saudi Arabia					
This work	10·1–11·4	2·4–2·9	2·5–3·2	4·4–4·5	0·79–0·81
Egypt					
Farag & Kebary (1992)	12·36	3·10	3·90	4·47	0·80
El-Agamy (1983)	13·10	3·70	2·90	5·80	0·70
El-Bahay (1962)	12·10	3·50	3·80	3·80	0·80
Ethiopia					
Knoess (1976)	14·40	4·50	5·50	3·40	0·90
Mukasa-Mugerwa (1981)	13·36	4·02	4·33	4·21	0·79
India					
Khan & Appanna (1964)	13·00	3·76	3·08	5·43	0·73
Ohri & Joshi (1961)	13·37	3·95	3·78	4·88	0·95
Israel					
Yagil & Etzion (1980)	14·3	4·60	4·30	4·60	0·60
Libya					
Gnan & Sheriha (1986)	13·03	3·30	3·30	5·61	0·82
Kenya					
Farah & Ruegg (1989)	12·20	3·11	3·15	5·24	0·80
Pakistan					
Yasin & Wahid (1957)	13·01	3·67	2·90	5·78	0·66
Knoess *et al.* (1986)	—	2·20–2·59	2·20–4·70	4·59–5·33	—
Somalia					
Hjort & Dahl (1984)	13·70	3·00	5·40	3·30	0·70
Sudan					
El-Amin (1979)	10·0–14·0	3·6–4·7	4·0–5·5	—	0·8–1·0
USSR					
Kheraskov (1953)	13·60	3·50	4·50	5·00	0·70

Table 4. Nitrogen distribution (mg/100 ml) in milks of Majaheim, Wadah and Hamra camels and Friesian cow of Saudi Arabia. Results presented as mean ± standard deviation (range given in parentheses)

Content[a]	Camel			Cow
	Majaheim	Wadah	Hamra	
TN	456 ± 38·5 (395–503)	369 ± 19·2 (345–398)	395 ± 28·7 (362–431)	516 ± 8·0
NPN	44·6 ± 3·3 (41–49)	38·1 ± 4·5 (31–44)	40·4 ± 3·1 (36–44)	26 ± 1·5
PN	411 ± 35·8 (354–454)	331 ± 15·8 (309–354)	354 ± 26·1 (324–388)	490 ± 6·50
CN	300 ± 27·1 (256–338)	244 ± 16·3 (215–262)	255 ± 23·2 (224–281)	405 ± 7·5
NCN	156 ± 17·1 (136–178)	126 ± 16·8 (112–149)	140 ± 21·0 (117–151)	112 ± 4·5
WPN	112 ± 12·2 (98–130)	87·6 ± 11·7 (70–105)	99·4 ± 8·8 (81–108)	88·5 ± 3·5

[a]TN = total nitrogen; PN = protein nitrogen; NPN = nonprotein nitrogen; CN = casein nitrogen; NCN = noncasein nitrogen; WPN = whey protein nitrogen.

Majaheim camel milk, agreed well with the data reported by Sawaya *et al.* (1984), Abu-Lehia (1987), Elamin & Wilcox (1992) and Mehaia (1994) (Table 2). However, the mean values reported in our previous paper (Mehaia & Al-Kanhal, 1989) for protein and total solids were relatively higher than the mean values reported in this work and this difference appears to be related to the individual variations of conditions, i.e. feeding, season, different region and drought conditions (Yagil & Etzion, 1980). Table 3 summarizes, on the other hand, the average composition of dromedary camel milk, reported in the literature, from various parts in the world. The data show wide ranges of variations in the chemical composition. This could be greatly affected by the type of camel, feeding, season and drought conditions (Ahmed, 1988).

Nitrogen distribution in milk

Nitrogen distribution (mg N/100 ml milk) in milks of Majaheim, Wadah and Hamra camels and cow is given in Table 4. NPN, CN and WPN were all found to vary considerably between the different camel individuals and also between the three ecotype camel milks. The largest NPN content was in milk from Majaheim (44·6 ± 3·3 mg N/100 ml) and Hamra (40·4 ± 3·1 mg N/100 ml) and the lowest was in milk from Wadah (38·1 ± 4·5 mg N/100 ml). These values of NPN account for 9·8, 10·3 and 10·2% of the TN (Table 5) in milks of Majaheim, Wadah and Hamra, respectively. These results are in agreement with the published data, reported for Majaheim camel milk, by Mehaia & Al-Kanhal (1989). On the other hand, our results were relatively lower than previously reported for Egyptian camel milk and were slightly higher than those reported for camel milk in Kenya (Table 6). However, the average values of the NPN contents for camel milks were higher than those of cow's milk (Tables 4 and 5), and this agrees well with other reports (Cerbulis and Farrell, 1975; Abu-Lehia, 1987; Mehaia & Al-Kanhal, 1989, 1992). NPN content in cow's milk has been reported in the range 25–35 mg/100 g of milk (Walstra & Jenness, 1984). The NPN fraction has biological importance, although a large part of it does not have the same

Table 5. Nitrogen distribution (%N of TN) in milks of Majaheim, Wadah and Hamra camels and Friesian cow of Saudi Arabia. Results presented as mean values (range given in parentheses)

Content[a]	Camels			Cow
	Majaheim	Wadah	Hamra	
NPN	9.8 (9·1–10·4)	10·3 (9·8–11·4)	10·2 (9·5–10·7)	5·0
PN	90·2 (89·6–90·7)	89·7 (88·6–91·2)	89·8 (89·3–90·5)	95·0
CN	65·7 (62·9–68·1)	66·0 (62·3–69·6)	64·6 (62·0–69·0)	78·4
NCN	34·3 (32·8–37·1)	34·0 (30·4–40·3)	35·4 (31·0–38·1)	21·6
WPN	24·6 (22·6–27·1)	23·7 (19·0–27·2)	25·5 (21·4–27·6)	16·6

[a]TN = total nitrogen; PN = protein nitrogen; NPN = nonprotein nitrogen; CN = casein nitrogen = casein number; NCN = noncasein nitrogen; WPN = whey protein nitrogen.

Table 6. Average nitrogen distribution (mg/100 ml; % of N given in parentheses) of dromedary camel milk from various parts of the world[a]

Reference	TN	NPN	PN	CN	NCN	WPN
Saudi Arabia						
This work (Majaheim)	456	45	411	300	157	111
	(100)	(9·8)	(90·2)	(65·7)	(34·4%)	(24·3)
Mehaia & Al-Kanhal	526	56	470	320	206	150
(1989)	(100	(10·6)	(89·4)	(61·0)	(39·2)	(28·5)
Egypt						
Farag & Kebary	500	79·5	420·5	321	179	99·5
(1992)	(100)	(15·9)	(84·1)	(64)	(36)	(19·9)
Taha & Kielwein	500	67	433	320	180	113
(1989)	(100)	(13·4)	(86·6)	(64)	(36)	(22·6)
Kenya						
Farah & Ruegg	418	28	390	318	100	72
(1989)	(100)	(6·7)	(93·3)	(76)	(24)	(17·2)

[a]TN = total nitrogen; PN = protein nitrogen; NPN = nonprotein nitrogen; CN = casein nitrogen = casein number; NCN = non-casein nitrogen; WPN = whey protein nitrogen.

nutritional value as protein (Packard, 1984). The biological importance of NPN is due to the content of free amino acids (such as taurine), B vitamins, and nucleotides and their precursors such as orotic acid.

With respect to PN, as well as average composition of protein fractions (casein and whey proteins) of camel milk, Wadah and Hamra were somewhat similar, while Majaheim had the largest contents (Table 4). However, cow's milk had a higher content of PN and CN and a lower content of WPN compared to camel milk.

Casein is the principle protein component of milk, as well as the principle protein component of cheese; hence, the yield of cheese depends directly on the amount of casein in milk. Casein contents of camel milk varied from 255 ± 23·2 mg N/100 ml (1·63% protein) for Hamra to 300 ± 27·1 mg N/100 ml (1·91% protein) for Majaheim (Table 4). However, the average amount of casein in the camel milks was 266 ± 22·2 mg N/100 ml (1·70% protein), varying from 215 to 338 mg N/100 ml (1·37–2·16% protein) for individual samples. The corresponding value for cow's milk was 405 ± 7·5 mg/100 ml (2·58% protein). The percentage of TN of milk as casein is called the casein number (Waite, 1961), and it characterizes the suitability of milk for cheese production. The average casein numbers for Majaheim, Wadah and Hamra camel milks were 65·7, 66·0 and 64·6, respectively (Table 5). The overall average casein number was 65·4 with individuals varying from 62 to 70. This value is in agreement with our previous report and with that reported for Egyptian camels, while it was lower than that of camel milk in Kenya (Table 6). The casein number of cow's milk (78·4) was relatively higher than that of camel milk. Cerbulis & Farrell (1975) reported that the average casein number for cow's milk was 77·9 with individuals varying from 64·3 to 83·7. For the cheese industry, however, cow's milk would be best suited for the manufacturing of cheese while camel milk would be least suited. Mehaia (1993) reported that soft white cheese made from camel milk gave about half as much yield as that obtained from cow's milk. Moreover, Mohamed *et al.* (1990) reported that the hard cheese yield obtained from camel milk, in Somalia, was about 5%.

The average WPN comprises 24·5% of the total camel milk nitrogen. Milk of Hamra contained the highest (25·2%) WPN, and milk of Wadah contained the lowest (23·7%). These results were comparable to that reported for Majaheim camel milk (Mehaia & Al-Kanhal, 1989), but greater than those of Egyptian and Kenyan camel milks (Table 6). However, the average percentage of WPN of TN in camel milk (24·5%) was higher than that in cow's milk (16·6%) (Table 5). These results agree with other reports (Farah, 1986; Abu-Lehia, 1987). Cerbulis & Farrell (1975) reported that the average WPN in cow's milk was 17·2% of the total milk nitrogen. It has been reported that the biological value of the whey protein is the highest among the milk proteins (Cerbulis & Farrell, 1975). Since camel milk contains more WPN, it is of higher biological value than cow's milk, assuming a similar amino acid composition (Abu-Lehia, 1987).

Content of minerals

Table 7 lists the contents of five major minerals (Ca, Mg, P, Na and K) and four trace elements (Cu, Fe, Mn and Zn) in milks of Majaheim, Wadah and Hamra camels and Friesian cows of Saudi Arabia. There were wide variations in mineral contents, in camel milk, due to individual differences and types of camel. However, the average Ca and Mg contents in Majaheim camel milk were higher than those of the other two types of camel. Wadah camel milk had the highest contents of Na and K and the lowest content of P, whereas Hamra camel milk had the highest content of P and the lowest content of Mg. The Mg content of Saudi camel milk was similar to the mean value of Friesian cow's milk, but contents of Na and K were substantially higher and contents of Ca and P were relatively lower than those of cow's milk. Similar observations were reported by Sawaya *et al.* (1984) and Ahmed (1988).

Table 8 summarizes the average mineral contents of

Table 7. Mineral content (mg/100 g) in milk of Majaheim, Wadah and Hamra camels and Friesian cow of Saudi Arabia. Results presented as the mean ± standard deviation (range given in parentheses)

Component	Camel				Cow
	Majaheim	Wadah	Hamra	Average	
Major minerals					
Ca	120±5·1 (110·1±133·5)	109±4·5 (101·5±117·7)	119±6·7 (112·7–136·1)	116	124±3·5
Mg	13·0±1·1 (11·5–15·2)	12·4±1·5 (10·5–14·5)	11·6±1·6 (8·5–16·5)	12·3	11·7±0·5
P	88·6±1·2 (80·5–91·6)	83·5±1·6 (82–95)	90·1±2·0 (86–97)	87·4	96·2±0·6
Na	65·0±3·1 (62–76)	73·4±4·5 (65–81)	64·6±2·7 (60–70)	67·7	57·5±2·5
K	135±4·2 (126–141)	172±5·6 (161–190)	124±3·6 (121–132)	144	126±4·5
Trace elements					
Cu	0·12±0·02 (0·09–0·16)	0·17±0·02 (0·09–0·19)	0·14±0·01 (0·10–0·18)	0·14	0·013±0·005
Fe	0·18±0·02 (0·14–0·23)	0·25±0·02 (0·18–0·31)	0·26±0·02 (0·18–0·34)	0·23	0·060±0·015
Mn	0·06±0·001 (0·03–0·09)	0·092±0·001 (0·08–0·12)	0·093±0·001 (0·08–0·13)	0·08	0·003±0·001
Zn	0·64±0·025 (0·44–0·78)	0·52±0·03 (0·41–0·61)	0·62±0·03 (0·46–0·66)	0·59	0·490±0·010

dromedary camel milk reported in the literature from various parts of the world. Our results for Ca, Mg, P and Na for Majaheim camel milk were comparable with those reported by Abu-Lehia (1987), but values for K were substantially lower. On the other hand, Sawaya *et al.* (1984) reported lower values of Ca and P, and higher values of Na and K than our values. These variations in the Na and K contents could be attributed to the level of water intake as well as to seasonal heat (Yagil & Etzion, 1980). Moreover, Elamin & Wilcox (1992) reported the lowest values for Ca, Mg, Na and K in Majaheim camel milk (Table 8). Reasons for these major discrepancies might be due to the analytical procedures and/or unknown reasons.

Table 8. Average mineral content (mg/100 g) of dromedary camel milk from various parts of the world

Reference	Ca	Mg	P	Na	K	Cu	Fe	Mn	Zn
Saudi Arabia									
This work (Majaheim)	120	13·0	88·6	65·0	135	0·12	0·18	0·060	0·64
Elamin & Wilcox (1992)	30·0	4·5	—	43·1	72·5	—	0·28	—	—
Abu-Lehia (1987)	115	13·5	83·8	58·8	173	0·15	0·21	0·018	0·44
Sawaya *et al.* (1984)	106	12·0	63·0	69·0	156	0·16	0·26	0·020	0·44
Egypt									
Farag & Kebary (1992)	107	8·8	121	31·2	214	—	—	—	—
Ahmed *et al.* (1977)	197	21·0	62·6	—	—	0·49	0·37	—	—
Ethiopia									
Knoess (1976)	40·0	—	138	—	—	—	0·5	—	—
India									
Khan & Appanna (1964)	128	18·1	97·4	—	—	—	0·32	—	—
Israel									
Yagil & Etzion (1980)	132	10·0	45·0	23·0	152	—	—	—	—
Kenya									
Farah & Ruegg (1989)	157	8·3	104	—	—	—	—	—	—

Table 8 also indicates that the Egyptian camel milk had the highest contents of Ca and Mg, as reported by Ahmed *et al.* (1977), and the highest contents of P and K, as reported by Farag & Kebary (1992). Israeli camel milk had the lowest value for Na as reported by Yagil & Etzion (1980). However, the variations in the major mineral contents of camel milk, as indicated in Table 8, could be due to breed differences, feeding, drought conditions and/or analytical procedures.

With respect to the trace elements, the contents of Cu, Fe, Mn and Zn of Majaheim, Wadah and Hamra camel milks were all similar with some individual variations (Table 7). However, the average contents of Cu, Fe and Mn of camel milk were almost 11, 4 and 27 times higher than that of cow's milk, respectively, whereas the average Zn content of camel milk was comparable to that of cow's milk. These results agree with other reports (Sawaya *et al.*, 1984, Abu-Lehia, 1987) (Table 8). Moreover, Ahmed (1988) reported that the levels of Zn, Fe, Cu and Mn in camel milk were higher than those of cow's milk.

The Fe content of Saudi camel milks is somewhat lower than the Fe contents of Egyptian, Indian and Ethiopian camel milks. Moreover, the Cu level of the Saudi camel milks was substantially lower than that of Egyptian camel milk (Table 8). Variations in the levels of trace elements in different camel milks could, for example, be due to variations in the levels of these elements in the feed and water, breed differences and/or use of different analytical procedures.

CONCLUSIONS

From the foregoing results it could be concluded that Majaheim camel milk contains higher amounts of fat, protein and total solids than the other two ecotypes. With respect to NPN, PN, CN and WPN in milk, Wadah and Hamra were similar, while Majaheim had the greatest contents. However, cow's milk had higher contents of PN and CN and lower contents of NPN and WPN than camel milk. The mean values of Ca and Mg in Majaheim camel milk were higher than those of the other two ecotypes. Wadah camel milk had the highest contents of Na and K and the lowest content of P, whereas Hamra camel milk had the highest content of P and the lowest content of Mg. The contents of Cu, Fe, Mn and Zn of Majaheim, Wadah and Hamra camel milks were similar, with some individual variations. However, the average contents of Cu, Fe and Mn of camel milk were almost 11, 4 and 27 times higher than that of cow's milk, respectively. More extensive studies are needed to explore factors that influence camel milk composition from different ecotypes.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the support and the assistance provided by the Center for Agriculture and Veterinary Research, College of Agriculture and Veterinary Medicine, King Saud University—Qassim, Buriedah, Saudi Arabia. The authors are very grateful to Dr Osman A. I. Salem, Hail Agricultural Development Co. (HADCO), for his skilful technical assistance in mineral analysis. Also, the assistance provided by the Department of Food Science, College of Agriculture, Riyadh, is highly appreciated.

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