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Seasonal variations in the chemical composition of camel milk in Jordan

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The principal chemical components of milk from the Arabian camel (*Camelus dromedarius*) were monitored in Jordan over one year. The analyses included total solids, fat, protein, vitamins, minerals and organic acids. Large seasonal variations in total solids and fat were apparent, with maxima in mid-winter of 139 and 39·0 g/l, respectively, and minima in August of 102 and 25·0 g/l. These differences may be sufficient to alter the sensory properties of the milk, and the fat: casein ratio may need standardisation for cheesemaking. The mean values of trace elements like zinc (5·8 mg/l), iron (4·4 mg/l) and manganese (0·05 mg/l) in Jordanian camel milk could provide valuable additions to the diet of urban populations, as could the mean concentration of vitamin C (33 mg/l). The levels of organic acids were generally higher than in bovine milk and, as with all the constituents of the milk, there were discernible patterns linking concentration and season of the year.

Keywords: Jordan, camel milk, chemical analysis, seasonal variation.

The one-humped Arabian camel (*Camelus dromedarius*) is a creature of the desert, and it was first domesticated about 3000 B.C. in southern Arabia (Buillet, 1975; Higgins, 1984). For the Bedouin, this new-found relationship with the camel not only solved all their problems of transportation, but also provided them with a ready supply of food and milk (Chatty, 1986); in addition, its hair was utilized to make carpets and clothes. Furthermore, it was well adapted to the harsh desert climate – camels can survive without drinking water for up to forty days (Hassan, 1971), and they have the ability to convert spiny and thorny plants, e.g. Acacia and Salsola which few mammals can consume, into human food products (meat and milk). Indeed, camels can produce a volume of milk well beyond the capacity of other domestic animals in the same arid zones, and a typical camel can yield 3,500 or more litres of milk during a lactation period which can extend for 18 months (Knoess, 1977).

Yet despite this long history of domestication, only recently have attempts been made to fully exploit the commercial potential of the camel (Anon., 1997). However, a number of countries in the Middle East are seeking to become more self-sufficient with respect to food supplies (Al-Haddad & Robinson, 2003), and the Ministry of Agriculture in Jordan has begun to assess the possibility that camels may offer a means of utilising the large, arid regions of the country (Haddadin, 2001).

Milk production is seen as the most attractive option, but it is important to recognise that most potential consumers live in the large cities where they have become accustomed to purchasing pasteurised bovine milk, albeit reconstituted from milk powder in many cases, to meet their daily requirements for fresh milk. Although the unique flavour of fresh camel milk may enable it to compete in the market, consumers will expect the milk to be available in convenient cartons in supermarkets, and to have a uniform quality comparable to the bovine product. It will be important also for consumers to be provided with information about the potential nutritional value of the milk, and hence the overall aim of this project was to obtain some basic data about the existing situation in Jordan.

More specifically, the intention was to collect samples of camel milk from one farm over a period of a year and: (i) monitor the extent to which the chemical composition of the milk might vary with season; and (ii) compare mean values of important components with those of typical bovine milk.

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Materials and Methods

Freshly-drawn, camel milk, which is whiter than bovine milk and has a sweetish, sharp taste, was obtained from a herd being managed in an area called Dair Al Quin located to the North East of Jordan and about 170 km from the capital, Amman. The lactating camels feed on natural desert plants throughout the year but, in winter (from November till March), a supplementary feed of dried barley is provided each evening. The camels are milked twice a day, at 5 am, and again in the evening at 6 pm after the herd has returned from grazing. The camels are made to lie down on the sand to rest for 1 h before milking, and each one, in turn, is then tethered to allow the calf to suckle and enhance the release of milk before the herders start hand-milking.

Once a collection pail was full, the milk was poured into stirred, bulk containers (~45 l) along with the milk from other camels. Once a month, a composite sample of around 5 l was ladled from the bulk tanks into two sterile glass bottles which were stoppered tightly and kept in an ice box (0–5 °C) during transport to the Laboratory. On arrival, the two samples were mixed together, and test portions taken according to a standard method (International Dairy Federation (IDF), 1985); those subsamples not required for immediate analysis were stored at 5 °C. Chemical analyses were completed as soon as convenient after the samples had reached the laboratory Duplicate analyses of milk composition were carried out on the monthly samples

Analytical procedures

Total solids were determined by the method of IDF (1987a), and ash according to the British Standard Method (BSI, 1970). Lactose was determined colourimetrically (Marier, 1959) at 490 nm (Spectrophotometer model: Busch Lamb-spectronic 20D). A standard curve was prepared using a series of solutions of lactose monohydrate in distilled water. Fat was determined by the Gerber Method (Case et al. 1985), and the total nitrogen content of the milk was determined by the Kjeldahl method (IDF, 1962). The crude protein content was calculated using the general conversion factor for dairy products of 6·38.

A more accurate picture of the protein content was obtained by determining the non-protein nitrogen and non-casein nitrogen fractions using the procedure of Rowland (1938). In each case, the total nitrogen in 20 ml of the filtrate was obtained by the Kjeldahl method (IDF, 1962).

Total phosphorus was determined (IDF, 1987b), and the elements calcium (Ca), zinc (Zn), copper (Cu), iron (Fe), sodium (Na), potassium (K), magnesium (Mg) and manganese (Mn) were measured with an Atomic Absorption Spectrophotometer (AOAC, 1995). Standard stock solutions were prepared to allow quantification of the individual elements.

Fat-soluble vitamins were extracted using the procedure of Augustin et al. (1984). The residue was then dissolved in a mobile phase of acetonitrile: methanol (75 : 25, 25 ml) prior to analysis by HPLC (Isocratic HPLC with a UV/Visible detector – Jasco Model 880, Jasco Co., Tokyo, Japan). Standards for vitamins A, D_3 and E (Polyscience Inc., Niles, Ilinois, USA) and the extracted materials were examined under the following column and conditions: Hypurity Elite-C-18, 150 × 4·6 mm; injection volume: 20 µl; mobile phase; flow rate of 1 ml/min; detection at 280 nm; temperature of the column cabinet 40 °C.

For the water-soluble vitamins, an extraction solution was prepared by dissolving 2·0 g pentane sulphonic acid (sodium salt) in 1·5 l distilled water, adding 20 ml glacial acetic acid, and adjusting the final volume to 2 l. Twenty ml milk were pipetted into a 100 ml amber volumetric flask, and 80 ml extraction solution added; the flask was then placed into an ultrasonic bath (50 °C) for 15 min (Augustin et al. 1984). After cooling, the solution was clarified by passage through a sinter-glass filter. Standard solutions of vitamins B_1, B_2, B_6, B_{12}, niacin, folic acid, pantothenic acid and vitamin C were prepared in the mobile phase and, during the analysis, test samples were run alongside standards to monitor the accuracy of the apparatus. The analyses were carried out under the following conditions: column type: Hypersil BDS C-18, 150 × 4·6 mm; injection volume: 20 µl; mobile phase: methanol: 0·05 M phosphate buffer (30 : 70) at pH 3·5; flow rate of 1 ml/min and detection at 254 nm (UV).

The organic acids – hippuric, orotic, uric, citric, pyruvic, formic, acetic, propionic and butyric – were detected using HPLC, and the conditions of the analyses were as follows: column type: Hypersil SAX, 100 × 4·6 mm; injection volume: 20 µl; mobile phase: 0·02 M-Phosphate buffer, pH 7; flow rate 1 ml/min; detection at 210 nm (UV) at a temperature of 40 °C (Marsili et al. 1981).

The triglycerides in the milk fat were determined by an enzymatically (Anon., 1987). The phospholipid content of the same samples was determined by measuring the phosphorus content of fat with the calorimetric method reported by Sandhu (1976), results are expressed as a percentage of the total lipids. Cholesterol was determined by GLC (Bligh & Dyer, 1959) using a Shimadzu Gas Chromatogram (Model: GC 2010, Shimadzu Inc., Koyoto, Japan) and column TRB/5. The fatty acid composition was also determined by the GLC (Bligh & Dyer, 1959), and the results analysed according to SAS (1988).

Results and Discussion

The broad chemical composition of Jordanian camel milk over a period of one year is given in Table 1a. The most important factor affecting the overall composition of the milk was its water content, which varied from 861 g/l during the winter (December) to a high of 898 g/l in

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Table 1. Mean concentrations of (**a**) the main components, (**b**) important fatty acids, (**c**) some minerals, (**d**) some vitamins and (**e**) some organic acids of raw camel milk from one farm in Jordan over a period of one year

Values are means for $n=2$ except annual mean where $n=12$

Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Table 1a Main components g/l													
Water	863^{fg}	866^{efg}	870^{de}	869^{def}	879^{c}	875^{cd}	892^{ab}	898^{a}	893^{ab}	889^{b}	872^{de}	861^{g}	877 ± 12·7
Total Solids	137^{a}	134^{ab}	130^{bcd}	131^{bc}	121^{c}	125^{cd}	108^{f}	102^{g}	107^{fg}	111^{f}	128^{cd}	139^{a}	123 ± 12·7
Lactose	$39·0^{a}$	$39·0^{a}$	$39·0^{a}$	$39·0^{a}$	$39·0^{a}$	$39·4^{a}$	$39·3^{a}$	$39·0^{a}$	$39·1^{a}$	$39·0^{a}$	$39·8^{a}$	$40·2^{a}$	39·2 ± 0·5
Fat	$35·0^{a}$	$31·0^{b}$	$31·0^{b}$	$30·0^{bc}$	$30·0^{bc}$	$29·0^{bc}$	$28·0^{cd}$	$25·0^{c}$	$25·5^{cd}$	$29·0^{bc}$	$30·0^{bc}$	$31·0^{b}$	29·5 ± 2·6
Protein	$29·0^{a}$	$28·5^{ab}$	$28·0^{b}$	$26·3^{c}$	$26·1^{c}$	$26·5^{c}$	$25·0^{d}$	$24·8^{d}$	$25·0^{d}$	$26·0^{c}$	$28·9^{ab}$	$29·0^{a}$	26·9 ± 1·6
Ash	$8·6^{a}$	$8·4^{a}$	$8·4^{a}$	$8·4^{a}$	$8·5^{a}$	$8·2^{ab}$	$7·9^{b}$	$7·8^{b}$	$7·8^{b}$	$7·8^{b}$	$8·2^{ab}$	$8·6^{a}$	8·2 ± 0·3
Table 1b Fatty acids weight % of the total fatty acids													
Palmitic acid (C_{16})	$26·6^{cd}$	$26·4^{cd}$	$26·7^{c}$	$28·6^{a}$	$28·5^{ab}$	$27·9^{b}$	$26·0^{de}$	$25·3^{f}$	$25·2^{f}$	$25·5^{ef}$	$26·6^{cd}$	$26·4^{cd}$	26·6 ± 1·2
Palmitoleic acid ($C_{16:1}$)	$11·6^{c}$	$11·8^{c}$	$11·5^{cd}$	$14·2^{b}$	$15·0^{a}$	$15·1^{a}$	$11·0^{d}$	$10·4^{e}$	$9·4^{f}$	$9·3^{f}$	$12·0^{c}$	$11·5^{cd}$	11·9 ± 1·9
Stearic acid ($C_{18:0}$)	$15·0^{bc}$	$15·3^{b}$	$15·1^{bc}$	$19·0^{a}$	$18·8^{a}$	$18·5^{a}$	$15·2^{bc}$	$15·1^{bc}$	$14·8^{cd}$	$15·5^{b}$	$14·3^{d}$	$15·2^{bc}$	16·0 ± 1·7
Oleic acid ($C_{18:1}$)	$20·5^{e}$	$21·0^{e}$	$20·2^{e}$	$30·1^{a}$	$32·0^{a}$	$29·4^{ab}$	$25·0^{cd}$	$26·0^{c}$	$26·3^{bc}$	$26·4^{bc}$	$22·0^{de}$	$21·4^{e}$	25·0 ± 4·0
Linoleic acid ($C_{18:2}$)	$0·6^{c}$	$0·5^{c}$	$0·6^{c}$	$1·2^{ab}$	$1·5^{a}$	$1·1^{b}$	$0·7^{c}$	$0·6^{c}$	$0·7^{c}$	$0·7^{c}$	$0·6^{c}$	$0·7^{c}$	0·8 ± 0·2
Linolenic acid ($C_{18:3}$)	$1·2^{b}$	$1·1^{b}$	$1·1^{b}$	$2·3^{a}$	$2·8^{a}$	$2·3^{a}$	$1·3^{b}$	$1·2^{b}$	$1·4^{b}$	$1·3^{b}$	$1·3^{b}$	$1·3^{b}$	1·5 ± 0·6
Table 1c Minerals, cations mg/l													
Calcium	1590^{a}	1570^{ab}	1475^{c}	1480^{bc}	1470^{c}	1350^{d}	1190^{ef}	1060^{g}	1110^{fg}	1250^{e}	1388^{cd}	1250^{e}	1370 ± 133
Zinc	$5·9^{ab}$	$5·8^{ab}$	$5·8^{ab}$	$6·1^{a}$	$5·5^{b}$	$5·6^{b}$	$5·5^{b}$	$6·2^{a}$	$5·6^{b}$	$5·8^{ab}$	$5·9^{ab}$	$6·2^{a}$	5·8 ± 0·2
Copper	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr. = Trace
Iron	$4·5^{a}$	$4·6^{a}$	$4·5^{a}$	$4·4^{a}$	$4·4^{a}$	$4·4^{a}$	$4·5^{a}$	$4·4^{a}$	$4·4^{a}$	$4·5^{a}$	$4·4^{a}$	$4·4^{a}$	4·4 ± 0·08
Magnesium	96^{a}	98^{a}	97^{a}	96^{a}	95^{a}	92^{ab}	85^{bc}	77^{d}	78^{cd}	76^{d}	92^{ab}	98^{a}	90 ± 8·6
Sodium	575^{d}	522^{f}	439^{i}	460^{g}	448^{h}	437^{i}	710^{b}	725^{a}	727^{a}	720^{a}	550^{e}	590^{c}	575 ± 118
Potassium	780^{h}	840^{fgh}	927^{def}	910^{efg}	940^{de}	1010^{d}	1250^{c}	1400^{b}	1650^{a}	1610^{a}	875^{efgh}	830^{gh}	1085 ± 311
Manganese	$0·06^{ab}$	$0·07^{a}$	$0·06^{ab}$	$0·07^{a}$	$0·06^{ab}$	$0·05^{abc}$	$0·04^{abc}$	$0·03^{bc}$	$0·02^{c}$	$0·04^{abc}$	$0·07^{a}$	$0·06^{ab}$	0·05 ± 0·02
Phosphorus	960^{a}	940^{ab}	880^{bc}	830^{cd}	810^{de}	760^{ef}	730^{f}	610^{g}	630^{g}	640^{g}	970^{a}	990^{a}	830 ± 155
Table 1d Vitamins µg/l													
Vitamin A	400^{a}	350^{c}	280^{d}	200^{fg}	260^{de}	210^{fg}	200^{fg}	150^{h}	180^{gh}	230^{ef}	360^{bc}	390^{ab}	267 ± 80
Vitamin D_3	$6·0^{a}$	$4·0^{c}$	$3·0^{d}$	$3·0^{d}$	$2·5^{e}$	$2·5^{e}$	$2·0^{f}$	$1·5^{g}$	$2·0^{f}$	$2·0^{f}$	$5·0^{b}$	$6·0^{a}$	3·0 ± 0·2
Vitamin E	$28·0^{a}$	$23·3^{c}$	$18·5^{d}$	$18·0^{d}$	$15·0^{ef}$	$14·5^{f}$	$12·5^{g}$	$11·3^{h}$	$9·0^{i}$	$16·0^{e}$	$22·5^{c}$	$24·8^{b}$	17·8 ± 5·8
Thiamin	440^{g}	470^{ed}	445^{fg}	460^{ef}	500^{ab}	490^{bc}	450^{fg}	480^{cd}	460^{ef}	450^{fg}	510^{a}	440^{g}	480 ± 70
Riboflavin	1550^{i}	1580^{gh}	1620^{f}	1980^{a}	1800^{c}	1880^{b}	1750^{d}	1600^{fg}	1650^{e}	1620^{f}	1550^{i}	1570^{hi}	1680 ± 140
Pyridoxine	602^{c}	660^{b}	712^{a}	557^{d}	520^{f}	540^{e}	560^{d}	480^{g}	485^{g}	433^{h}	505^{f}	550^{de}	550 ± 81
Vitamin B_{12}	$8·7^{abc}$	$8·9^{a}$	$8·9^{a}$	$8·5^{bcd}$	$8·5^{bcd}$	$8·5^{bcd}$	$8·3^{d}$	$8·2^{d}$	$8·4^{cd}$	$8·4^{cd}$	$8·7^{abc}$	$8·8^{ab}$	8·5 ± 0·24
Niacin	660^{gh}	700^{f}	740^{e}	895^{b}	932^{a}	895^{b}	890^{b}	780^{d}	800^{c}	750^{e}	645^{h}	670^{g}	780 ± 102
Folic acid	92^{d}	103^{b}	109^{a}	85^{e}	80^{f}	82^{ef}	75^{g}	70^{h}	72^{gh}	74^{gh}	98^{c}	110^{a}	87 ± 15
Pantothenic acid	3500^{e}	3820^{abc}	3790^{bcd}	3740^{cd}	3500^{e}	3760^{cd}	3910^{a}	3300^{f}	3870^{ab}	3720^{d}	3900^{a}	3350^{f}	3680 ± 213
Vitamin C (mg/l)	$35·5^{a}$	$33·5^{cd}$	$34·2^{b}$	$30·5^{f}$	$35·3^{a}$	$30·2^{f}$	$34·0^{bc}$	$32·0^{e}$	$34·1^{bc}$	$33·2^{d}$	$30·6^{f}$	$33·5^{cd}$	33·0 ± 1·7
Table 1e Organic acids mg/l													
Hippuric	$8·8^{ef}$	$9·8^{de}$	$10·7^{bcd}$	$10·5^{cd}$	$11·0^{ab}$	$12·0^{a}$	$11·6^{ab}$	$10·2^{cd}$	$10·6^{bcd}$	$10·3^{cd}$	$8·7^{f}$	$8·6^{f}$	10·2 ± 1·1
Orotic	$65·4^{h}$	$71·6^{fg}$	$77·9^{d}$	$80·2^{c}$	$94·5^{a}$	$84·2^{b}$	$80·1^{c}$	$77·5^{d}$	$74·3^{e}$	$73·0^{ef}$	$70·3^{g}$	$64·5^{h}$	76·1 ± 8·3
Uric	$17·2^{ef}$	$16·8^{g}$	$17·6^{d}$	$18·6^{b}$	$19·5^{a}$	$18·4^{b}$	$18·0^{c}$	$18·0^{c}$	$18·0^{c}$	$17·5^{de}$	$17·1^{fg}$	$17·4^{def}$	17·8 ± 1·0
Citric	708^{i}	806^{g}	820^{f}	866^{e}	905^{c}	962^{a}	930^{b}	866^{e}	882^{d}	810^{fg}	787^{h}	662^{j}	846 ± 68
Pyruvic	$4·9^{ef}$	$4·7^{ef}$	$5·4^{d}$	$6·2^{b}$	$5·4^{d}$	$5·9^{bc}$	$6·7^{a}$	$5·6^{d}$	$5·9^{bc}$	$5·0^{e}$	$4·9^{ef}$	$4·6^{f}$	5·4 ± 0·6
Formic	$8·8^{g}$	$8·7^{g}$	$10·3^{ef}$	$11·9^{ab}$	$12·0^{a}$	$11·2^{c}$	$11·4^{bc}$	$10·9^{cd}$	$10·5^{de}$	$10·2^{ef}$	$9·9^{f}$	$8·5^{g}$	10·3 ± 1·2
Acetic	$23·1^{h}$	$24·9^{ef}$	$24·1^{g}$	$27·4^{a}$	$26·5^{b}$	$26·2^{c}$	$25·1^{e}$	$25·8^{cd}$	$25·6^{d}$	$25·2^{e}$	$24·6^{f}$	$24·0^{g}$	25·2 ± 1·2
Propionic	$34·9^{f}$	$35·3^{f}$	$37·6^{c}$	$39·9^{a}$	$40·2^{a}$	$38·5^{b}$	$38·1^{b}$	$37·5^{c}$	$37·6^{c}$	$37·6^{c}$	$37·0^{d}$	$36·5^{e}$	37·5 ± 1·7
Butyric	$63·5^{f}$	$68·9^{e}$	$70·0^{de}$	$85·4^{a}$	$75·3^{c}$	$80·5^{b}$	$70·5^{de}$	$70·3^{de}$	$72·0^{d}$	$70·5^{de}$	$55·5^{h}$	$60·1^{g}$	70·0 ± 8·2

[a–i]Means in any row with different superscript letters are significantly different ($P<0·5$)

August when the temperature ranged from 40–45 °C. These differences in water contents can be explained by the availability of drinking water. Thus, while the camels were allowed free access to water during the winter rainy season, water restrictions in summer meant that the camels were rationed to a limited amount of water twice a week. The result is a pattern linking water intake with the water content of the milk which, according to Knoess et al. (1987) and Ramet (1994), indicates the importance of the water content in the milk for the young camels living in drought areas. Obviously this dilution of the milk in hot weather is an advantage for the calf, but it means that the total solids in the milk drops from 139 g/l in January to 102 g/l in August. The impact of this variation (37 g/l) on the organoleptic properties of the liquid milk, its ability to withstand pasteurisation and/or be further processed will

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need investigation, for the comparable change in bovine milk is around 4·0 g/l (Tamime & Robinson, 1999).

The lactose content of the milk (mean of 39·0 g/l) remained almost unchanged throughout the year, and similar mean figures for lactose were reported by Shalash (1979) for Egyptian camels and Sawaya et al. (1984) for milk produced in Saudi Arabia; lower values (34·0 g/l) were reported by Knoess (1977) for Ethiopian camel milk.

The fat content of the milk varied with season from 25 to 35 g/l, a much wider range than is typical of bovine milk – a difference of about 4 g/l is observed for Freisian milk in the UK (Tamime & Robinson, 1999) and, unless standardised for the market, the impact on the sensory properties of pasteurised milk for human consumption might be important. In addition, the fall of 10 g/l recorded in Table 1a could be relevant technically and economically, especially if the milk is to be further processed into cheese. Thus, although both the protein and fat contents of camel milk are lowest in August, the protein content is only 4·2 g/l below the maximum value (see Table 1a), and hence the fat: casein ratio alters quite markedly between January and August. If camels are to make a contribution to food supplies in Jordan, then breed requires consideration. The mean of fat content of Jordanian camel milk (29·5 g/l) was substantially lower than those reported by Sawaya et al. (1984), Taha & Kielvein (1989) and Mohamed et al. (1989) for milks from Saudi Arabian, Egyptian and Somalian camels, namely 56, 52·2 and 46·6 g/l, respectively. Whether or not special diets contributed to these elevated fat contents is not known, but a difference of over 20 g/l between the Saudi Arabian and Jordanian milks deserves an explanation.

The cholesterol level (3·5 g/kg of milk fat) was lower than in some bovine milks but, in practical terms, it is relevant that milk and cheese do not make a major contribution to the cholesterol intake of an average adult (Tamime, 1993). Some of the main fatty acid components are shown in Table 1b, and it was found that, in comparison with bovine milk, the fatty acids in camel milk showed a higher degree of unsaturation, with especially high quantities of the essential fatty acids like linolenic acid and linoleic acid. Some seasonal variations were noted, e.g. the increase in oleic acid during April and May, and it is likely that these vernal rises reflect the improved grazing on fresh grasses and herbs stimulated by the winter rains.

The mean total nitrogen value for Jordanian camel milk was 4·21 g/l, which gives a value for crude protein of 26·9 g/l. The figure for total nitrogen is lower than the comparable means for different breeds of Saudi Arabian camel (4·72–8·00 g/l), but these data may include higher levels of non-protein nitrogen (Mehaia, 1994a). Thus, the mean figure for non-protein nitrogen (340 mg/l) in the Jordanian camel milk means that 92% of the total nitrogen was derived from true protein of which 19·8 g/l was casein and 4·3 g/l whey protein. These figures compare well with those of Desai et al. (1982), who found Dromedary milk (mid-lactation) in India had 26·8 g protein/l, being 21·1 g casein and 5·7 g whey protein/l. Farag & Kebary (1992) recorded similar levels of casein in camel milk from Egypt.

The mean value for manganese shown in Table 1c is slightly below that recorded by Al-Awadi & Srikumar (2001) for camel milk in Kuwait, but the concentration of zinc was higher; hence, Jordanian milk could be regarded as an excellent source of these essential minerals. Equally important is the high and stable concentration of iron for if, as observed by Al-Awadi & Srikumar (2001), the iron from camel milk is easily absorbed from the intestine, 1l of Jordanian camel milk would provide around 30% of a typical daily requirement. It was noticeable also that the concentrations of minerals associated with water balance, e.g. sodium and potassium, increased during the summer in parallel with the water content of the milk, whilst the levels of calcium and phosphorus mirrored the changes in total solids. Nevertheless, the mean calcium content of the milk (1·37 g/l) was higher than in typical bovine milk (1·23 g/l, Banks & Dalgleish, 1990), and above the values reported for other samples of camel milk (Farah, 1993; Dell'Orto et al. 2000); the level for magnesium (90 mg/l) was slightly lower than in bovine milk (140 mg/l).

The analyses shown in Table 1d indicate that the levels of vitamin C and niacin were higher than in bovine milk (Banks & Dalgleish, 1990), and the exceptionally high level of vitamin C (33 mg/l) could be relevant for humans living in desert areas where green vegetables and fruits are difficult to find (Mehaia, 1994b). Conversely, the amount of vitamin A in the camel milk was low and, as with the other fat-soluble vitamins, the detectable level followed the decline in fat content during the summer months. The mean riboflavin and thiamin levels in camel milk were comparable with bovine milk, but the concentrations of pantothenic acid, folic acid and B_{12} were marginally higher. While riboflavin and niacin showed peak concentrations in the spring, the analyses of the other B-group vitamins revealed no obvious seasonal pattern, e.g. pantothenic acid and thiamin, or, alternatively, just a general trend towards lower concentrations in mid-summer.

The organic acids that were determined (see Table 1e) in these samples of camel milk are much higher than in typical bovine milk, and this contrast may reflect the nature of the desert flora (Wolfschoon-Pombo & Klostermeyer, 1981) and/or differences between the intestinal microfloras of the two mammals. Certainly the values for all the acids (except pyruvic) tend to peak during April–June suggesting, perhaps, a direct link with the varied array of plants available for grazing. The influence of acids like citric or butyric on the flavour of camel milk could be relevant, as could the possible preservative effects of the acetic or propionic acids in a warm desert climate; the storage stability of raw camel milk is often commented upon by the Bedouin (Haddadin, unpublished

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data). A more direct nutritional value for humans may arise from the high level of orotic acid, for Korycka et al. (1979) suggested that the acid reduces the risk of cardiovascular disease.

Clearly the protein content is lower than in bovine milk and the percentage of fat can vary by as much as 10 g/l over the year, but the consistently high levels of trace elements like iron and zinc, as well as vitamin C, make camel milk a potentially valuable dietary component. The presence of manganese (mean of 0·05 mg/l) has also been cited as an asset, but its concentration is much lower in summer milks. Nevertheless, if camel milk production in Jordan can reach commercially attractive volumes (Abou Ragib et al. 2002), then the product could have a desirable impact on the nutrition of the local population.

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