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Effect of freeze-drying on camel's milk nutritional properties

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Abstract

The purpose of this research was to study the effect of freeze-drying process on camel's milk nutritional characteristics compared with fresh milk. The results showed that the protein, casein, whey proteins, lactose and ash percentage were significantly higher ($P< 0.05$) in freeze-dried skim milk than fresh milk. The average of mineral contents in reconstituted freeze-dried skim camel's milk was slightly higher than that of fresh camel milk except Ca, K and P contents. On the other hand, freeze-dried skim camel's milk had a slightly higher concentration of water-soluble vitamins except vitamin C. Vitamins B, A, D and E showed relatively stable values after freeze-drying treatment. Freeze-drying process skim camel's milk was characterized by slightly higher contents of all amino acids. Freeze-dried whole milk showed higher contribution of Protein efficiency ratio, Biological value and Net protein utilization than that of fresh whole milk. Freeze-dried process had a little effect on fatty acid profile in camel milk fat. Nutritional properties of lyophilized camel's milk remained basically unchanged compared with fresh milk.

Introduction

Camel milk is highly nutritious so that many generations of our ancestors survived on this beverage alone. Camel milk is almost a complete food consisting of proteins (mainly casein), fat, salts and lactose as well as vitamins and minerals (Sawaya *et al*., 1984). Camel milk and bovine milk had similar amino acid composition. Camel milk casein contained most of the essential amino acids in high ratios. Glutamic acid was the most abundant amino acid followed by Leucine, Lysine and Aspartic acid (Abu-Tarboush and Ahmed, 2005). In Africa and the Middle East, camel milk is used therapeutically against dropsy, jaundice, problems of the spleen, tuberculosis, asthma, anemia, piles, diabetes and against Hepatitis C Virus (Rao, *et al*., 1970; El-Fakharany *et al.*, 2008). Beneficial role of raw camel milk in chronic pulmonary tuberculosis patients has been observed (Mal *et al*., 2001). Treatment of type–I diabetes with oral supplementation of raw camel milk was reported to be effective and reduces the insulin daily doze from 30 to 35% (Agrarwal *et al*., 2003). Research has demonstrated the presence of potent anti-bacterial and anti-viral factors in camel milk. Antimicrobial properties were partially attributed to well characterize proteins, such as lactoferrin, lactoperoxidase, lysozyme and immunoglobulin G. These proteins were shown to have higher concentrations or higher activity in camel milk (El-Agamy *et al*., 2009). In addition, camel milk could have significant therapeutic attributes such as anti-cancer (Magjeed, 2005).

Egypt considered as one of the world's highest Hepatitis C. There are several traditional medicines used by different Egyptian patients sectors. The most popular one is the camel milk, 50% of the patients shown a marked improvement in general fatigue (El-Fakharany *et al*., 2008). Considering the health effect of camel milk proteins and its bioactive peptides, it could be the 'super food' of the future. Traditional dehydration processes usually cause physical and structural changes in the dried products due to heat application. In fact, caramelization, discoloration, loss in texture and physical form, loss of volatile flavoring characteristics, and poor rehydration ability of many dried foods have left an imprint on the mind of consumers (Desrosier, 1977). Freeze-drying or lyophilization is a process in which a solvent is removed from a frozen solution by sublimation. This process minimizes the degradation reactions and maintains adequate physical, chemical, and biological stability of the product during long-term storage at ambient temperature (Fonseca *et al*., 2004). Being a cold process, freeze-drying is especially useful for drying heat sensitive foods. Freeze-drying is recognized as the best method of producing drier material of high quality. The dried products obtained from freeze-drying processes have good flavour appearance, and a high preservation of

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nutrition. Moisture level as low as 2% can be reached with freeze-drying. It can be benefit to produce freeze-dried camel milk to take advantage of its nutritional and therapeutic properties. In spite of all these nutritional and therapeutic properties of camel milk, the changes in physical and chemical properties of freeze-drying camel milk is still unknown. The objective of this study was to investigate the effects of the lyophilization (freeze-drying) treatment on physical, chemical and nutritional characteristics of camel's milk.

Materials and Methods

Camel's milk

Fresh whole camel milk from healthy and uninfected Magrabi camels *(Camelus dromedarius)* was obtained from Sidi-Barani areas Matrouh Governorate, North West Coast, Egypt. The udder was cleaned and washed with disinfectant solution (Safflon 20%), before collection of milk. Autoclaveable plastic containers (1000 mL) were used for the collection of samples. Containers were sterilized at 120°C for 15 min and kept ready for milk collection from different sites (Omer and Eltinay, 2009).

Preparation of freeze-dried camel's milk samples

Batches of skimmed milk were prepared from fresh camel milk by centrifugation at 4000 g for 10 min at 15°C. Freeze-drying of whole and skim camel milk was performed in a Freeze Dryer (Thermo-Electron Corporation-Heto power dry LL300 Freeze Dryer, Czech Republic). The freeze-dryer was programmed to operate for 1 h initial freezing at -45°C followed by primary drying at 30°C at 0.10 mbar pressure for 48 h and secondary drying at 5°C for 3 h at the same pressure. After the end of freeze-drying cycle, the vials were sealed under vacuum and stored at 5°C until analyzed (Ivanova, 2011).

Raw whole and skimmed milk - freeze-dried whole and skimmed milk

Proximate analysis (total solids, fat, total nitrogen, ash content and titratable acidity %) for raw whole and skimmed milk was determined as described by Ling (1963). The casein and whey protein was determined by micro Kjeldahl method as mentioned by Rowland (1938). Lactose content was determined by the phenol-sulfuric spectrophotometeric method as reported by Barnett and Abd-El-Tawab (1957).

The total solids in freeze-dried whole and skimmed milk was determined according to the IDF procedure (1993), fat (Rose Gottlieb method), ash content, titratable acidity and total protein (Kjeldahl) in freeze-dried whole and skimmed milk were determined as mentioned in AOAC, (1997). Lactose determination in freeze-dried whole and skimmed milk samples were estimted according to the modified phenol-sulfuric acid procedures described by Lawrence (1968) using a Jenway 6850 spectrophotometer (Jenway Instruments, Beacon Road, Stone, Staffordshire, ST15 OSA, UK) at a wave length of 490 nm . The casein and whey proteins were determined by micro Kjeldahl method as mentioned by Rowland (1938).

Vitamins determination

Water-soluble vitamins such as vitamin C and vitamin B complex (B1, B2, B3, B5, B6, B9 and B12) and fat soluble vitamins such as vitamins A, D and E were determined by the method of Albala-Hurtado *et al.* (1997) and Paixao and Campos (2003), respectively. Prepared samples were analyzed for vitamins C, A, D, E and B complex (B1, B2, B3, B5, B6, B9 and B12) group by liquid phase chromatography HPLC (Dionex™ UltiMate™ 3000 RS systems –Thermo Scientific system). The sample (20 µL) was injected into the HPLC with a syringe (Hamilton, Reno, NV, USA). The HPLC column used was a reversed-phase Discovery C18 (150 mm × 4.6 mm, 5 µm) from Supelco (Bellefonte, PA, USA). The column eluate was monitored with a photodiode-array detector at 265 nm for vitamins C, 325 for A, 295 for E, 260 for D, 234 nm for thiamine, 266 nm for riboflavin, 324 nm for pyridoxine, 282 nm for folic acid, 204 nm for cobalamin, 261 nm for niacin, and 204 nm for pantothenic acid. Identification of compounds was achieved by comparing their retention times and UV spectra with those of standards stored in a data bank. Concentrations of the water-soluble and insoluble vitamins were calculated from integrated areas of the sample and the corresponding standards.

Minerals determination

Minerals were determined in ash solution (Srivastava, 2010). Calcium, magnesium, phosphorus, manganese, cupper, iron and zinc concentrations were determined using atomic absorption spectrophotometer (Unicam Analytical System, Model 919, Cambridge, UK) while sodium and potassium concentrations was determined using flame photometer (Jenway PF7 Flame Photometer, Essex, UK).

Amino acid composition

Milk samples were prepared by acid hydrolysis (6N HCl) for 24 h at 110°C and the final mixture was filtrate using Whatman filter paper no. 42. About 0.2 mL of filtration was evaporated at 140°C for one hour and finally adds 1ml of diluting buffer to the dried sample. Hydrolyzes were analyzed by Beckman Amino Acid Analyzer, Model 119CL as mentioned by Nagasawa *et al*. (1970).

Analysis of fatty acids by Gas Chromatography

Fatty acid methyl esters FAMES were prepared as described in AOAC (1990) method 969.33. A GC equipped with a flame ionisation detector and an auto sampler (model 7673, Hewlett–Packard, Palo Alto, CA, USA), was used for analyzing FAMES. The GC conditions were: column oven temperature was 70°C for 1 min, increased to 200°C (20°C/min) and kept at 200°C for 1 min, then increased to 220°C (1°C/min) and kept at 220°C for 20 min, Injector temperature and detector temperature was 260°C, flow rate 1.1 ml/min (He) and the split ratio used was 1:25. A FAME Standard (mixture 463) was used to identify the FAME, and the FA amount was expressed as percent of total FAs.

Nutritive value

Protein efficiency ratio (PER) based on the amino acid contents of camel milk were calculated according to the recommendations of Alsmeyer *et al.* (1974) using the following equations:

PER1= -0.684+0.456 (leucine) – 0.047 (proline)
PER2= -0.468+0.454 (leucine) – 0.105 (tyrosine)
PER3= -1.816+0.435 (methionine) + 0.78 (leucine) + 0.211 (histidine) – 0.944 (tyrosine)

Biological value (BV) and net protein utilization (NPU) were calculated using the equations suggested by Block and Mitchell (1946): BV= 49.9 + 10.53 PER
NPU= BV× Digestibility (protein 95%).

Total energy in all sample of camel milk was expressed in calories (Watt and Merrill, 1963), and calculated using the following equation:

Calories= (protein × 4.27) + (fat × 8.78) + (lactose × 3.87).

Statistical analysis

Experimental data were analyzed as Complete Random Design (CRD) according to SPSS package (SPSS v.20, 2012). Standard error of the means was derived from the error mean square term of the ANOVA, which was used the least significant difference (LSD) test. Differences were considered significant at (*P*<0.05). All measurements were performed in triplicate.

Results and Discussion

Data presented in Table (1) show the chemical composition of fresh and freeze-dried camel's milk. The results indicated that the moisture content of whole and skim freeze-dried camel milk was lower as a result of freeze-drying. Thus, moisture level as low as 2% can be reached with freeze-dried foods (Dalgleish, 1990), this makes the products much lighter than those dried by other drying methods and they do not require refrigeration. In general, total protein, caseins, whey proteins, lactose and ash % were significantly higher (*P*< 0.05) in freeze-dried skim milk than freeze-dried whole camel milk. Changes in the composition of some constituents in freeze-dried milk can be explained as a function of the freeze-dried process. These changes coincided with changes in moisture content (Kumar and Mishra, 2004). However, no significant differences in total energy for both freeze-dried and fresh milk (Table 1).

Mineral content in camel milk were found here (Table 1) was within the range with values reported by various researchers (Elamin and Wilcox, 1992; Gorban and Izzeldin, 1997; Haddadin *et al.*, 2008). The average of all major and trace element contents in reconstituted freeze-dried camel's milk was slightly higher than those of fresh camel milk, thus might be due to freeze-dried possess except Ca, K and P contents were significantly differences (*P*< 0.05). In contrast, the influence of process of freeze-dried on trace element was not significant.

Milk is a valuable source for both water-soluble and fat-soluble vitamins. Therefore, we compare the concentration of vitamins in fresh and reconstituted freeze-dried camel's milk (Table 2). The results showed that freeze-dried skim camel's milk was a slightly higher concentration of water-soluble vitamins except vitamins C. Lyophilization process significantly affected the amount of vitamin C in milk (Vincenzetti *et al.*, 2011). Further, freeze-dried yoghurt showed reduction in levels of ascorbic acid (Karadimov and Karadimova, 1979). On the other hand, vitamins B group were relatively stable in all samples with no significant differences (*P*< 0.05) between all samples. Vitamins B group are relatively stable to most food-processing operations and storage (Fox and McSweeney, 1997). Fresh whole camel's milk had a slightly higher concentration of fat-soluble vitamins (A, D and E) than freeze-dried whole camel's milk.

Table (3) shows the amino acid concentration of fresh and reconstituted freeze-dried camel's milk (g/100 g protein). The results indicated that Glutamic acid (Glu) was the major amino acid in all milk

Table 1. Chemical composition of fresh and freeze-dried camel's milk

Constituents	**Fresh milk**		**Freeze-dried milk**	
	Whole	**Skim**	**Whole**	**Skim**
Moisture %	$87.87^{b}\pm0.67$	$90.73^{a}\pm1.12$	$3.33^{c}\pm0.47$	$4.23^{c}\pm0.25$
Dry matter %	$12.10^{b}\pm0.20$	$9.33^{c}\pm0.12$	$96.73^{a}\pm0.85$	$95.80^{a}\pm1.01$
Protein %	$3.33^{c}\pm0.21$	$3.33^{c}\pm0.32$	$26.13^{b}\pm1.0$	$33.93^{a}\pm0.55$
Casein %	$2.64^{c}\pm0.14$	$2.62^{c}\pm0.10$	$21.03^{b}\pm0.76$	$26.90^{a}\pm1.56$
Whey proteins (%)	$0.76^{c}\pm0.03$	$0.79^{c}\pm0.02$	$6.07^{b}\pm0.15$	$8.13^{a}\pm0.29$
Fat %	$3.20^{b}\pm0.20$	$0.20^{c}\pm0.01$	$25.63^{a}\pm1.58$	$2.03^{b}\pm0.67$
Lactose %	$4.70^{c}\pm0.26$	$4.90^{c}\pm0.17$	$36.57^{b}\pm3.0$	$50.47^{a}\pm1.42$
Ash (%)	$0.93^{c}\pm0.12$	$0.93^{c}\pm0.12$	$7.20^{b}\pm0.20$	$9.27^{a}\pm0.15$
Titratable acidity %	$0.17^{a}\pm0.01$	$0.18^{a}\pm0.01$	$0.15^{b}\pm0.01$	$0.15^{b}\pm0.01$
Total energy based on DM	$500.33^{a}\pm01.75$	$374.49^{b}\pm0.55$	$494.56^{a}\pm0.94$	$373.73^{b}\pm0.47$
Minerals content of fresh and reconstituted freeze-dried camel's milk* **(mg /100 ml)**				
Major minerals				
Calcium	$133.43^{c}\pm4.45$	$141.10^{b}\pm2.01$	$136.50^{bc}\pm2.78$	$149.33^{a}\pm4.04$
Magnesium	$12.93^{a}\pm0.91$	$13.13^{a}\pm1.07$	$13.23^{a}\pm1.15$	$13.73^{a}\pm0.86$
Phosphorus	$87.43^{b}\pm2.62$	$62.40^{c}\pm5.05$	$91.50^{a}\pm4.50$	$64.53^{c}\pm1.75$
Potassium	$125.00^{b}\pm1.73$	$131.33^{a}\pm5.51$	$127.30^{b}\pm3.11$	$133.70^{a}\pm3.16$
Sodium	$68.70^{a}\pm2.54$	$70.50^{a}\pm1.57$	$69.53^{a}\pm1.75$	$71.20^{a}\pm2.81$
Trace elements				
Zinc	0.933±0.06	0.990±0.10	0.950±0.04	1.037±0.11
Iron	0.665±0.03	0.655±0.03	0.693±0.02	0.707±0.03
Manganese	0.207±0.01	0.207±0.01	0.222±0.01	0.225±0.02
Copper	0.166±0.02	0.164±0.02	0.176±0.01	0.179±0.01

*Reconstituted freeze-dried whole camel's milk (Dry matter 12.1%) and freeze-dried skim milk (Dry matter 9.3 %).
abc.. Means followed by different letter in the same row are significantly different. (P <0.05)

Table 2. Vitamin concentrations in fresh and reconstituted freeze-dried camel's milk*

Vitamins	Fresh milk (mg/l)		Freeze-dried (mg/l)	
	Whole	Skim	Whole	Skim
Vitamin (C)	$35.50^{a}\pm3.50$	$38.23^{a}\pm1.72$	$29.73^{b}\pm2.37$	$30.23^{b}\pm2.93$
Thiamin(B_1)	$0.443^{a}\pm0.04$	$0.493^{a}\pm0.06$	$0.470^{a}\pm0.05$	$0.513^{a}\pm0.03$
Riboflavin (B_2)	$1.553^{a}\pm0.22$	$1.593^{a}\pm0.11$	$1.593^{a}\pm0.10$	$1.623^{a}\pm0.15$
Niacin (B_3)	$3.610^{a}\pm0.19$	$3.667^{a}\pm0.41$	$3.867^{a}\pm0.25$	$3.950^{a}\pm0.18$
Pantothenic acid (B_5)	$0.813^{a}\pm0.08$	$0.860^{a}\pm0.03$	$0.830^{a}\pm0.04$	$0.850^{a}\pm0.03$
Pyridoxine (B_6)	$0.633^{a}\pm0.06$	$0.683^{a}\pm0.10$	$0.633^{a}\pm0.06$	$0.710^{a}\pm0.10$
Folic acid (B_9)	$0.082^{a}\pm0.01$	$0.084^{a}\pm0.01$	$0.091^{a}\pm0.01$	$0.093^{a}\pm0.01$
Cobalamin (B_{12})	$0.032^{a}\pm0.00$	$0.033^{a}\pm0.00$	$0.036^{a}\pm0.00$	$0.036^{a}\pm0.00$
Retinol Vitamin (A)	$0.380^{a}\pm0.03$	ND**	$0.310^{a}\pm0.03$	ND
Vitamin (D) (μg)	$6.000^{a}\pm1.00$	ND	$5.200^{a}\pm0.20$	ND
Vitamin (E) (μg)	$26.00^{a}\pm1.73$	ND	$23.40^{a}\pm1.97$	ND

*Reconstituted freeze-dried whole camel's milk (Dry matter 12.1%) and freeze-dried skim milk (Dry matter 9.3 %)
abc.. Means followed by different letter in the same row are significantly different. (P<0.05)
**ND=Not determined

Table 3. Amino acid concentration of fresh and reconstituted freeze-dried camel's milk (g/100 g protein) *

Amino acids	Fresh milk		Freeze-dried	
	Whole	Skim	Whole	Skim
Arginine (Arg)	$4.93^{a}\pm0.29$	$5.10^{a}\pm0.52$	$5.23^{a}\pm0.21$	$5.60^{a}\pm0.35$
Histidine (His)	$5.13^{a}\pm0.35$	$5.30^{a}\pm0.30$	$5.10^{a}\pm0.17$	$5.40^{a}\pm0.40$
Isoleucine (Ile)	$7.90^{b}\pm0.36$	$8.23^{ab}\pm0.21$	$8.23^{ab}\pm0.25$	$8.50^{a}\pm0.35$
Leucine (Leu)	$9.73^{a}\pm0.15$	$10.10^{a}\pm0.10$	$10.13^{a}\pm0.42$	$10.13^{a}\pm0.12$
Lysine (Lys)	$8.00^{b}\pm0.35$	$8.20^{b}\pm0.17$	$8.30^{ab}\pm0.10$	$8.70^{a}\pm0.26$
Methionine (Met)	$5.00^{a}\pm0.53$	$5.23^{a}\pm0.21$	$5.10^{a}\pm0.10$	$5.43^{a}\pm0.15$
Phenylalanine (Phe)	$6.80^{c}\pm0.10$	$7.20^{b}\pm0.20$	$7.00^{ab}\pm0.20$	$7.50^{a}\pm0.10$
Threonine (Thr)	$6.80^{a}\pm0.10$	$7.10^{a}\pm0.20$	$6.90^{a}\pm0.10$	$7.00^{a}\pm0.17$
Valine (Val)	$7.90^{c}\pm0.10$	$8.20^{ab}\pm0.17$	$7.70^{bc}\pm0.26$	$8.50^{a}\pm0.10$
Alanine (Ala)	$3.50^{bc}\pm0.10$	$3.70^{ab}\pm0.17$	$3.40^{c}\pm0.17$	$3.90^{a}\pm0.01$
Aspartic acid (Asp)	$8.90^{b}\pm0.17$	$9.20^{a}\pm0.20$	$8.70^{ab}\pm0.26$	$9.10^{ab}\pm0.26$
Glutamic acid (Glu)	$18.10^{a}\pm1.15$	$18.20^{a}\pm0.72$	$18.50^{a}\pm0.46$	$18.80^{a}\pm0.53$
Glycine (Gly)	$2.10^{b}\pm0.26$	$2.20^{ab}\pm0.20$	$1.90^{b}\pm0.10$	$2.50^{a}\pm0.10$
Proline (Pro)	$9.70^{b}\pm0.26$	$10.10^{ab}\pm0.10$	$9.90^{b}\pm0.26$	$10.50^{a}\pm0.26$
Serine (Ser)	$6.70^{a}\pm0.30$	$7.10^{a}\pm0.26$	$6.90^{a}\pm0.44$	$6.90^{a}\pm0.40$
Tyrosine (Tyr)	$6.30^{b}\pm0.10$	$6.60^{ab}\pm0.26$	$6.40^{b}\pm0.10$	$6.80^{a}\pm0.17$

*Reconstituted freeze-dried whole camel's milk (Dry matter 12.1%) and freeze-dried skim milk (Dry matter 9.3 %)

[abc..] Means followed by different letter in the same row are significantly different. (P<0.05)

Table 4. Nutritive value of fresh and reconstituted freeze-dried camel's milk*

Item	Fresh milk		Freeze-dried milk	
	Whole	Skim	Whole	Skim
	Protein efficiency ratio (PER)			
PER1	3.30	3.45	3.47	3.44
PER2	3.29	3.42	3.46	3.42
PER3	3.08	3.22	3.34	3.17
	Biological value (BV)			
BV1	84.62	86.20	86.44	86.14
BV2	84.52	85.96	86.32	85.88
BV3	82.37	83.86	85.05	83.26
	Net protein utilization (NPU)			
NPU1	80.39	81.89	82.12	81.83
NPU2	80.30	81.66	82.01	81.59
NPU3	78.25	79.67	80.80	79.09

*Reconstituted freeze-dried whole camel's milk (Dry matter 12.1%) and freeze-dried skim milk (Dry matter 9.3 %)

Table 5. Fatty acid profile of whole fresh and reconstituted freeze-dried camel's milk (g/100 g fat)*

Class	Fatty acid	Whole milk	
		Fresh	Freeze-dried
Saturated, short chain	Butyric (4:0)	0.74±0.05	0.72±0.02
	Caproic (6:0)	0.39±0.03	0.37±0.01
Saturated, medium chain	Caprylic (8:0)	0.37±0.02	0.38±0.02
	Capric (10:0)	0.39±0.02	0.39±0.03
	Lauric (12:0)	0.82±0.02	0.84±0.02
Saturated, long chain	Myristic (14:0)	12.10±1.01	12.20±0.35
	Palmitic (16:0)	24.30±0.75	24.40±1.44
	Stearic (18:0)	13.80±0.35	13.70±0.52
Monoun-Saturated	Palmitoleic (16:1)	12.60±0.53	12.50±0.44
	Oleic (18:1)	26.70±1.13	26.70±1.13
Polyun-Saturated	Linoleic (18:2)	3.67±0.38	3.70±0.26
	Linolenic (18:3)	2.17±0.15	2.23±0.12
Saturated		52.91	53
Monounsaturated		39.3	39.2
Polyunsaturated		5.75	5.9
Total		97.96	98.1

*Reconstituted freeze-dried whole camel's milk (Dry matter 12.1%) and freeze-dried skim milk (Dry matter 9.3 %)

treatments. These values are in accordance with those found by El-Agamy (2006), Kamal *et al.* (2007) and Shamsia (2009). However, freeze-dried skim camel's milk was characterized by slightly higher contents of all amino acids. The essential amino acids Ile, Lys, Phe and Val were significantly ($P< 0.05$) higher in freeze-dried skim milk compared to their amounts in the other milk treatments .In the case of non-essential amino acids, all amino acids except Glu and Ser were significantly ($P< 0.05$) higher in freeze-dried skim milk compared to their amounts in the other milk treatments. Protein efficiency ratio (PER), biological value (BV) and net protein utilization (NPU) of freeze-dried milk were higher than those of fresh milk (Table 4). This result could be attributed to the higher concentration of leucine in the freeze-dried milk than in the fresh milk. On the other hand, the nutritive values calculated for both milk types using the third equation showed an equal value. Data presented in (Table 5) shows the fatty acid profile of whole fresh and freeze-dried camel's milk (g/100 g fat). In general, short-chain fatty acids (C4:C12) in fresh and freeze-dried camel milk were present in very small amounts compared with those reported in cows' milk (Abu-Lehia, 1989). However, the concentrations of C14:0, C16:0, C18:0 and C18:1 is relatively high. Fresh and freeze-dried camel milk has high amounts of linolenic acid (C18:3) and long-chain polyunsaturated fatty acids compared with those reported in cows' milk. Our findings are similar to those reported by Abu-Lehia, (1989); Farah, (1993). The main saturated fatty acids in freeze-dried camel milk were 14:0 (12.2%), 16:0 (24.4%) and 18:0 acids (13.7%). The major unsaturated fatty acids of fresh and freeze-dried camel milk triacylglycerol's were 18:1 and 16:1. The freeze-dried process had a little effect on fatty acid profile in camel milk fat. This result are in agreement with Karadimov and Karadimova, (1976), who reported that there were no changes in the fatty acids (C4: C12) of the dried product.

Conclusion

Lyophilization of camel's milk demonstrated that the nutritional characteristics of this product remained basically unchanged compared with fresh milk. The results obtained also, confirmed the possibility of producing freeze-dried camel milk with beneficial properties using camel's milk as raw material and lyophilized camel milk powder is easy to transport, requires no special conditions for prolonged storage. In addition, lyophilization of camel's milk can help in supplying camel's milk on the market all-over the year.

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