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Full Length Research Paper

The dietary and therapeutic properties of Camel and human milks

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Camel and human milk samples (twenty individuals' samples each) were analysed for fat, total protein (casein, whey protein), lactose, minerals as well as vitamins; B_1, B_2, niacin and C. Meanwhile, amino and fatty acid compositions and, antimicrobial factors namely; lysozyme (LZ), lactoferrin (LF) and total immunoglobulins (Igs) were determined. Results indicated that camel milk contained higher fat, protein (especially casein), ash, Ca, Mg, P, K, Na, Fe, and Cu but lower in whey protein, lactose and Zn than human milk. Vitamins C and niacin were higher in camel milk than human milk. Camel milk proteins contained satisfactory balance of essential amino acids. The ratio of essential to non-essential amino acids was 0.93 and 1.07 in camel and human milk proteins, respectively. Camel milk was characterized by higher ratio of Igs but lower in both LZ and LF than human milk. General pattern of camel milk fatty acids indicated that short chain fatty acids (C_4 –C_{12}) were present in very small amount, but higher than in human milk fat. On the contrary the concentration of $C_{14:0}$, $C_{16:1}$ and $C_{18:0}$ are relatively high in camel's milk fat as compared to human milk fat. Appreciable amounts of essential fatty acids were present in camel milk. It can be concluded that camel milk can be considered as a good food of high nutritive and therapeutic applications. Meanwhile, the high content of antimicrobial agents in camel milk may explain its potential as an antiviral activity specially against diarrhea-causing viruses.

Key Words: Human milk composition, camel milk composition, nutrition, lysozme, lactoferin, immunoglobulins, gel electrophoresis.

INTRODUCTION

It is well known that the best nutritional option for newborns is their mother's milk: however, some infants may not be exclusively breast fed during the first months of life. Therefore, there is a need for another substitute of close composition and properties as human milk. Modified cow's milk preparations are the most used substitutes for human milk (Posati and Orr, 1976). However, many nutritional problems were reported from its use for infant feeding due to cow's milk allergy (El-Agamy, 2007; El-Agamy et al*.,* 2009). Other types of milk has been proposed as substitute of human milk such as goat (Park and Haenlein, 2006), sheep (Haenlein and Wendorff, 2006), buffalo (Shamsia, 2005), but little information are available on the use of camel milk for its purpose. According to FAO statistics, there are about 19 million camels in the world. Nowadays, camel milk production is in progress in many countries in both Asia and Africa due to increased demand. Pasteurized milk and other dairy products made from camel milk are available in the mar-kets in Gulf area and Mauritania (El-Agamy, 2006).

Therefore this study aims at studying the composition of camel milk as compared with human milk in order to evaluate its nutritional and therapeutic values with respect to infants and adults feeding.

MATERIALS AND METHODS

Materials

Camel (*Camelus dromedaries*) milk (20 samples) was obtained from farms at El-Alamin and Sidi-Barani areas around Alexandria, human milk (20 samples) was collected from healthy volunteer women at El-Shatby hospital, Alexandria, Egypt. Pure strains of rabbits were obtained from the farm of Faculty of Agriculture, Alexandria University, Egypt.

Protein marker, agarose, Tricine buffer, carboxy methyl cellulose (CM-Cellex) and all chemicals of gel electrophoresis were

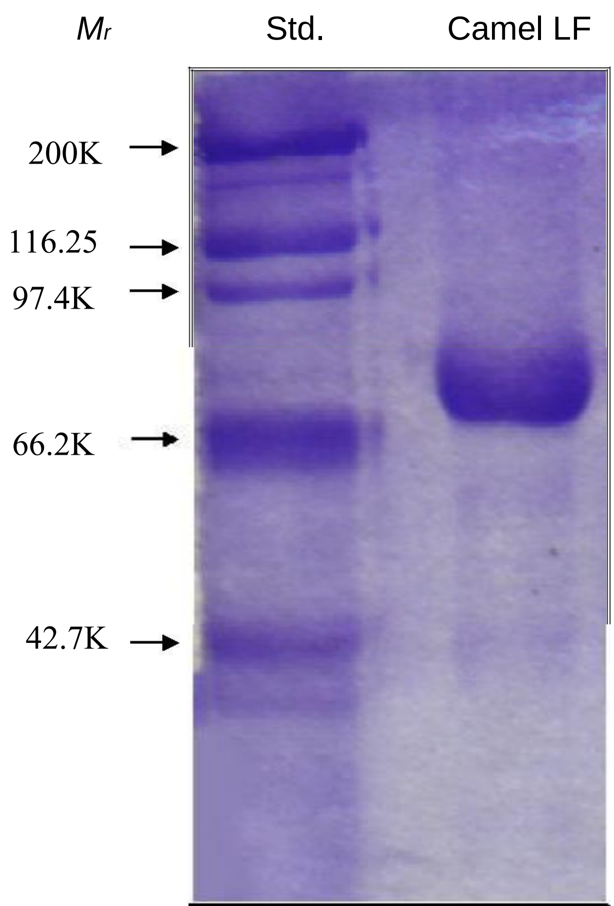

Figure 1. SDS-PAGE of isolated camel milk lactoferrin (LF). Std. High molecular weight standard protein. Anode is toward bottom of photo.

from Bio-Rad, CA, USA. Egg white lysozyme, Freund's adjuvants, *Micrococcus lysodiekticus* and human lactoferrin were purchased from Sigma, Chemical Co, USA.

Purified camel and human immunoglobulins were kind gift from Prof. E. I. El-Agamy, Department of Dairy Science, Faculty of Agriculture, Alexandria University, Egypt.

Methods

Physicochemical analyses

Milk samples were analysed for pH, titratable acidity, specific gravity, total solids, fat and ash according to Ling (1963), lactose by phenol sulphuric acid method (Marier and Baulet, 1959), nitrogen fractions, that is the total nitrogen, noncasein nitrogen, non-protein nitrogen as described by Rowland (1938), were determined by micro-Kjeldahl method (AOAC, 1980) . Energy contents were calculated by multiplying protein, lactose and fat contents by factors of 5.86, 3.95 and 9.11, respectively (Perrin, 1958). The water soluble vitamins were determined by reverse_ phase HPLC technique. A Hewlett Packard HPLC Series 1100, USA equipped with degasser, quaternary pump, auto sample and diode array was used (AOAC, 1990).

Determination of minerals

Calcium, magnesium, phosphorus, manganese, cupper, iron and zinc concentrations were determined by atomic absorption (Perkin-Elmer, Norwalk, CT), according to the method of AOAC (1980). Flame photometry (Instrumentation Lab, Lexington, MA) was used to quantify sodium and potassium concentrations (Lough et al., 1988) while chloride concentration was determined by titration (Kit 630, Oxford Labs, Foster City, CA) (Lough et al.,1988).

Amino acid composition:

Amino acids were determined in proteins hydolysate prepared by digestion of protein with 6N HCl for 24 h at 110°C (Ozols, 1990), the hydrolysates were analysed by Beckman Amino Acid Analyzer, Model 119CL.

Fatty acid composition

Milk fatty acids were determined by gas chromatography of methyl esters of fatty acids on a diethylene glycol succinate column (Supelco, Inc., Bellefonte, PA) using a time-temperature program on a 5730A gas chromatograph (Hewlett -Packard, Avondale, PA). Starting temperature for each run was 60^{O}C, and the temperature rose to 8^{O}C ⁄ min until column temperature reached 180^{O}C (Lough et al., 1988).

Purification of lactoferrin

Camel milk lactoferrin was purified from rennet whey using carboxy methyl cellulose (CM-Cellex) and the procedure described by El-Agamy et al. (1996) . The purified protein was examined for purity by SDS-PAGE (Figure 1).

Protein determination

Protein concentration in solutions was measured spectrophotometrically (Bradford, 1976).

Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE)

The method of Laemmli (1970) for SDS-PAGE was followed in the separations of milk proteins. Protein solution (50 µg / ml) was mixed with the sample buffer (0.25 M Tris- HCl, pH 6.8, 7.5% glycerol, 2% SDS, 5% β-mercaptoethanol) in the ratio 1:1 (v/v) and heated in a boiling water bath for 10 min. Samples were cooled to room temperature, centrifuged at 10,000 xg for 10 min to remove any insoluble material. 50 µl of the sample was applied to the gel using the discontinous buffer system. Runs were carried out at 150v until the end of electrophoresis, and gels were stained using 0.1% Coomassie blue R-250. Molecular masses (kDa) of purified camel milk lactoferrin were determined according to the method described by Weber and Osborn (1969) using SDS-PAGE and a standard protein marker.

Antisera production (Immunization)

Polyvalent antisera to camel and human lactoferrins were prepared according to the procedure described by Clausen (1988). Rabbits

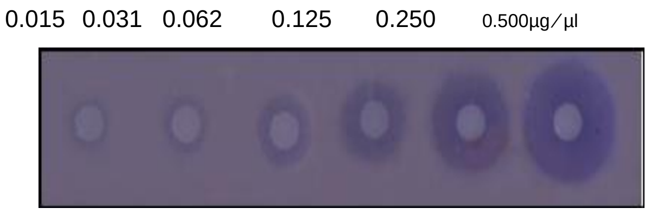

Figure 2. Lyso-plate assay for egg white lysozyme activity (standard curve). Clearance zones around well express the activity of lysozyme.

Table 1. Physico-chemical (%) characterizations of camel and human milks.

Constituents	Camel milk	Human milk
	mean values ±SD	
Total Solids %	13.2± 0.45	10.71 ± 0.11
Fat %	4.0 ± 0.21	2.1 ± 0.15
Protein%	3.46± 0.20	1.94± 0.14
Casein %	2.65± 0.09	0.63± 0.05
Whey Protein %	0.81± 0.03	1.31± 0.08
Whey protein / casein	0.31	2.08
Lactose %	4.86± 0.07	6.45± 0.08
Ash %	0.87± 0.07	0.22± 0.01
pH	6.64± 0.05	6.89± 0.08
Titratable acidity %	0.162± 0.007	0.072± 0.004
Specific gravity	1.033 ±0.015	1.027± 0.011
Energy (kcal/ L)	759 ± 4.51	560 ± 3.51

were firstly immunized with 0.5 ml of protein (5 mg/ml sterile NaCl, 0.9%) in suspension with 0.5 ml. Freund's complete adjuvant was injected intramuscularly in several sites at week 1. In weeks 3 and 5, each animal was injected intradermaly with booster dose 0.5 ml (10 mg/ml) in suspension with 0.5 ml Freund's incomplete adjuvant. The rabbits' sera were tested for antibody production before each and after the third immunization. The animals were bled about 14 days after the last immunization. Sera were collected and stored at -30°C until used.

Single radial-immunodiffusion

Lactoferrin and immunoglobulin concentrations in camel and human milks were detemined in the presence of specific polyvalent anti-serum to each type of protein using the single radial- immuno-diffusion analysis as described by (Mayer and Walker, 1990).

Lysozyme activity assay

The lysoplate assay was used for lysozyme activity as described by Lie et al . (1986) using *Micrococcus lysodiekticus* as a substrate mixed in agarose 1% (Figure 2).

RESULTS AND DISCUSSION

Physicochemical properties:

Table (1) presents the physico-chemical properties of camel and human milks. The acidity, specific gravity and pH values of both types of milk were clearly different from that reported by El-Agamy et al. (1998) who found that the physical parameters of human milk were similar to those of mares and donkey milks than those of ruminant animals. Total solids (TS) content was higher in camel milk than human milk. It represents 1.23 much more time than that of human milk. However, the TS content of mother's milk in the present study was lower than that reported by Kisza and Zbikowski (1975); Lonnerdal et al. (1976); El-Agamy and Khatab (1992).This may due to the difference stage of lactation and nutritional status of mothers. On the other side, TS in camel milk in the present study was higher than that reported by Mehaia and Al-Kahnal, (1989); Bayoumi, (1990); El-Agamy et al. (1998). These variations are mainly due to variations in breeds, feeding system and stage of lactation.

Also, camel milk contained higher fat, protein (especially casein) and ash contents but lower whey protein and lactose contents than human milk. These results are in agreement with those reported by El-Agamy et al. (1998).The lower casein and higher whey protein contents in human milk make it very nutritious for newborn due to the resultant soft coagulum after milk ingestion and higher digestibility and absorption of soluble proteins (Fox and McSweeney, 1998).

It is well known that -lactalbumin is part of the enzyme system responsible for lactose synthesis. So the higher content of lactose in human milk is expected due to the fact that -lactalbumin is the dominant serum protein in human milk.

The ratio of whey protein to casein in camel and human milks were extremely different, but that ratio in camel milk was higher that those in cow, buffalo, sheep and goat (El-Agamy et al., 1998). Results revealed that camel milk had higher calorific value than human milk. This is due to the higher contents of fat and protein.

Mineral contents

Table (2) shows the mineral contents of camel and human milks. It is clear that the major salt constituents in both types of milk are, K > Cl > Ca > P > Na. Their concentrations differed markedly between the two milk, being higher in camel milk than in human milk. The concentrations of Ca, K and Cl were represented by 3.2, 2.9 and 2.1 times their concentration in human milk. Therefore, camel milk can be considered as a good source of these minerals specially Ca and K. Camel milk in contained also higher values of P, Na, Cu and Fe but lower Zn than human milk. These results are agreements with those

Table 2. Salts content in camel and human milks (mg/100 ml).

Salt	Camel milk	Human milk
	Mean Values ± SD.	
Ca	109 ± 7.50	34 ± 3.50
Mg	14 ± 0.70	3 ± 0.35
P	76 ± 2.55	16 ± 0.85
Ca/P	1.43	2.16
Na	58 ± 3.50	10 ± 0.34
K	179 ± 8.50	62 ± 6.5
Na/K	0.32	0.16
Cu	0.19 ± 0.006	0.06 ± 0.001
Fe	0.21 ± 0.40	0.04 ± 0.00
Zn	0.19 ± 0.018	0.23 ± 0.016
Mn	0.06 ± 0.003	0.04 ± 0.003
Cl	132 ± 7.50	63 ± 6.50

Table 3. Nitrogen fractions in camel and human milks (mg/100 ml).

Nitrogen Component	Camel Milk	Human Milk
	Mean values ± SD	
Total N (TN)	610±65	363±41
NPN	68±8	59±5
NPN/TN	11.1	16.3
Protein N (PN)	542±32	304±27
Casein N (CN)	415±62	99±18
CN/TN	68	27.3
Whey Protein N WPN)	127±12	205±23
WPN/TN	20.8	56.5

previously reported (Abu-Lehia, 1987; Aderson, 1991; El-Agamy et al*.*, 1998).

Nitrogen compounds

The distribution of nitrogenous components in camel and human milk is shown in Table (3) . Camel milk contained higher levels of TN, CN and NPN but lower level of WPN than human milk. These results are in agreements to those reported (Lonnerdal et al., 1976; El-Agamy et al*.,* 1998; Morgan, 2006) especially for human milk.

Results showed also that the ratio of NPN/TN was lower in camel milk (11.1%) than human milk ratio (16.3%). This NPN/TN ratio in human milk is lower than those reported by other researchers; 19.3% (Lonnerdal et al., 1976); 20-38% (Nishikawa et al.,1977); 23.7% (Chavalittamrong et al.,1981).

Table 4. Amino acid composition of camel and human milks (g/100g)*.

Amino Acid	Camel milk	Human milk
Alanine	3.3	4.2
Arginine	5.1	3.9
Aspartic	7.2	6.8
Cystine	1.5	1.2
Glutamic	21.1	16.6
Glycine	1.2	1.5
Histidine	2.9	2.6
Isoleucine	4.9	4.0
Leucine	9	8.9
Lysine	6.6	11.1
Methionine	2.6	1.3
Phenylalanine	3.7	3.2
Proline	13	10.2
Serine	3.0	3.2
Threonine	5.3	8.6
Tyrosine	3.0	2.6
Tryptophan	1.8	0.7
Valine	4.8	9.4

*Values are means of three composite samples.

Amino acid composition

Table (4) shows amino acid composition in camel and human milks. Glutamic acid was the major amino acid in both milks. However, several differences were found in the amino acids patterns of both milks. Camel milk was characterized by high contents of all amino acids except lysine, glycine, threonine and valine. The ratio of essential to non-essential in camel milk was close to that of human milk proteins. Generally, the amino acids pattern of camel milk proteins revealed that they have the satisfactory quality balance of essential amino acids for human diet or exceeding the FAO/WHO/UNU (1985) requirements for amino acids .These results are in agreement with that reported by El-Agamy (2006).

Fatty acid composition

Table (5) shows the fatty acid composition of camel and human milk fats. General, camel's milk fat contained higher saturated and less unsaturated fatty acids than human milk fat. Camel's milk fat contained small amount of short chain fatty acids (C_4 –C_8), while human milk fat was free of C_4 and traces of C_6 and C_8. On the other hand, human milk fat contained higher C_{10} and C_{12} than camel's milk fat and less C_{14} - $C_{18:0}$, $C_{18:1}$and $C_{18:2}$ contains of human milk fat were much higher than that in camel's milk fat, but $C_{10:1}$, $C_{14:1}$, $C_{16:1}$ and $C_{18:3}$ were much lower. The fatty acid composition of camel's milk fat in the present study is consistent with that reported by El-

Table 5. Fatty acid composition (w/w %) of camel and human milk fats.

Fatty Acid	Camel milk fat	Human milk fat
C4:0	0.76	--
C6:0	0.32	0.008
C8:0	0.19	0.005
C10:0	0.26	1.25
C12:0	0.45	2.7
C14:0	9.9	7.2
C16:0	27.2	24
C18:0	13.6	6.8
C20:0	0.9	---
Unsaturated		
10:1	0.09	---
14:1	1.6	---
16:1	12.3	5.3
18:1	26.2	39.8
18:2	4.8	12.2
18:3	1.5	0.9

Agamy (2006). Generally adequate amounts of essential fatty acids were present in camel milk fat. This character makes camel milk fat important from the nutritional point of view.

Vitamin contents

Table (6) shows the water soluble vitamins in camel and human milks. Results revealed that camel milk contained higher levels of B_2, C and niacin than human milk, but lower in B_1.This result indicates that camel milk is good source of vitamin C and niacin. Previous reports found that camel milk was rich in Vitamin C (El-Agamy, 2006).

Camel milk composition and nutritional requirements

Human consumption of camel milk as compared with recommended dietary allowances (RDA) is presented in Table (7). It is clear that camel milk can provide significant part of daily needs of humans from different nutrients especially amino acids.

Antimicrobial factors

Table (8) shows the concentration of antimicrobial factors in camel and human milks. Results revealed that camel milk is richer in immunoglobulins than human milk. However, its contents of lactoferrin and lysozyme were very low. El-Agamy and Nawar (2000) found that camel milk is contain 1.64 mg/ml of immunoglobulinG versus 0.67, 0.63, 0.70, 0.55 and 0.86 for cow, buffalo, goat,

Table 6. Vitamins content in camel and human milks (mg/100 ml).

Vitamin	Camel Milk	Human Milk
Vitamin C	4.6	3.5
Thiamine (B_1)	0.05	0.013
Riboflavin (B_2)	0.07	0.04
Niacin	0.52	0.21

Table 7. Camel milk intake compared with recommended dietary allowances (RDA) for human (Podrabsky,1992).

Constituents	Camel milk (1L) contains	RDA
Protein (g)	34.6	63
Energy (kcal)	759	2300
Calcium	1090	800
Phosphorus	760	800
Magnesium	140	350
Potassium	1790	---
Iron	2.1	10
Zinc	1.9	15
Sodium	580	---
B1	0.5	1.2
B2	0.7	1.4
Ascorbic acid	46	60
Niacin	5.2	15
Arginine *	2.0	----
Histidine*	1.16	----
Leucine	3.6	2.2
Isoleucine	1.96	1.4
Lysine	2.64	1.6
Methionine	1.04	2.2
Phenylalanine	1.48	2.2
Threonine	2.12	1.0
Tryptophan	0.72	0.5
Valine	1.92	1.6

*Amino acids required in childhood.

sheep and human milk, respectively. A comparative study of lysozyme concentration in milk of different species (El-Agamy et al., 1997) showed that camel milk contained significantly higher content of lysozyme than cow, buffalo, sheep and goat but very low content as compared to lysozyme content of human, mare and donkey milks. The same study showed that camel milk contained also signi-

Table 8. Antimicrobial factors in camel and human milks.

Antimicrobial Factor	Camel milk	Human milk
Mean Values ±SD		
Immunoglobulins (mg/ml)	1.54 ± 0.032	1.14 ± 0.055
Lactoferrin(mg/ml)	0.24 ± 0.035	1.95 ± 0.050
Lysozyme(μg/ml)	0.06 ± 0.02	0.65 ± 0.045

ficantly higher level of lactoferrin (0.22 mg/ml) than cow, buffalo, sheep and goat but very low compare with that of human milk.

Conclusions

a- Camel milk differs in its chemical composition than human milk.
b- Camel milk fat is characterized by very low content of short chain fatty acids and higher contents of long chain fatty acids. However, it had more saturated fatty acids than human milk.
c- Camel milk can be considered as a good source of protein, calcium, phosphorus, vitamin C and niacin and can meet part of the daily needs of humans from these nutrients.
d- Camel milk was characterized by higher ratio of Igs but lower in both LZ and LF than human milk.

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